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ADDITIVE MANUFACTURING PROCESSES IN FLUID POWER – PROPERTIES AND OPPORTUNITIES DEMONSTRATED AT A FLOW-OPTIMIZED FITTING

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Abstract:
In recent years, additive manufacturing (AM) techniques have gained in significance. For example, geometries can be produced which, years ago, could only be produced economically with original forming processes, for example due to undercuts or their geometrical properties. AM techniques enable a design of component and machine in which the function fulfilment determines the construction and not the manufacturing possibilities. Components manufactured by AM are increasingly being used in series production and, for example in the aerospace sector, are enabling considerable weight reductions. While other industries have already made efforts and progress in the application AM processes, comparatively little progress has been made in the hydraulics industry. For example, enormous increases in power density could be achieved with this novel approach of manufacturing.
The aim of this publication is to present additive manufacturing processes for processing metals which are suitable for use in hydraulic applications and to show ways of making them usable. At first, the methods are presented and their properties and special features are dealt with. Subsequently, the achievable properties are also discussed. Following, an overview on the state of the art for the hydraulics industry is presented and classified with regard to the possibilities of additive manufacturing. Finally, an example is used to illustrate the possibilities offered by AM where a rectangular fitting is presented which has a significantly reduced line resistance thanks to AM and flow-optimization. The design is presented as well as results which allow a classification of the achieved loss reduction.

Keywords*: Additive Manufacturing, Hydraulics, Fittings*

1. Introduction

In recent years, additive manufacturing (AM) has become one of the most revolutionary and promising technology application in manufacturing. The process of making a product layer by layer instead of using traditional molding or subtractive methods is often referred to also as 3-D printing. Once employed purely for prototyping, AM is now increasingly used for spare parts and small series production. So far, adoption of AM has been highest in industries where its higher production costs are outweighed by the additional value AM can generate improved product functionality, higher production efficiency, greater customization and shorter time to market. Currently, AM's market penetration is still hindered by lack of design knowledge, high production cost and limited production scale. But as the AM industry is currently growing exponential [1], it is essential for each technical domain to evaluate the potential benefits from AM and leverage those. Since fluid technology has paid little attention to this technology and its research is still focused on increasing efficiency, this paper aims to highlight the opportunities for fluid power arising through AM.

2. Introduction to Additive Manufacturing

In this chapter, a short definition of the general principle as well as the shared advantages and disadvantages of many AM processes are given. The available AM processes for the manufacturing of metallic parts are then introduced with process principle, specific characteristics and available materials.

2.1 Overview

In recent years, many different processes have entered the manufacturing world under the label of Additive Manufacturing (AM). According to ASTM, an AM process is defined as a "process of joining materials to make parts from 3D model data, usually layer upon layer" [2], as opposed to subtractive (e.g. milling) or formative (e.g. bending) manufacturing [3]. Most AM processes share common characteristics and thus common advantages and disadvantages due to the manufacturing, joining and subsequent stacking of layers.

One of the biggest advantages of AM is the high possible part complexity due to the reduction of a 3D part to a 2,5D manufacturing issue. Even undercuts and internal structures are possible, with the complexity limited by the process resolution and the amount of data. Also, the "tool-less" (the tool is the same for all parts) manufacturing directly from 3D data leading to short lead times and cost savings. On the downside, parts manufactured layer-by-layer by AM processes usually exhibit anisotropies in the material properties and a staircase effect on slanted surfaces. When the slanted surface is facing downwards it is commonly called an overhang and, when exceeding a critical angle, cannot be manufactured by many AM processes without support structures (see **figure 2**).

2.2 Available Processes

AM processes are commonly classified into the following categories [2]:

- **Binder jetting**: AM process in which a liquid bonding agent is selectively deposited to join powder materials
- **Directed energy deposition**: AM process in which focused thermal energy is used to fuse materials by melting as they are being deposited
- **Material extrusion**: AM process in which material is selectively dispensed through a nozzle or orifice
- **Material jetting**: AM process in which droplets of build material are selectively deposited
- **Powder bed fusion**: AM process in which thermal energy selectively fuses regions of a powder bed
- **Vat photopolymerization**: AM process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization
- **Sheet lamination**: AM process in which sheets of material are bonded to form a part

An overview of the most important AM processes for the production of metal parts is given in **table 1**.

Table 1: Overview of metal AM processes

Process	**Laser powder bed fusion (L-PBF)**	**Electron beam melting (EBM)**	**Binder jetting**	**Laser metal deposition (LMD)**
ASTM category	Powder bed fusion	Powder bed fusion	Binder jetting	Directed energy deposition
Principle	Laser-induced heat selectively melts metal powder in powder bed	Electron-beam-induced heat selectively melts metal powder in powder bed	Liquid binder is selectively applied to metal powder in powder bed by inkjet print head	Laser-induced heat melts metal powder as it is deposited
Materials	Fe, Ni, Ti, Al, Cu, CoCr, TiAl, Au, Ag, CoCr, …	Ti, CoCr, Inconel 718	Polymers, sand, ceramics, metals	Ti, Fe, Cu, Ni, Al, Co, …
Application / industry	Aerospace, Turbomachinery, Automotive, Dental/Medical, Tooling	Aerospace, Turbomachinery, Medical	Tooling, Automotive, Medical	Turbomachinery, Tooling
Machine suppliers (examples)	Aconity3D, EOS, Trumpf, SLM Solutions, Concept Laser, Renishaw, GE Additive	Arcam, Freemelt	ExOne, 3DSystems, Desktop Metal, Digital Metal	Trumpf, DMG Mori, Optomec, Okuma

2.3 Laser Powder Bed Fusion

Laser powder bed fusion (L-PBF) is one of the most common AM processes for the production of dense parts from metal powder [4]. Example applications are in aerospace for the production of lightweight parts and in turbomachinery for the production of parts from heat resistant superalloys. The process principle is shown in **figure 1**. In an iterative process, a thin (30 – 50 μm) layer of powder is applied on a b by a recoating mechanism. The areas of the powder later constituting the solid part are selectively melted by focused laser radiation. The build plate is then lowered by the amount of the layer thickness. The cycle is repeated until the part is finished. A detailed description of the process can be found in [5]. The powder is almost fully melted, parts with a relative material density near 100 % can be manufactured. Unused powder is fully reconditioned and reused, making the process resource efficient. The process is shielded by an inert atmosphere and gas flow, usually Argon or Nitrogen, to protect the material from oxidation and for removal of process byproducts from the laser beam.

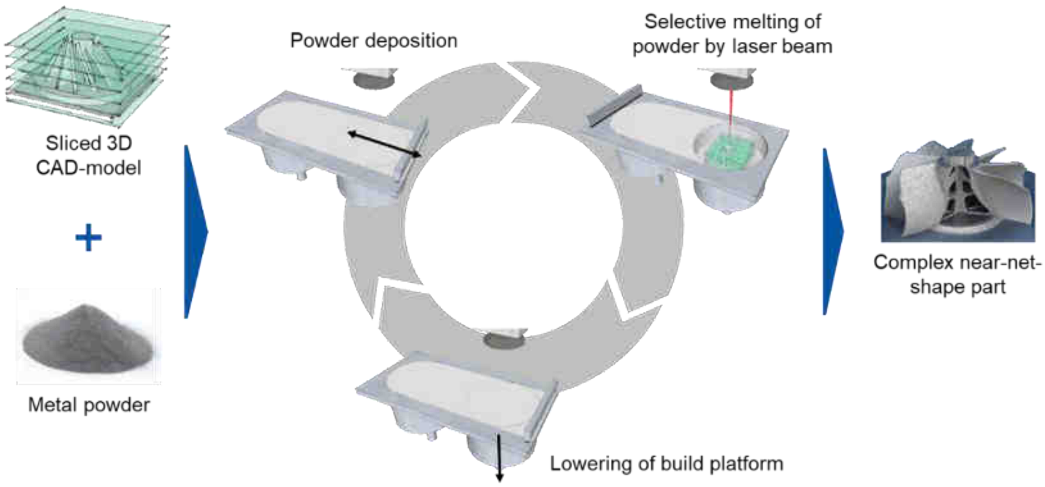

Fig. 1. L-PBF process principle [6]

A wide range of materials can be processed by L-PBF. Standard materials commercially available from many suppliers include, among others, Aluminum alloys (AlSi10Mg, AlSi12), Stainless and Tool Steels (1.4404, 1.4542, 1.2709), Nickel-based alloys (Inconel 718 and 625) as well as pure Titanium (Titanium Grade 2) and Ti6AlV4 [7,8]. Due to the rapid solidification rates of the molten material, reaching up to $7x10^6$ K/s, the materials generally exhibit a very fine and homogeneous microstructure throughout the whole part [9,3]. This results in high strength comparable to the standard cast and sometimes wrought material properties, albeit often with anisotropies in the build direction. Heat treatments are available for reduction of anisotropies or sometimes necessary for reaching the standard material properties.

The cooldown and shrinkage of the bonded consecutive layers leads to a buildup of residual stresses in the material, as shown in **figure 2**.

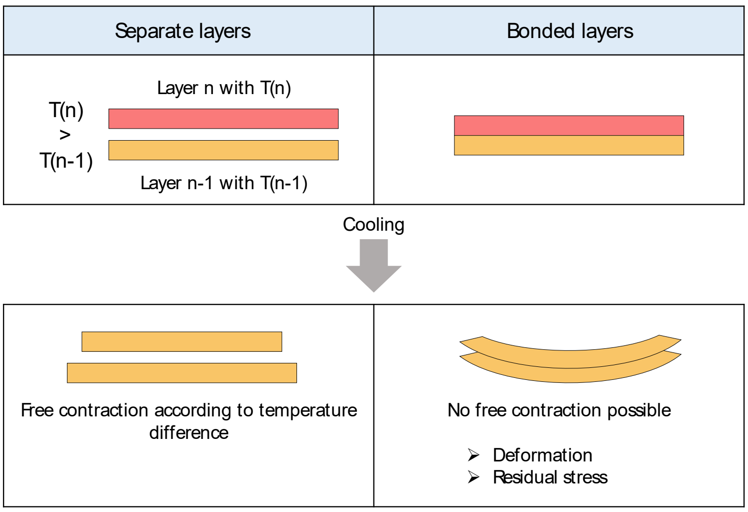

Fig. 2. Buildup of residual stresses

When overhangs are produced, the residual stresses result in deformation and, when the critical overhang angle is reached, in failed builds. Support structures are therefore needed to counteract the stresses. The support structures and the typically rough surfaces of L-PBF-parts covered with partly melted powder particles (R_a = 10 – 20 µm) generally require post-processing of the parts, consisting at least of (manual) removal of the support structures, abrasive blasting and, in case of functional surfaces with high quality requirements, machining. The need for support structures and thus for post-processing can be greatly reduced by a part design taking into account the process restrictions.

2.4 Electron Beam Melting

The basic cyclic process for EBM is very similar to L-PBF: Powder is applied in thin layers (thickness 50 – 200 µm) and selectively melted to form solid areas. The main differences arise from the use of an electron gun as the source of thermal energy. The electrons transmitted to the powder particles may lead to a buildup of charge inside the particles due to the insulating property of the oxide layers. The resulting electrostatic forces can displace powder out of the powder bed in a phenomenon known as “smoke” [10]. To avoid the buildup of charge and to hinder the movement of the particles, each powder layer is heated before the melting step by the defocused electron beam, sintering the particles slightly into a “cake”. The EBM process thus being a high-temperature process with powder and part temperatures reaching up to 1100 °C leads to two main differences to the L PBF-process: As an advantage, the temperature gradient between subsequent layers is small and the parts are consequently almost free from residual stresses, leading to excellent mechanical properties and a reduced need for support structures. As a disadvantage, the sintered powder is difficult to remove from internal structures, hindering the usage in fluid technology. A comprehensive overview of the process can be found in [10].

2.5 Binder Jetting

Similar to the L-PBF and the EBM process, Binder jetting is a powder bed process, in which powder is applied in thin layers and selectively joined to form solid areas. Differently to these processes, the joining is not achieved by melting particles, but by applying a liquid binder selectively in small droplets with a print head similar to an inkjet print head. As no thermal energy is involved, the layers don’t shrink due to cooling and thus the material is free from residual stresses. As a result, parts can be produced without support structures and “nested” within the build chamber to make best use of the available volume. The principle of joining particles with binder leads to a much bigger range of material types than in other AM principles. It is possible to process powders made from metal, polymers and ceramics as well as sand for the production of molds and cores for casting. Also, full-color models can be produced by using colored binders, similar to inkjet printers.

Directly after the printing process, parts produced by Binder jetting exhibit low strength and low ductility. This may be sufficient for the production of sand molds or colored design prototypes. For the production of functional prototypes or end-use parts, the parts can be sintered or infiltrated with low-melting alloys (typically bronze) after the additive manufacturing step, resulting in denser parts with higher strength and hardness [11].

2.6 Laser Metal Deposition

Unlike most AM processes, LMD is not limited to layer-by-layer production. Material can be deposited on freeform surfaces, only limited by the degrees of freedom of the handling system on which the processing head is mounted and the accessibility. In conventional LMD, in order to deposit material, a melt pool is generated on the surface of the part by thermal energy from the absorption of focused laser radiation. Metal powder is then blown into the melt pool either from a lateral or coaxial powder nozzle. Alternatively, in a process called Extreme High-Speed Laser Material Deposition (EHLA), the powder is melted in the flight phase, minimizing the size of the melt pool and the heat affected zone [12] and increasing the area deposition rate. In both processes, the material is metallurgically bonded with the substrate with minimal mixing of the components. The process principles are shown in **figure 3**.

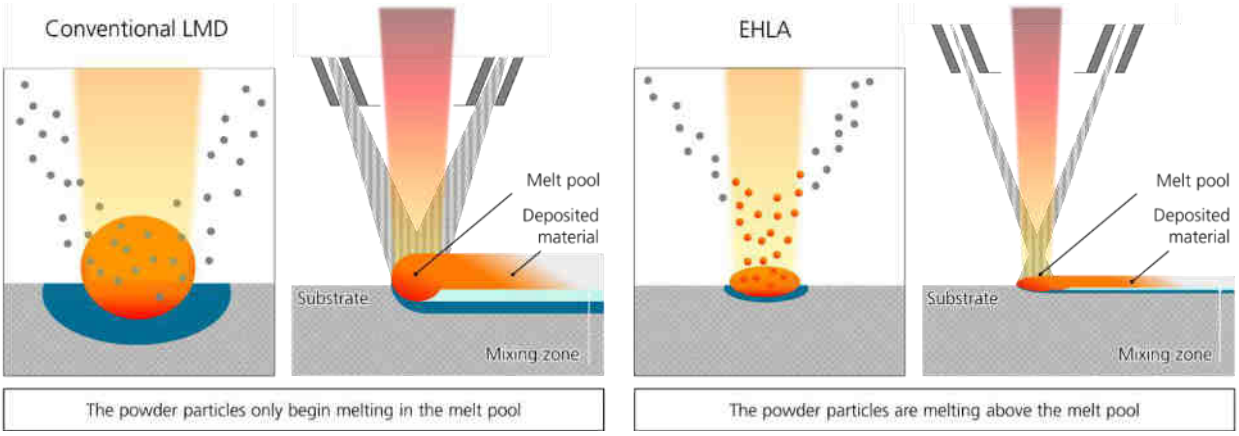

Fig. 3. Process principle of LMD and EHLA [12]

The process may be used for the additive manufacturing or repair of parts by stacking layers, or for the coating of parts with wear and corrosion resistant layers. In case of EHLA, the main application is the production of coatings on rotationally symmetric parts like hydraulic cylinders. This is due to the high deposition rates only usable on lathes. The heat transfer into the substrate is small, resulting in small thermal deformation of the substrate. The composition of the powder can be influenced during the process, making it possible to produce layers with material combinations or gradients difficult to produce with conventional processes [12].

The processable materials include standard alloys from a wide range of material types, like Ti6Al4V, 1.2344 and Inconel 625. Also, by mixing of powders, metal matrix composites containing carbides and nitrides can be manufactured. The deposited material exhibits a relative density near 100 % and excellent mechanical properties [12,13].

3. Classification of additive manufacturing processes for hydraulics

In the following chapter AM is being classified for the hydraulics industry. Starting from the status quo of traditional production technology in hydraulics, the possibilities arising from AM are shown. Based on a selection of previous investigations regarding AM for use in hydraulics, the utilization of AM potential is estimated. The chapter concludes with a few example applications which make use of AM.

3.1 Influence of traditional manufacturing processes on hydraulic components

Components of hydraulic components have been manufactured in the past decades and are still mostly produced today with milling machines, lathes, electric discharge machining, laser cutting or casting. These are predominantly CNC-supported manufacturing processes, which allow high economies of scale in series production with well-coordinated process control. On the other hand, there are high start-up times for setting up the machines in production lines for series production of new parts, which are usually 30 days or more. This makes it more difficult to implement small batches quickly. In addition, the design freedom of a component is severely restricted by these processes, since each process has its own requirements for accessibility to the component such as lathing which is only possible orthogonally or coaxially to the lathing axis. Additionally, each process might need its own clamping surfaces. For example, valve blocks are hydraulic components whose shape is largely determined by the production process. Except by means of original forming processes, which are frequently used in standardized valve blocks for mobile machines, it is not possible to manufacture internal connecting lines, so each channel must be led out of the component, at least at one point. All channels must be placed in such a way that no unwanted connections occur and sufficient compressive strength is guaranteed at all points. Since the components are milled from the solid, this results in unnecessary material expenditure as well as weight. The removal of unneeded material by means of subtractive procedures is, however, not economical. Since these manufacturing processes have not undergone any far-reaching innovations in recent decades the design of hydraulic components has hardly changed. A production-oriented rather than function-oriented design is still the predominant paradigm in the industrial sector.

3.2 Possibilities of additive manufacturing techniques for hydraulic components

A decisive design parameter of hydraulic components is the efficient guidance of the fluid through the component, taking into account the restrictions imposed by other functional surfaces and the manufacturing possibilities. Compared to traditional manufacturing processes, additive manufacturing processes entail significantly fewer restrictions, whereby process-specific restrictions also exist here. Strong overhangs can only be produced using support structures that are difficult to remove within cavities. In addition, high surface qualities are difficult to produce. Taking these restrictions into account, however, additive manufacturing technology allows great freedom of design. Orthogonal channels often occur in classical valve blocks, as these are drilled in as few clamping operations as possible. These hard flow deflections often lead to energy and thus efficiency losses. Usually the complete borehole is not required, which leads to unnecessary dead water areas, which represent unwanted capacity and areas for deposits. AM processes, on the other hand, make it possible to optimize flow control. Flow-optimized channel guidance allows the flow losses and the stresses introduced into the material at the points of flow deflection to be significantly reduced [14]. Within the same installation space, a higher volume flow with lower energy loss can be achieved using less material. Cooper et al. compared the flow profile of an additive block with a conventional block using Particle Image Velocimetry (PIV). In the additive block, the flow velocities are partly 250 % higher compared to the conventional block due to less strong flow deflections which results in lower losses. Test channels with heat treatment increase the strength of the component from ~350HV to ~500 HV [15]. Semini et al. also investigated the effects of the fluid on the surface, whereby the components are treated by shot-peening before the flow test was conducted in order to remove production residues from the surface. No significant effect of the flow on the surface even after a longer loading time were reported [16]. Weight savings are achieved with components redesigned for AM, where the scope is 30% and more. In addition to the gains from a design of the components that is function-oriented, further advantages can be achieved. For complex hydraulic drive components, Guerrier et al. consider the achievement of a shorter development cycle, reduced storage costs for material, better and new repair possibilities to be promising [17].

3.3 Use of additive manufacturing technology in the manufacture of hydraulic systems

Currently, additively manufactured hydraulic components are often substitutes for existing traditionally manufactured components. Schubert and Kroll propose a six-stage redesign process for the production-ready redesign of such components using additive processes. This begins with the analysis of the functional structure of the existing component. Once all the basic elements have been identified, they can be individually optimized. An example of this is the adaptation of the shape so that surfaces of high quality are built up in a vertical direction or a flow optimization. This was followed by the iterative determination of the position of all basic elements. All connecting channels were then created. This offers further optimization potential such as flow optimization or the use of a channel as a support structure for another element. Finally, the design of secondary structures such as stiffeners or mountings [18] is carried out. A similar approach is also proposed by Sossou et al. While final designs determined by topology optimization can be produced with AM, it is often more practicable to give a rough shape starting with the functional surfaces, similar to the design process using traditional manufacturing techniques, and then refine this design by topology optimization [19].

At present, many hydraulic components cannot be installed immediately after additive manufacture. In many cases, printed functional surfaces do not have the necessary surface properties. Valve seats, for example, require machining to achieve the necessary surface quality at the sealing seats or running surfaces. Additive manufacturing processes are usually carried out outside line production. This makes it more difficult to integrate additively manufactured components into production, especially for small quantities. However, this problem does not only affect the hydraulics industry. Machine tools or cells, which master additive as well as subtractive processes, are of great interest across industries and in development and are expected to be ready for use within the next years [20].

3.4 Existing Advanced Solutions of Hydraulic Additively Manufactured Systems

The implementation of additive systems has increased progressively in recent years. More and more industries are concerned with harnessing the advantages of AM for their products. The annual Wohlers Report 2017 states that of those industries that are particularly relevant to the hydraulics industry, especially the aerospace industry is concerned with AM not only to save on weight [4]. As can be seen in **figure 4,** it is the second largest sales market for AM products after industrial/business machines which includes office supplies, computers and printers but also automation equipment and parts for robotics.

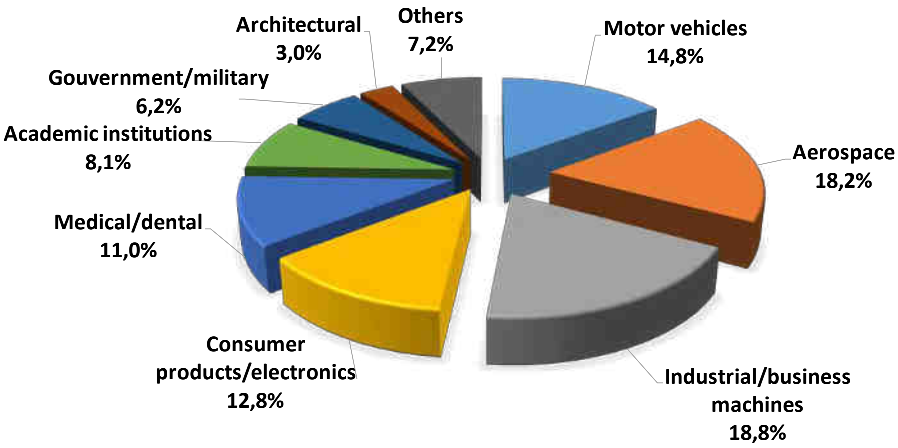

Fig. 4. Sales AM industry by sales market [4]

The first hydraulic additive manufactured component and used worldwide in a commercial aircraft is a valve block from Liebherr Aerospace (see **figure 5**). The valve block is part of the spoiler actuator of the A380 and is important for primary flight control. The block is made of titanium powder and is just as powerful as a conventional valve block made of a titanium forged part, but consists of fewer individual parts and is 35 percent lighter. The valve block has been in use since the first quarter of 2017.

Fig. 5. Spoiler-actuator valve block by Liebherr-Aerospace [21]

The manufacturer Aidro is also active in the additive production of valve components. Their additive manufactured valve blocks are characterized by lower weight, more compact design and lower losses. Additively manufactured valve spools have also been tested. AM here offers great freedom in the design of the valve’s control windows, so that larger volume flow rates are possible with the same geometrical dimensions of the spool and at the same pressure difference [22]. Another highly integrated solution made possible by AM is the "Integrated Smart Actuator (ISA)" developed by Moog for robotics (see **figure 6**). The cylinder housing and valve are designed as a single component and all channels are designed for optimum flow. This actuator provides an outlook on development opportunities for compact drives, which are becoming increasingly popular on the market.

Fig. 6. Integrated Smart Actuator (ISA) for Robotics Systems by Moog [23]

Also the humanoid robots of Boston Dynamics have a very advanced design, which unfortunately is not documented in scientific publications. Here, the lines are integrated into the supporting structure similar to blood vessels. Cartridge valves and actuators are placed in the support structure, whereby their housings are also integrated into the structure. It is demonstrated how functional surfaces of hydraulic components can be merged with the supporting structure, resulting in an exceptional power-to-weight ratio. Another component benefitting from AM are heat exchanger. AM allows much more compact designs at higher surface to weight ratios and less pressure drop [24].

4. Case Study – a Flow-Optimized Fitting

One of the biggest challenges for additive technologies in fluid power applications is the manufacturing cost compared to alternative manufacturing techniques. Connection elements in hydraulics can be found in every application from mobile to stationary hydraulics, see **figure 7**. The manufacturing is cost-optimized by forging and drilling. This results in sharp edges within the channel geometry. Pressure losses are of secondary interest, since an optimization would result in a change of manufacturing process.

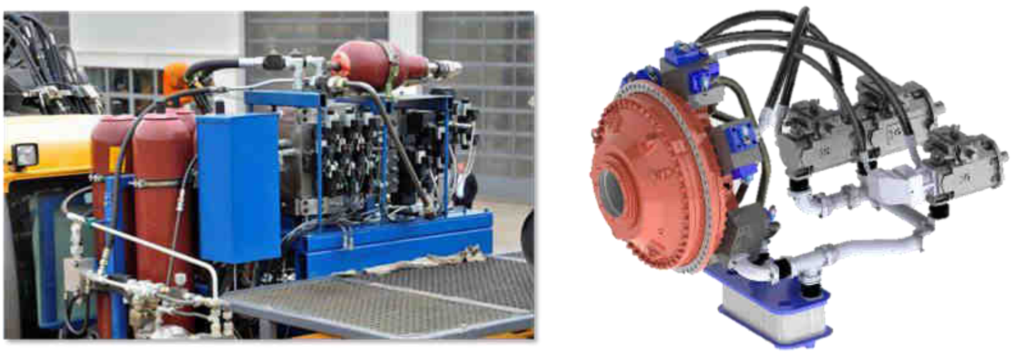

Fig. 7. Hydraulic connectors on a mobile machine (left) and for a hydrostatic wind drive (right)

Considering a stationary hydraulic manufacturing machine with parameters presented in **table 2**, an assumed 40% reduction in pressure losses, 300 l/min flow rate and 1000 hours of operation per year, one can illustrate the possible savings for the operator using equations (1) and (2).

Table 2: Estimated values for case study

Characteristic	Descriptor	Value	Unit
Flow rate	Q	300	l/min
Pressure drop 90° connector	Δp_C	0.5	bar
Pressure drop 90° connector w/ Inlay	Δp_I	0.3	bar
Energy cost per kWh	C	0.15	€/kWh
Hours of operation p/a	t_{Op}	1000	h

$$P = Q \cdot \Delta p \quad (1)$$

$$C_{total} = P \cdot C \cdot t_{Op} \quad (2)$$

With the aforementioned assumptions, the savings in energy cost per year would be above 11 € just looking at one connector. For a whole system, this amount would increase significantly.

At ifas, this case study was used to develop a flow-optimized geometry using additive manufacturing, namely poly-jet printing of polymer. The idea was to keep the original design and manufacturing process of a 90° connector as it is and develop an inlay to optimize the flow path. **Figure 8** shows the initial design concept, see [25]. Here, the symmetry plane of the 90° connector is used to create two identical inlays that can be mounted into each channel, meeting at the plane of symmetry. This gives the inlays a defined mounting position. Detachment of the inlays is prevented by mounting tubes or pipes at each end of the connector. The flow optimization was done focusing on minimizing the losses due to the 90° bend. Introducing an additional rotational spin to the fluid flow benefits the pressure drop immensely.

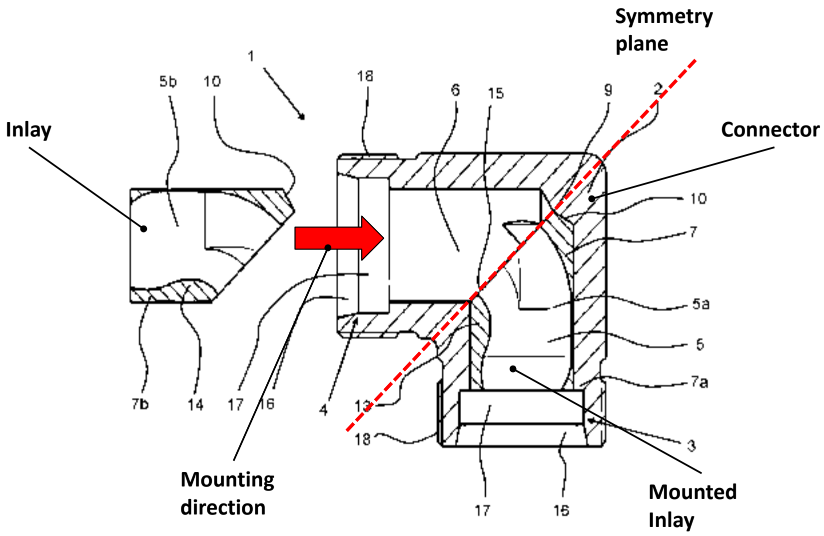

Fig. 8. Conceptual design of an additively manufactured inlay for mounting into a 90° connector [25]

It was found with the design shown in **figure 8**, pressure losses over the connector can be reduced by up to 40% depending on the flow conditions. An additional benefit is the symmetrical layout. This guarantees a bidirectional flow with identical flow characteristics.

Regarding manufacturing costs, the inlays can be manufactured using AM techniques requiring only little cost compared to the saving potential. Due to the design, these parts don't need to be pressure resistant since the connector acts as a wall.

5. Conclusion and Outlook

In this paper, the manufacturing capabilities currently offered by AM were presented with a special focus on laser powder bed fusion. The AM industry is currently growing exponentially and is constantly penetrating new markets and industries. Compared to traditional processes, it offers the possibility of aligning the design of components more closely to the functions, which is currently of particular interest for fluid components with flow channels. The channels can be optimally aligned to the expected flow conditions and higher flow rates, lower pressure losses and more compact structures can be realized in this way. In the fluid power industry, AM is currently still not well represented. For hydraulics, AM is used in the fields of aerospace, racing and robotics. This may be due to the fact that AM components are still used as substitutes in existing designs. The higher costs must therefore usually be more than compensated by a single factor from the user's perspective, for example an outstanding power-to-weight ratio, which is of interest in the aerospace sector but not in stationary hydraulics. As the case study shows, however, AM can also be interesting in other areas and, with a long-term view to costs, can already offer solutions today that enable efficiency gains and cost savings in operation through a design that cannot be realized with traditional manufacturing methods.

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THE REVERSE ENGINEERING OF A PELTON BUCKET BY PHOTOGRAMMETRY

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Abstract: *The paper illustrates the Reverse Engineering of a Pelton bucket geometry, who was scanned through Photogrammetry technique and processed with the following software packages: Agisoft Photoscan and Geomagic Design X; the solid geometry and the drawing of the bucket were generating using the SolidWorks software. The 3D geometry of the bucklet was compared with the bucket mesh generated in Geomagic Design X based on point cloud obtained in Agisoft Photoscan software. Ultimately, the reconstructed geometry were compared with measured points on the real bucket on CNC machine.*

Keywords: *Reverse Engineering, Photogrammetry, Turbine, Pelton, bucket*

1. Introduction

The top efficiency harvesting of water courses hydropower potential by engaging low head hydroelectric plants [1], as also the efficiency growing at existing peak hydroelectric arrangements by acquiring pumped-storage hydroelectric power plants [2] or by endowing the operating hydroelectric plants with special supplementary micro-turbines, depend also on the accuracy by which the turbine's buckets are digitally designed and completed. Using the Reverse Engineering technology, the geometry of a scaled Pelton bucket with the mass equal to 0.704 kg, Fig. 1, will be reconstructed by following the next steps:

- 3D scanning of the bucket using Photogrammetry and the Agisoft Photoscan software;
- the bucket reconstruction using the Geomagic Design X and SolidWorks software packages.

Fig. 1. The bucket geometry

2. Acquisition of the images

The acquisition of photographic images was done with the NIKON D610 camera positioned on a tripod, generating 78 snapshots from different successive angles, covering 720 degrees on two levels of the bucket, Fig. 2. The following shooting parameters were used: Focal length 50, F-stop F / 11, ISO 1600, Shutter 1/60.

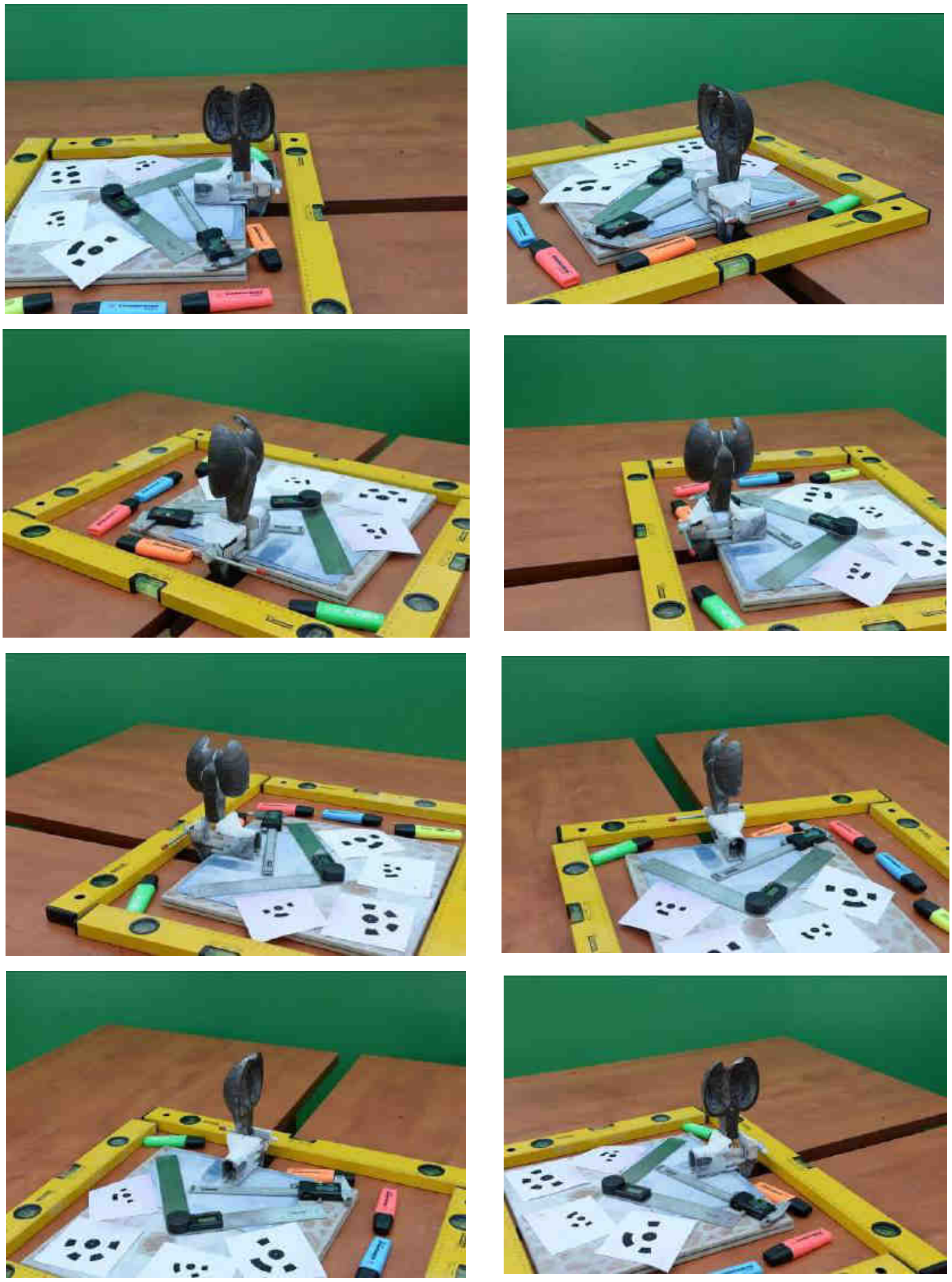

Fig. 2. The images sequence of the scaled bucket

3. Cloud Point Generation in Agisoft Photoscan software

The import of photos into the Agisoft Photoscan software is shown in Fig. 3. The sparse cloud of 169,445 points is shown in Fig. 4; the dense cloud of 1,780,197 points is shown in Fig. 5. The point cloud calibration (scaling the geometry to real values) based on known distances is shown in Fig. 6. The dense point cloud generated in the Agisoft Photoscan software was exported in OBJ format to be imported into the Geomagic Design X software.

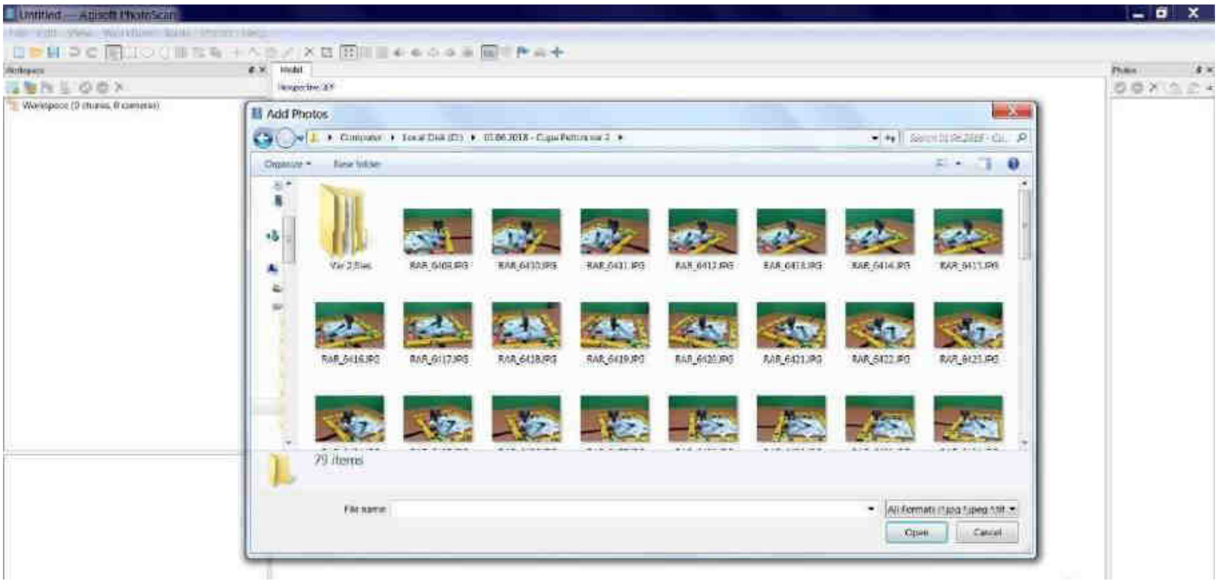

Fig. 3. Images inserted into the Agisoft Photoscan software

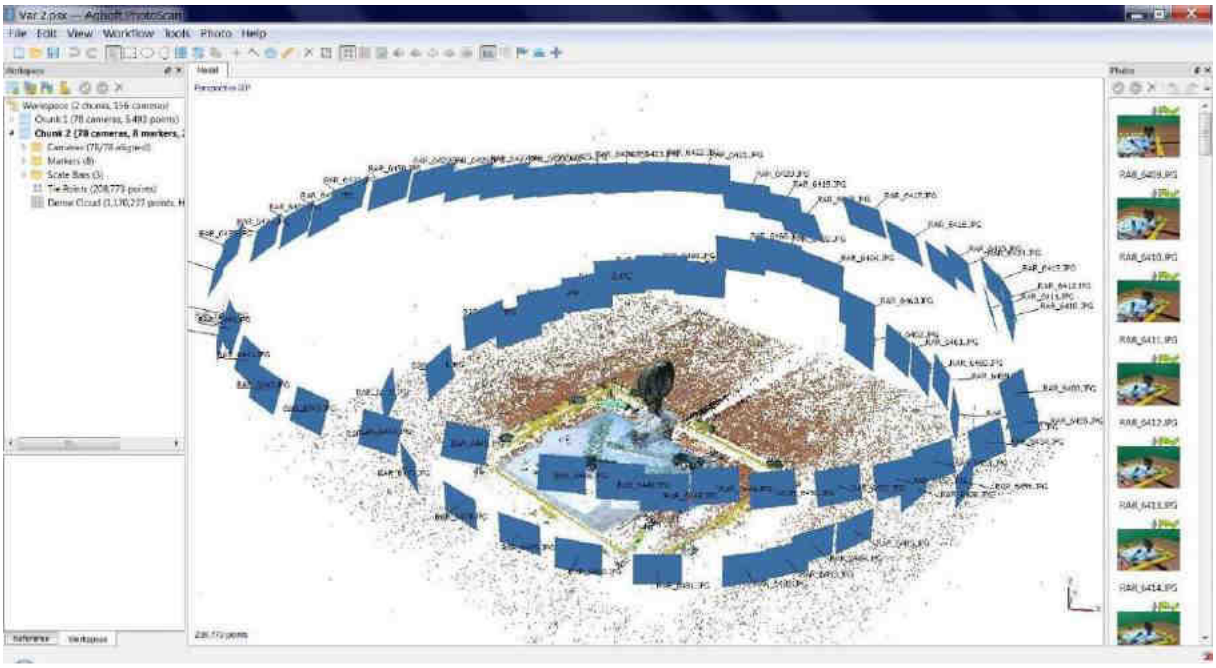

Fig. 4. Images aligned in Agisoft Photoscan and sparse cloud generation of 208,773 points

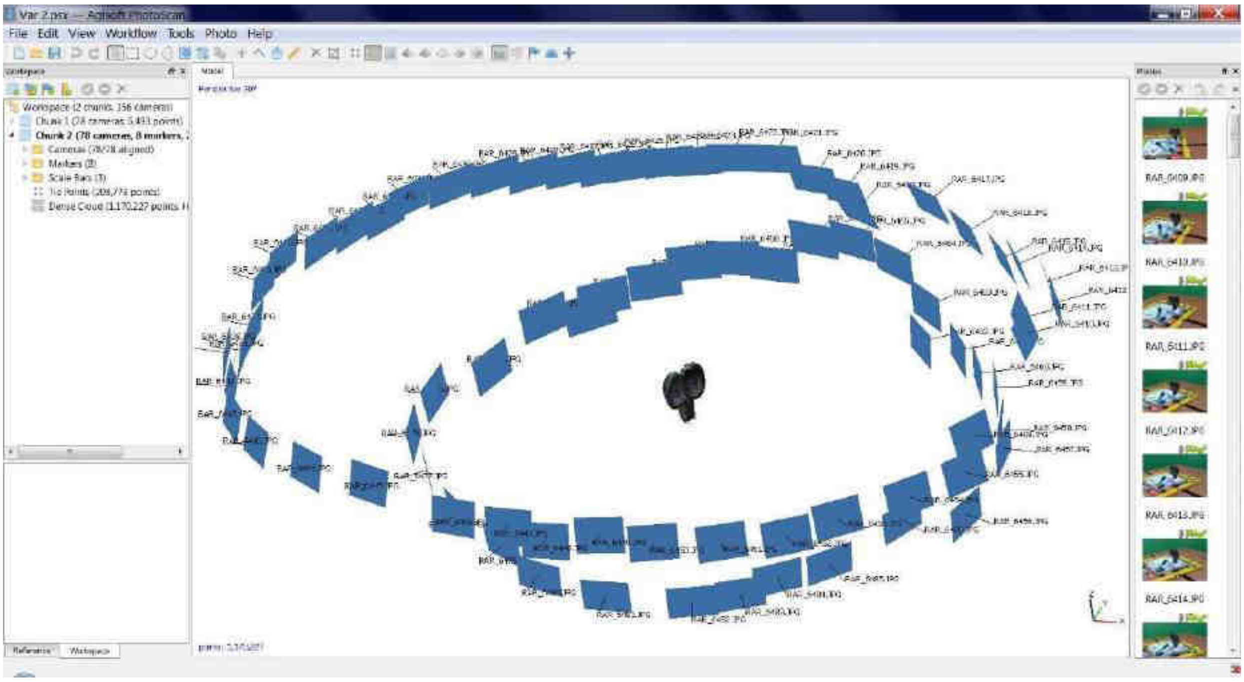

Fig. 5. Dense points cloud generation of 1,170,227 points in Agisoft Photoscan software

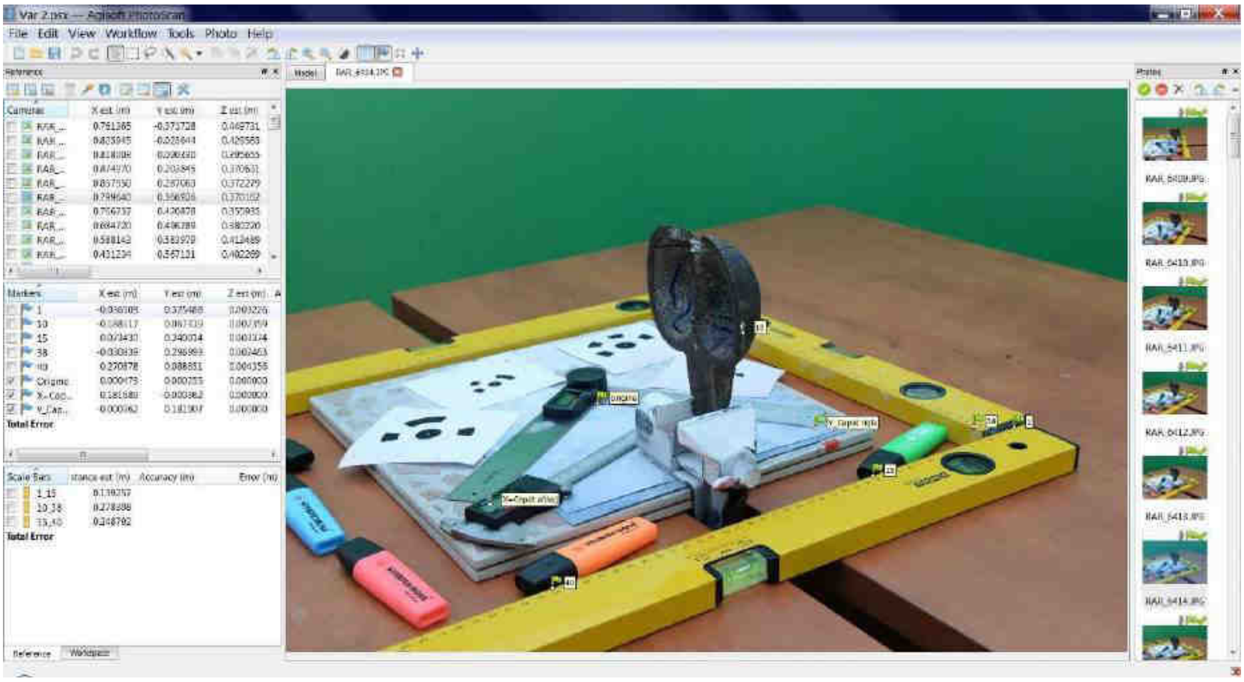

Fig. 6. Points cloud calibrating in Agisoft Photoscan software

4. Generate the bucket geometry in solid format

The dense points cloud of 1,170,227 points was loaded into the Geomagic Design X application, Fig. 7, in which the bucket surfaces were generated; then the surfaces were exported to SolidWorks, where solid bucket geometry was generated, Fig. 8. The mass of the solid bucket reported by SolidWorks is 0.701 kg. Fig. 9 shows the drawing of the reconstructed bucket.

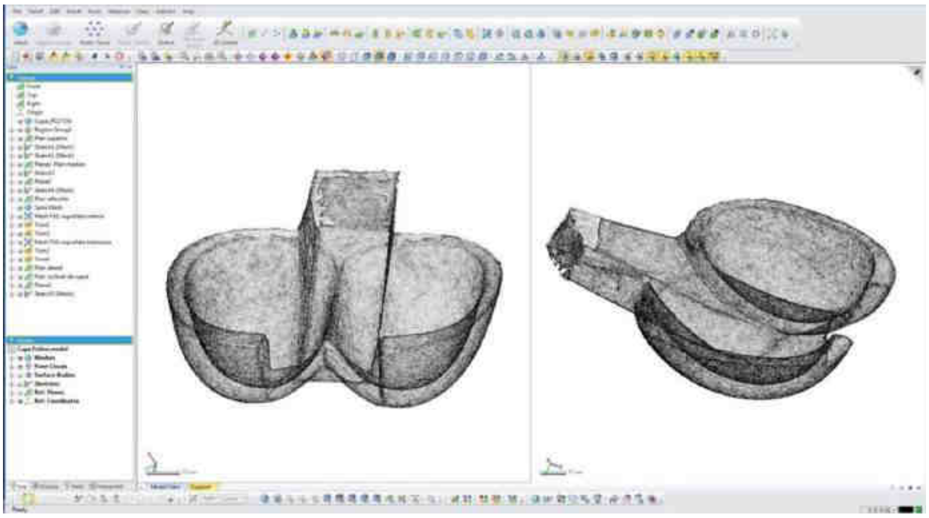

Fig. 7. Points cloud imported in Geomagic Design X software

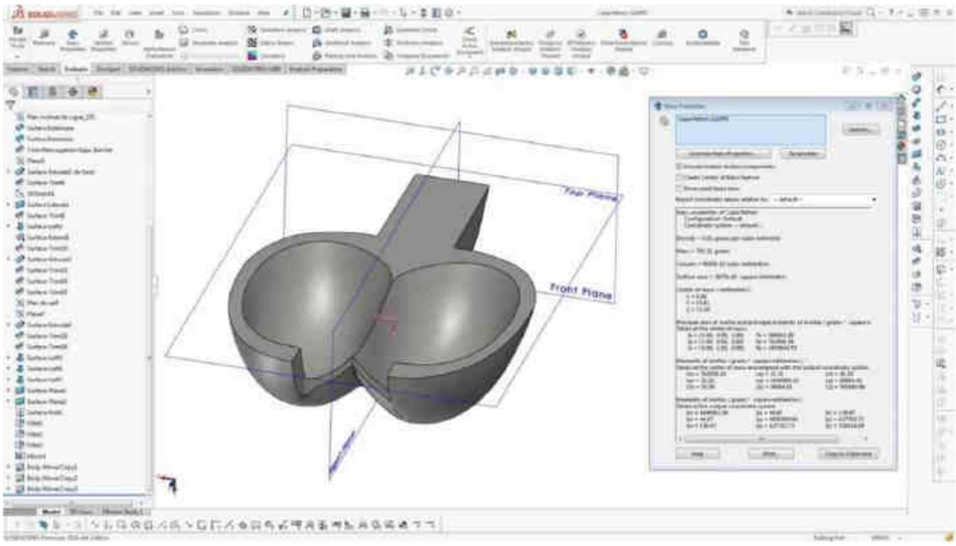

Fig. 8. The 3D bucket geometry in solid format

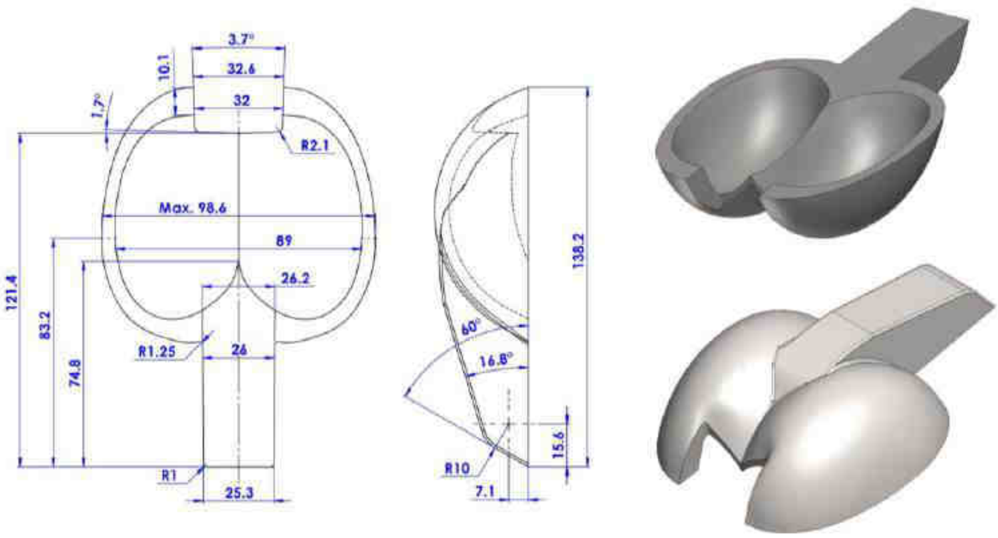

Fig. 9. The bucket drawing

6. Comparison of the bucket mesh with those reconstructed as solid format

Fig. 10 present the comparison of the bucket mesh generated in Geomagic Design X software, with the bucket reconstructed as solid format in SolidWorks. The two geometries were imported into the GOM Inspect application; the bucket was aligned with automatic best-fit alignment algorithm, so the geometry of the reconstructed bucket overlaps with minimum deviations over the mesh bucket. The most significant errors are in the area of the bucket top -1.87 ÷ +1.09 mm, but the rest of the values are within ± 0.28 mm.

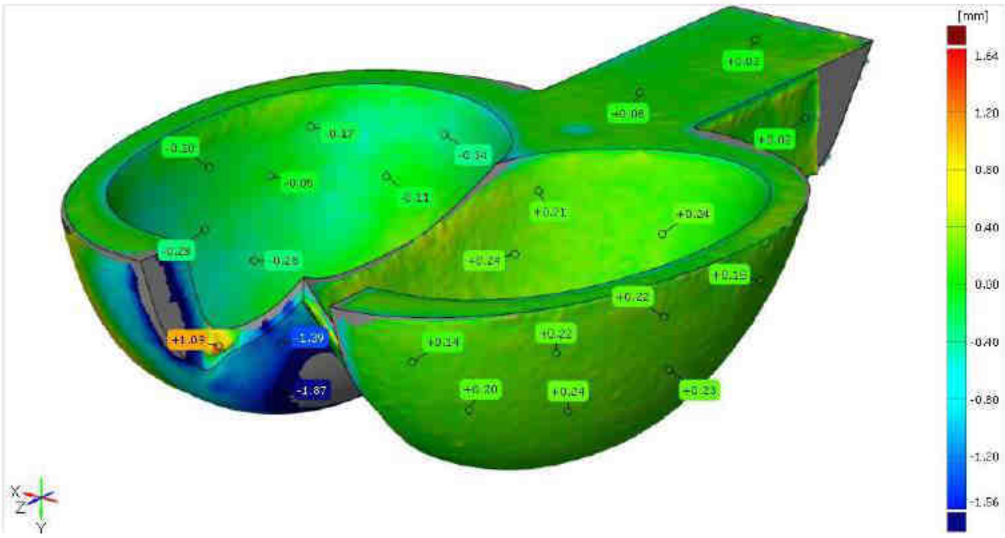

Fig. 10. The mesh comparison of the bucket with those in solid format

7. Comparison of the measured bucket with those reconstructed as solid in SolidWorks

To verify the accuracy of the bucket reconstruction, it was measured on the DMF 180 DECKEL MAHO CNC machine, Fig. 11, on four planes, A-A, B-B, C-C, D-D, for 22 points, Fig. 12 and Fig. 13. The numerical comparison is presented in Table 1. For 22 points measured, except for three points marked with bold in Table 1, the remaining deviations fall within ± 0,4 mm. These deviations include scanning and photogrammetry errors, SolidWorks geometry reconstruction, the alignment errors in the machine's vice and machine measurement errors.

Fig. 11. The bucket fixed in CNC machine

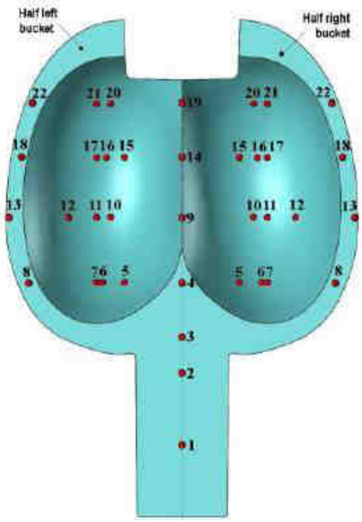

Fig. 12. The measured points

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DMF 180 DECKEL MAHO on the bucket

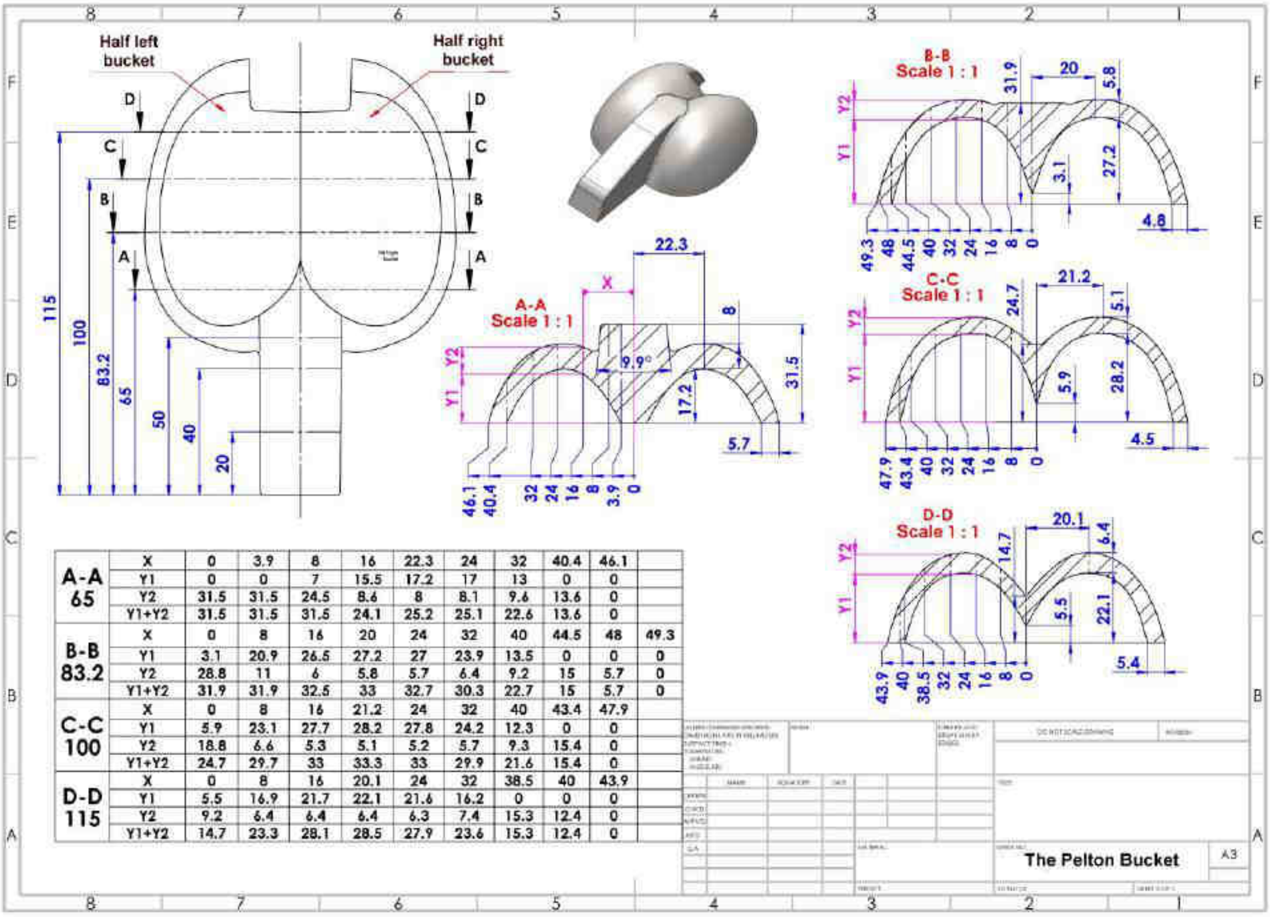

Fig. 13. The measured sections on the bucket

Table 1: Measurement results on Pelton bucket points

ID Point	Secţion Fig. 13	The section position Fig. 13	X Fig. 13	Y1 SolidWorks Fig. 13	Y1 measured on half left bucket	Y1 measured on half right bucket	Deviations	
							Δ_{left}	Δ_{right}
1	-	20	0	0	0.04		-0.04	
2	-	40	0	0	0.005		-0.005	
3	-	50	0	0	0.077		-0.077	
4	A-A	65	0	0	0.007		-0.007	
5	A-A	65	16	15.5	15.452	15.793	-0.048	0.293
6	A-A	65	22.3	17.2	16.847	17.668	-0.353	**0.468**
7	A-A	65	24	17	16.884	17.395	-0.116	0.395
8	A-A	65	43	0	0.157	0.073	0.157	0.073
9	B-B	83.2	0	3.1	3.364		-0.264	
10	B-B	83.2	20	27.2	27.274	27.424	0.074	0.224
11	B-B	83.2	24	27	27.09	27.252	0.09	0.252
12	B-B	83.2	32	23.9	24.279	23.683	0.379	-0.217
13	B-B	83.2	48.5	0	0.188	0.112	0.188	0.112

Table 1: Measurement results on Pelton bucket points

ID Point	Secţion Fig. 13	The section position Fig. 13	X Fig. 13	Y1 SolidWorks Fig. 13	Y1 measured on half left bucket	Y1 measured on half right bucket	Deviations	
							Δ_{left}	Δ_{right}
14	C-C	100	0	5.9	5.829		0.071	
15	C-C	100	16	27.7	27.636	27.495	-0.064	-0.205
16	C-C	100	21.2	28.2	28.392	28.012	0.192	-0.188
17	C-C	100	24	27.8	28.12	27.577	0.32	-0.223
18	C-C	100	45	0	-0.108	0.157	-0.108	0.157
19	D-D	115	0	5.5	5.733		-0.233	
20	D-D	115	20.1	22.1	21.465	21.767	**-0.635**	-0.333
21	D-D	115	24	21.6	20.947	21.195	**-0.653**	-0.405
22	D-D	115	42	0	0.239	-0.003	0.239	-0.003

8. Conclusions

The objective of the paper is to describe the reverse engineering stages to transform a real bucket object into a virtual geometry, using the Photogrammetry techniques. From the comparison of point cloud mesh with the bucket reconstructed in SolidWorks, it was concluded that the largest errors occurred in the range -1.87 ÷ +1.09 mm at the top bucket, but rest of the values were included within ± 0,28 mm. From the measurements made on the real bucket, the deviations of the reconstructed bucket fall within the deviations range within ± 0.4 mm.

Acknowledgments

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INNOVATIVE STAND FOR TESTING OF HYDRAULIC PUMPS AND MOTORS

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Abstract: *The article presents an innovative solution for developing of a stand on which both pumps and hydraulic motors are tested. The functional innovation of the stand is represented by the fact that the driving of the tested pump is made by the motor under tests, and the load on the shaft of the motor to be checked is provided by the checked pump.*

Keywords*: Stand, check, pump, motor*

1. Introduction

Hydrostatic pumps and motors are complex high-tech products used in a wide range of applications, of which we mention only their use in the production of stationary or mobile machinery and equipment.
For the verification of their technical characteristics and periodic certification or post-repair certification, these pieces of equipment must be checked according to specific methodologies on specialized test stands.
A modern testing system supposes the existence of computer resources in its structure. In addition, experimental testing systems must incorporate high precision sensors and transducers, as it is known that usually a transducer must be with an order of magnitude more precise than the degree of precision of the verified parameter. [1]

2. Checking of hydraulic pumps and motors

Checking the quality of hydraulic pumps and motors consists in performing the tests and checks as shown in Table 1.

Table 1

Ref. no.	Verifications, checks, tests	Pumps		Motors	
		TYPE tests	BATCH tests	TYPE tests	BATCH tests
1.	Running	x	x	x	x
2.	Exterior aspect	x	x	x	x
3.	Size of the main parts	x	-	x	-
4.	Materials of the main parts	x	-	x	-
5.	Connection and size dimensions	x	-	x	-
6.	Mass	x	-	x	-
7.	Displacement volume	x	x	x	x
8.	Maximum pressure	x	-	x	-
9.	Rated pressure	x	x	x	x
10.	Minimum (start) pressure	-	-	x	-

11.	Maximum speed	x	-	x	-
12.	Rated speed	x	x	x	x
13.	Minimum speed	x	-	x	-
14.	Internal flow losses	x	x	x	x
15.	Flow pulses	x	-	-	-
16.	Unevenness of speed	-	-	x	-
17.	External sealing	x	x	x	x
18.	Noise level	x	-	x	-
19.	Operation at extreme temperatures	x	-	x	-
20.	Running time (Endurance)	x	-	x	-

3. Test method for hydraulic pumps and motors

The method of testing hydraulic pumps and motors presented in this article concerns only the essential tests that are made for the qualitative assessment of these products.
For performing research testing, such as tests to verify dynamic operation, procedures can be completed with:
- measuring of physical parameters of mechanical nature (including hydraulic parameters) and converting them into electrical parameters;
- specialized IT (information technology) equipment for processing of signals from the testing process;
- test instructions adapted to the particular accuracy and special character of the tests.

3.1. Basic principles

Pumps and motors testing technology will include:
- hydraulic test diagram;
- structure of the hydraulic test diagram;
- instructions for the execution of the tests;
- indications regarding the expression of the verification results;
- other information necessary to perform the tests.

The running test was also included in the category of checks, although it is not a check in itself, but a functioning regime of a product that can be assimilated with a commissioning. [2]
By running it is intended to prepare the product to be able to operate at rated parameters by primary lubrication of the work surfaces in relative motion and their "fitting" so that it can take over maximum contact efforts.
Product life and the average time of proper functioning both depend on making correct running.
It is advisable to make the running on the test stand because it allows precise adjustment of functional parameters of the product and the working fluid.

3.2. Measurement of parameters

For the measurement of the parameters referred to above in point 2, in addition to conventional measuring instruments, there is also used modern equipment in which the measurement operations are carried out by means of transducers which allow the automation and introduction of information technology in the test process. In this way automatic setting of imposed parameters and automatic recording of the measured parameters are performed.
● Pressure measurement
The most common pressure transducers for equipping test stands for hydrostatic pumps and motors are:
- with elastic sensitive elements (curved tube, membrane, bellows, etc.);
- with piezoelectric elements.

● Flow measurement
Circulated flows are measured by direct or indirect methods:
- the transducers used for direct measurement are of the fixed volume measuring chamber type (graduated beaker) and are especially suited for pump discharge flows;
- the transducers used for indirect measurement of flow are: with hydraulic mill actuated by jet, with turbine, mass flow (Coriolis effect), with the reduction of flow section (with diaphragm, nozzle, Venturi tube), with swirled jet (Vortex type), with immersion device without articulation and without elastic reaction (rotameter), with articulated immersion device (with clapper).
● Speed measurement
The main types of speed transducers used in hydraulic systems are: direct or alternating current tohogenerators and speed transducers with photoelectric, inductive or magnetic elements.
● Power measurement
Determining the energy characteristics of hydrostatic pumps and motors requires measurements of torque moments and effective power.
Since the pump always works coupled with another motor machine, the power consumed on the pump shaft can be measured in two ways:
- directly, with electric power instruments and transducers in case of drive by electric motor and when is known the efficiency of the electric machine;
- indirectly, as in the case of the stand presented in this article, by measuring the torque by means of torsiometric couplings intercalated between the motor machine shaft and the pump shaft as well as the drive speed. [3]
● The other parameters involved in the test process - length, time, forces, temperature, density, viscosity, etc. - can be measured directly with the caliper, timer, etc. or indirectly with transducers of various types.

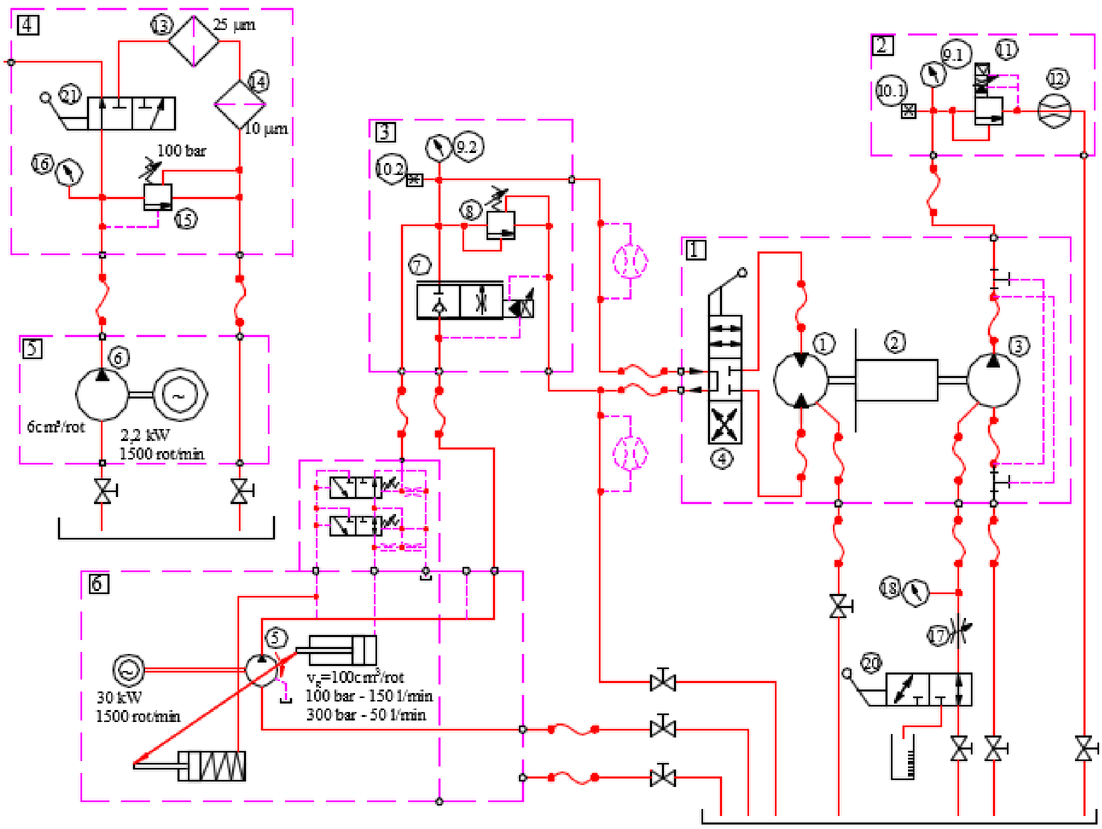
3.3. The test diagram and its structure

The test diagram of hydrostatic pumps and motors is shown in Fig. 1, and the structure of the diagram - in Table 2.

Table 2

Ref. no.	Furniture	Pcs.	Characteristics
1.	Hydraulic test / drive motor	1	125 cm^3 / rev; 320 bar;
2.	Speed and torque transducer	1	10 ... 3600 rev / min.;
3.	Test pump / load pump		
4.	4-way valve	1	rD 16; 320 bar;
5.	Electropump	1	30 kW; 1450 rev / min.; 100 cm^3 / rev; 320 bar; regulator DFLR
6.	Electropump for filtering and hydraulic controls	1	2.2 kW; 1450 rev / min; 6 cm^3 / rev; 100 bar;
7.	Proportional throttle	1	rD 16; 320 bar;
8.	Pressure valve	1	rD 16; 320 bar;
9.	Manometer Ø 100	2	400 bar; glycerine;
10.	Pressure transducer	1	400 bar; 4 – 20 mA;
11.	Proportional pressure valve	1	rD 16; 320 bar;
12.	Flow transducer	1	250 l / min.; 400 bar;
13.	Filter 25 µm	1	25 µm; 10 bar;
14.	Filter 10 µm	1	10 µm; 10 bar;

15.	Safety valve	1	rD 10; 100 bar;
16.	Manometer Ø 100	1	100 bar; glycerine;
17.	Throttle	1	rD 6; 10 bar;
18.	Manometer Ø 100	1	rD 6; glycerine;
19.	-		
20.	Three-way valve	1	rD 10; 10 bar;
21.	Three-way valve	1	rD 10; 100 bar



1. Pump drive and motor load device
2. Pressure adjustment subassembly
3. Flow control subassembly
4. Oil filter subassembly
5. Electropump for filtering and hydraulic controls
6. Electropump

Fig. 1. Stand for testing hydraulic pumps and motors. Hydraulic diagram

4. Structure of the test stand

The stand for testing pumps and hydraulic motors is made up of six subassemblies: pump drive and motor load device, pressure adjustment subassembly, flow adjustment subassembly, oil filter subassembly, stand electropump and oil filter and hydraulic controls electro-pump - see hydraulic diagram in figure 1.

4.1. Device for pump drive and motor load – fig. 1 /pos. 1.

It consists of a frame on which the hydraulic motor *1* is fixed to one end and the pump *3* at the other end. The motor shaft *1* rotates the pump shaft *3* by means of a coupling which encloses the torque and speed transducer *2*. The valve *4* inverts direction of rotation of the motor.

4.2. Pressure adjustment subassambly– fig. 1 /pos. 2.

The tested pump / load pump pressure *3* is measured with the manometer *9.1* and read with the pressure transducer *10.1*. The pump pressure is adjusted with the proportional valve *11* and the flow is measured with the flowmeter *12*.

4.3. Flow control subassembly – fig. 1 /pos. 3.

The speed of the hydraulic motor *1* is proportional to the oil flow with which it is powered by the stand electropump. Adjustment of this flow is done by means of proportional throttle *7*. The safety valve *8* limits the pressure on the discharge circuit of the pump. The pressure in the supply circuit of the hydraulic motor is indicated by the pressure gauge *9.2* and the pressure transducer *10.2*.

4.4. Oil filter subassembly – fig. 1 /pos. 4.

The subassembly consists of two cascade oil filters, a filter *13* with 25 µm and a filter *14* with 10 µm that provides filtering of the oil stand, a safety valve *15* which limits the pressure on this circuit at 100 bar, a manometer *16* and a valve *21* which switch the circuit on the filter function or hydraulic controls function.

4.5. Electropump for filtering and hydraulic controls – fig. 1 /pos. 5.

It ensures the operation of the hydraulic oil filter circuit in the test stand or the hydraulic controls if the pump or the motor to be tested has devices for variation of displacement volume with hydraulic control in its structure.

4.6. Electropump – fig. 1 /pos. 6.

The electropump *5* provides the required hydraulic power for the test stand. The variable flow required to achieve different test speeds is given by the variable speed pump *5* which has an L.S. pressure and flow control device.

5. Advantage of hydraulic actuation of the pump to be tested

At the test stand proposed in this article, the drive of the pump to be tested is achieved by a hydraulic motor. Figure 2 shows the graphs M - n for drive with hydraulic motor versus drive with electric motor and variable speed.

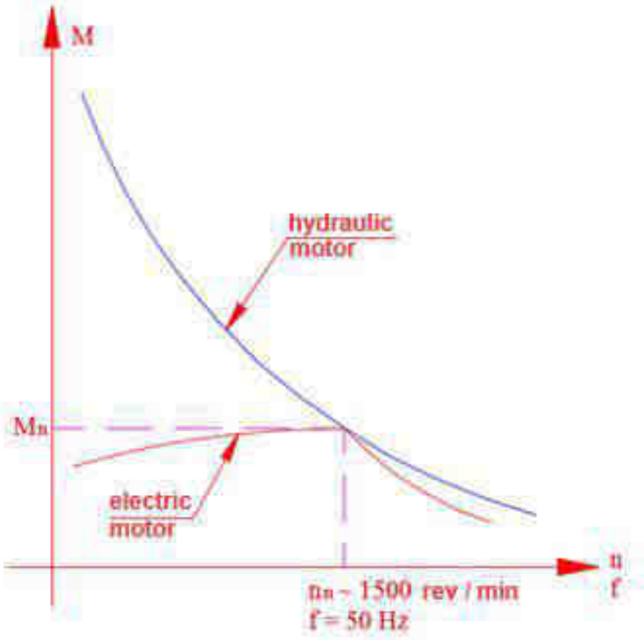


Fig. 2. Comparative chart M – n on electric and hydraulic drive

Hydraulic motor and variable speed drive is made on the constant power hyperbola P = n · M = ct. This means that if the test speed drops, the torque M = p · Vg increases, that is higher pressure tests and tests for higher capacity pumps can also be carried out. [4]
Electric drive with variable speed (frequency converter) lower than the rated one is made on the quasi-constant torque curve M = p · Vg $\sim ct$. This means that the values of the tested parameters: pressure and displacement volume cannot increase when the test speed decreases, and this is a disadvantage compared to the hydraulic drive.

6. Conclusions

The stand proposed in this article is an innovative solution in the field of hydraulic machines because:
● it allows the testing of both pumps and hydraulic motors on the same stand;
● it allows the hydraulic pumps to be tested at variable speed on the constant power drive hyperbola;
● it allows the carrying out of essential tests for the certification of the quality of hydraulic pumps and motors;
● it allows completion with special items for research purposes;
● it allows the realization of the controls, adjustments and registration of the tested parameters both in manual and automatic mode by implementing a control and monitoring system.

Acknowledgments

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NEW SOLUTION FOR WATERJET CUTTING AND MILLING MACHINE

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Abstract: *The paper presents a sealing system without liquid leaks which can be utilised to hydraulic pumps, and motors, especially those operating at high pressures. It describes the technical solution of the system and a mathematical model for determining the pressure, depending on several constructive parameters. The work is based on a patent application of the first author, registered with the State Office for Inventions and Trademarks.*

Keywords*: Hydraulic pump, sealing, folded membrane.*

1. Introduction

The current state of the art describes some sealing systems designed to work at high pressures. Hammelmann Gmbh sealing systems [1] are used for industrial cleaning systems (paint, rust etc.) and for waterjet cutting machines. These can be classified as follows:

- A sealing system called “packed sealing” that consists of a number of adjacent ring-shaped metal seals and guide bushing for the plunger. This seal can be used up to 1600 bar.
- A “labyrinth sealing” solution, which is used up to 2000 bar, comprises a bushing and plunger assembly with a very small clearance. A series of grooves cut in the bushing seals most of the water, the rest being discharged through the clearance between the plunger and bushing.
- The system called “dynamic sealing” consists of a seal between bushing and plunger and ensures good performance up to 3800 bar.

All three of the above solutions have the disadvantage of not ensuring a perfect seal and working with liquid loss. Furthermore, none of the above solutions work at pressures higher than 3800 bar.
Another sealing system is the one used by the company KMT which works at higher pressures than Hammelmann’s, but no more than 6200 bar. The system uses an oil-water intensifier with a ceramic plunger and an assembly of metal seals [2]. Its main disadvantage is that it too works with liquid loss.
Patents DE10215311 (A1) and JP2004003630 [3, 4] describe a seal between a plunger and a bushing which uses a metal ring which deforms with the rise of the working pressure. The disadvantage of this solution is the wear of deformable ring and the plunger, and it also has leaks.
Another disadvantage of sealing system which operate with liquid loss consists of the chemical and corrosive action of the liquid on the sealing system. Also, in the case of liquids which contain abrasive particles, there is a significant and fast wear of the sealing elements.
Membrane pumps and motors have a perfectly sealed chamber formed between the membrane and the housing and work without any liquid losses. They generally use rubber membranes that are reinforced with textiles and allow great deformations. The disadvantage of these membranes is that they cannot exceed 150 bars. Furthermore, the chemical industry utilizes a lot of liquids which quickly deteriorate non-metallic membranes.
Patent EP2589807 [5] shows a low-pressure pump for gasoline engines. The pump uses a metal bellow which is deformed by an electromagnet. The inside of the bellow creates a liquid-tight chamber that modifies its volume and in doing so pumps the gasoline. The disadvantage of this pump consists of the impossibility of operating at high pressures due to lateral deformations of the bellows.

2. Presentation of a new solution

The new solution presented in this paper consists in separating the piston and cylinder from the pressurized liquid by using a metal membrane. Figure 1 presents a section through the sealing system and its main components.

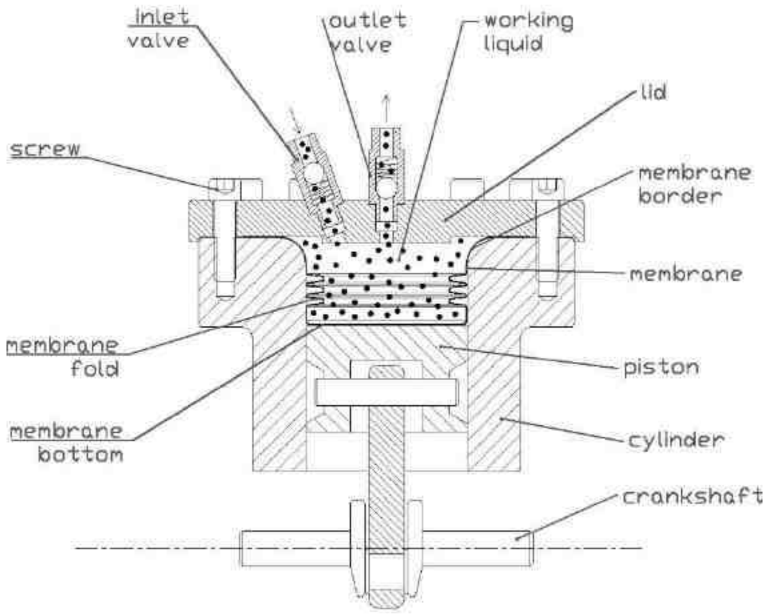

Fig. 1. Section through the sealing system

Figure 1 shows that the pump membrane is comprised of a cylindrical portion with folds. It has a border with a fillet on one end (the upper end in Figure 1), which helps secure the membrane between the cylinder and the lid. The other end of the membrane can be either of the following types:

- Open end that is welded to the piston (Figure 2);
- Closed end, that is not attached to the piston, but seats on the latter. This end can have different shapes, planar or curved shape (Figures 3a and 3b), which fits into the end of the piston.

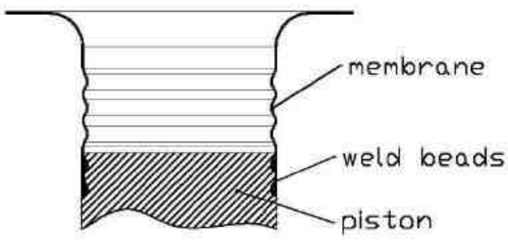

Fig. 2. The membrane with the open end welded to the piston

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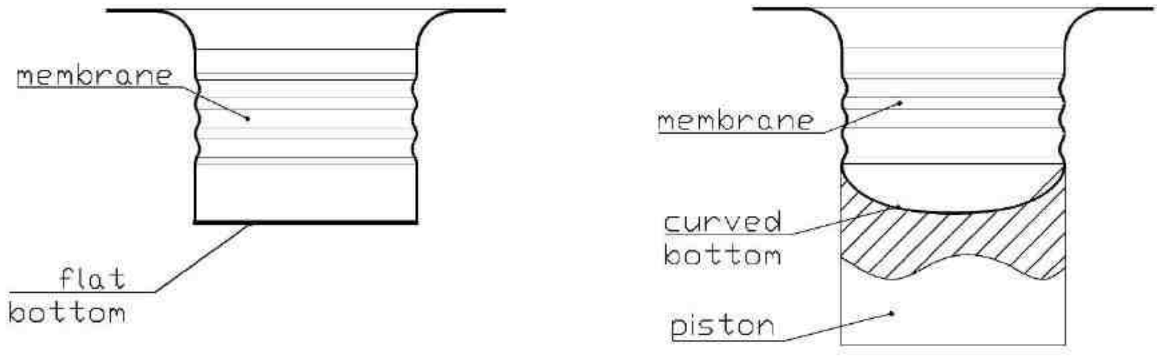
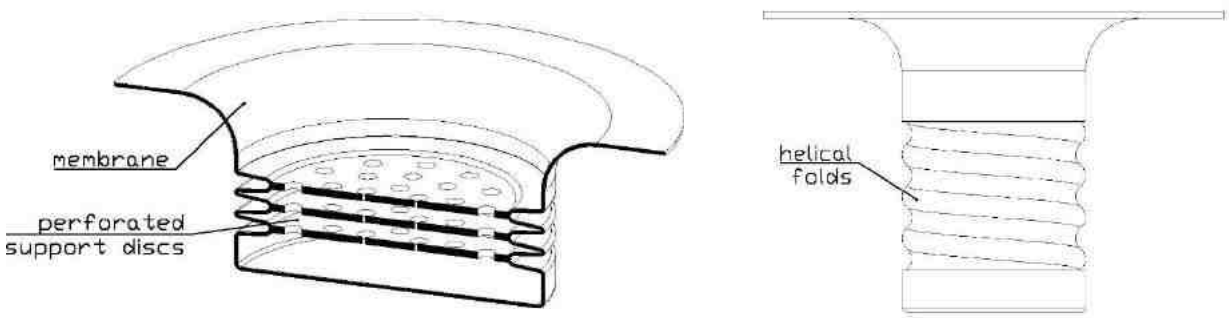


a) b)

Fig. 3. The membrane with a closed end shaped: a) flat b) curved

It is important that the membrane is elastic. This requirement means choosing an appropriate material and creating folds on its surface. The membrane with circular or helical folds (Figures 4a and 4b) works as a spring.



a) b)

Fig. 4. The shape of the folds: a) circular b) helical

As mentioned earlier, the chamber is sealed at the upper end (Figure 1) by fixing the membrane border between the cylinder and the lid and holding it down with screws. The sealing can be further improved by cutting grooves into the surfaces of the lid and the cylinder (Figure 5).

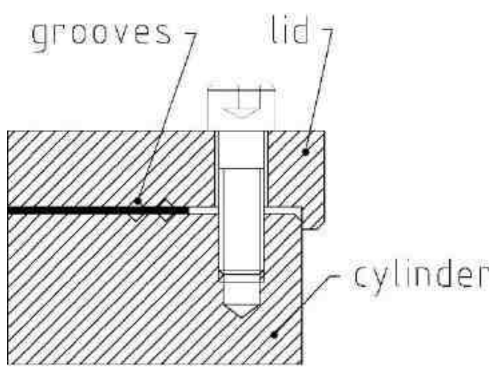


Fig. 5. Clamping of the membrane border

The working principle of the pump is as follows:

- Phase 1 (compression): the piston is moved by a force inside the cylinder and compresses the fluid between the membrane and the pump's lid by elastically deforming the membrane. As the pressure rises the fluid is ejected through the outlet valve.

- Phase 2 (suction): during the backstroke of the piston the membrane expands back to its original shape and sucks in fluid through the inlet valve.

The membrane can be designed in one of several variants considering the following options:

(a) The option to close or leave open the membrane end which sits on the piston;
(b) The option of having a flat or curved bottom, if the bottom is sealed;
(c) The option of having either circular or helical folds;
(d) The option of reinforcing the fold tips using perforated discs in order to reduce their deformation when acted upon by high pressure.

Membranes that have certain advantages can be obtained by combining options (a) - (d):

- The convex shape of the membrane where it borders the piston (Figure 3b) optimizes the pressure distribution of the liquid on the surface of the membrane;
- The helical shape of the folds (Figure 4b) improves the lubrication of parts of the membrane which slide on the cylinder wall;
- Reinforcing the folds prevents high plastic deformation from occurring when the membrane is subjected to high pressures.

Reinforcing the folds, when these have a circular shape, can be done by welding perforated metal discs inside the membrane (Figure 4a). The perforations of the reinforcing discs allow liquid to travel through.

The sealing solution can be further improved by modifying the shape of the lid by adding a bulge to it (Figure 6).

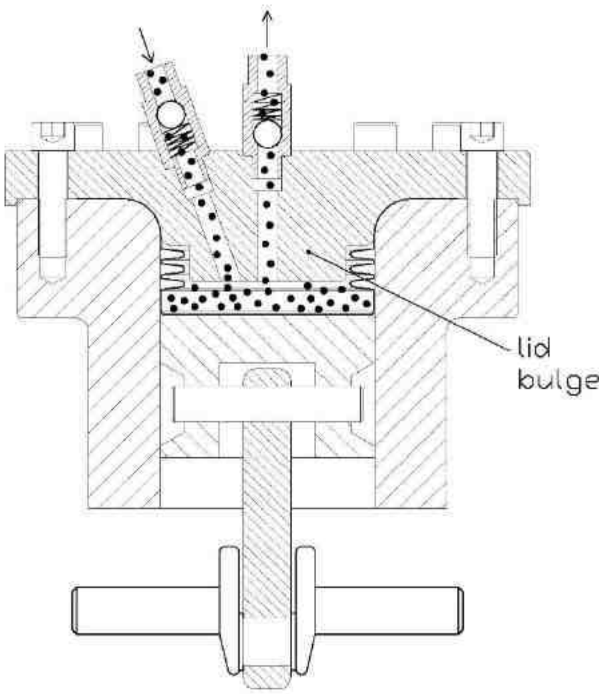


Fig. 6. Pump with a lid bulge

This lid bulge reduces the volume of the fluid chamber by occupying part of it. Due to the fluid's compressibility, the reduction of the volume of the fluid chamber causes a higher pressure in the chamber at a given stroke of the pump piston.

The friction and the wear between the membrane and the cylinder can be reduced by using diferent types of surface coatings, lubricants or material layers, for example, polytetrafluoroethylene (teflon).

The piston can be moved by a cam, a screw or by another element (hydraulic or electrical motor). If the sealing system is applied to a hydraulic motor, the piston may drive a crankshaft. In all variants of the invention, the piston of the pump may be replaced by a plunger, and the crankshaft may be replaced by any mechanical, electrical or hydraulic actuator.

3. Study on the pressure variation according to certain constructive parameters

The problem of alternating flows was treated in reference [6], and a mathematical model was presented in [7].
The study was conducted based on the simplifying hypotheses:

- There are no liquid losses around the seals or valves;
- The fold tips act as hinges and the sides don't deform;
- There are no pressure drops on the valves.

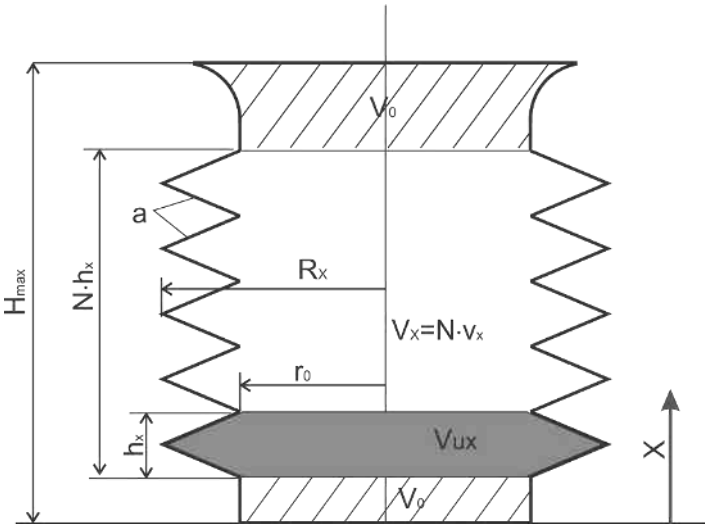


Fig. 7. The variation of the pump volume depending on the stroke x

Based on Figure 7, we can write the equations (1) – (2) of determining the unit volume Vu_x of a fold:

$$R_x = r_0 + \sqrt{a^2 - \left(\frac{h_x}{2}\right)^2} \tag{1}$$

$$Vu_x = \frac{2}{3}\pi h_x(R_x^2 + r_0^2 + r_0 \cdot R_x) \tag{2}$$

The total volume of the chamber is given by equation (3):

$$V_x = V_0 + N \cdot Vu_x \tag{3}$$

where N is the number of the membrane folds.

The pressure variation is determined considering the compressibility k of the fluid:

$$dp = -\frac{dV_x}{V_x \cdot k} \tag{4}$$

The pressure variation depending on the piston stroke may be approximated by equations (5) and (6):

$$p_x = p_a + \frac{1}{k} \cdot \frac{V_{xmax} - V_x}{V_{max}}; x \in [0, x_{max}];\ p_x \in [p_a, p_{max}] \tag{5}$$

$$p_{sx} = p_w - \frac{1}{k} \cdot \frac{V_{xmax} - V_x}{V_{max}}; x \in [\,x_{max}, 0];\ p_x \in [p_w, p_a] \tag{6}$$

The following notations were used:

p_a - pump supply pressure;
p_w - working pressure;
p_{sx} - pressure in the suction phase;
x - piston stroke.

Based on the above equations, a simulation program for the pressure variation was developed. The graphs in Figure 8 were developed based on the values in Table 1.

Table 1: Data for the simulation software

p_w	p_a	Hmax	r_0	a_j	N_j	x	k
[MPa]			[mm]				
40	0,5	120	20	6-12	24-10	0-80	$50\cdot10^{-10}$

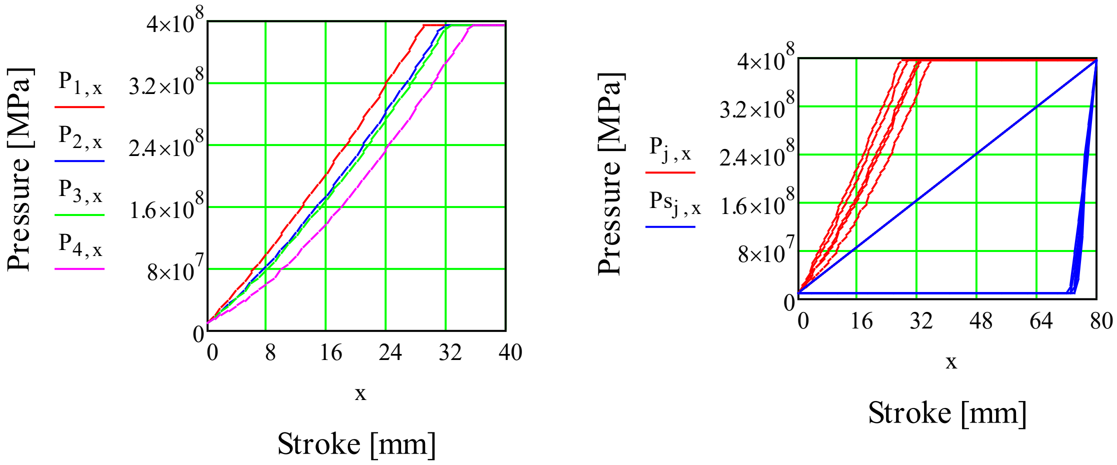


Fig. 8. Influence of the pump stroke on the pressure variation

4. Conclusions

The sealing system has the following advantages:

– Simple construction and high reliability;
– There are no liquid losses through the space between the cylinder and the piston;
– The system can be made of materials resistant to corrosion or to different chemical agents.

Based on the above study, it results that for the same operating conditions (pressure and flow), a pump with a larger number of folds performs better than a pump with fewer ones. Also, a higher compression of the folds increases the output flow of the pump.

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EXPERIMENTAL MODEL FOR THE DISINTEGRATION AND RECOVERY OF NOBLE METALS USING CAVITATION JETS

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Abstract: *Cavitation is a destructive phenomenon for elements of hydraulic systems, but this phenomenon can be used for beneficial purposes. Applications where the cavitational phenomenon is used: cleaning paint and rust from metal surfaces; removing marine biofilm and recovering noble metals with cavitation micro-jets by disintegration of emulsified material.*

Keywords*: Cavitation, cavitation micro-jets, noble metals, catalytic converter.*

1. Introduction

Cavitation is the phenomenon that occurs in a liquid stream, and is manifested by the emergence of a partial vacuum in which vapors bubble blows causing the walls of the duct or the container through which it flows.[1]

In normal liquids, these cavities (voids) are formed when the pressure at certain points is reduced to the value of the vapor pressure of the liquid. At these points or areas, the liquid boils and forms bubbles of steam, which together with the liquid stream - reach the area of high pressure, where the cavities fall. Condensation of the vapor bubbles in this region causes local hydraulic shocks and overpressures when the end of condensation, the surrounding liquid particles advancing towards the center of the bubble collide and suddenly stop.

Kinetic energy turns into elastic deformation energy. In areas where the cavitation process ends, the increase in pressure due to hydraulic shock reaches several tens, hundreds or even thousands of bars, and the energy of these crashes propagates in the form of external pressure waves with strong vibrations and characteristic noises. In the vaporization area there is an overlapping environment that can also be observed with the naked eye through a window. [2]

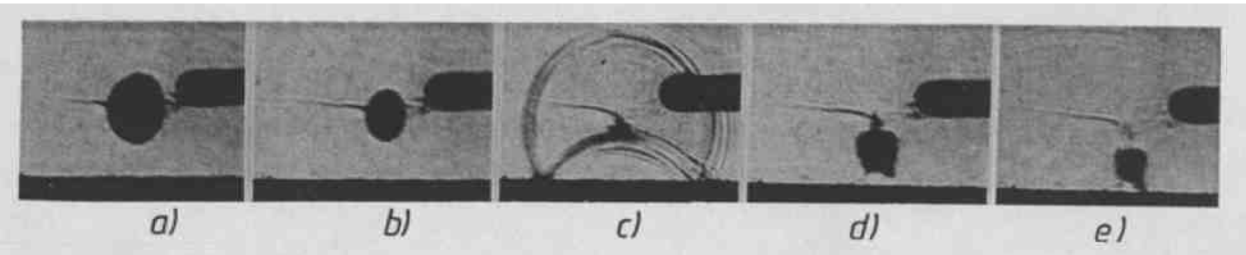


Fig. 1. Behavior of a cavitation bubble in the vicinity of a bubble wall:
a) generated vapor bubble to t_0 = 0: b) 1st collapse phase t_1 = 24μs c) beginning of the second oscillation period with emitted shock wave t_2 = 40μs; d, e) formation of a liquid jet towards the wall during the second oscillation phase t_3 = 68μs; t_4 = 100μs. Shock pressure of the emitted wave at the tip of the 6 mm remote needle probe P = 50 bar; Ambient pressure in the water 7 bar

The phenomenon of cavitation causes erosion and rapid wear of blades of turbines and hydraulic pumps, seagoing vessels, etc. These damages can be avoided by using various methods of protection against its destructive effects, from technological ones (the use of resistant materials) to physical (air-blowing, use of electric current, magnetic field, etc.).

The phenomenon of cavitation can be avoided by rationally designing and exploiting machine materials and machinery. The alloying of steels increases their resistance to cavitation destruction. Highly alloyed steels with 12 to 14% chromium, with or without nickel addition and a martensitic structure, and austenitic-ferrous stainless steels with 20% chromium and 8% nickel, resist cavitation well, these being the materials from which the turbine blades hydraulic. [3,4,5,6,7,8]

2. (Theoretical) aspects about the phenomenon of cavitation

For example, the flow of an ideal fluid, incompressible by a venturi type, consisting of a convergent truncated con- tinuous section with a short cylindrical portion called a constriction, and a divergent tronconic section at the exit (see Figure 2).

Considering two points M_1 and M_2 on the current line that coincides with the axis of the pipe so that M_1 belongs to the S_1 snap inlet section and the M_2 of the minimum cross section S_2, the difference between the static pressures p_1 and p_2 between the two points can be read either directly with open piezometric tubes, or can be determined by means of a differential pressure gauge.[9]

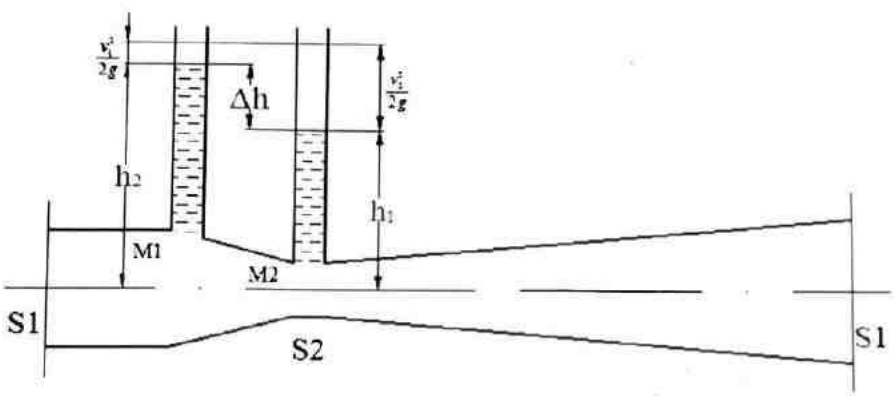


Fig. 2. Flowing through a Venturi tip [9]

According to the written continuity equation between section S_1 of area A_1 and section S_2 of area A_2:

$$v_1 \cdot A_1 = v_2 \cdot A_2 = Q \tag{1}$$

On the movement of the fluid between the two sections there is an increase of the velocity v_2 from the point M_2 belonging to the section S_2 as well as the decrease of the static pressure p_2 at the same point according to Bernoulli's relationship written between the points M_1 and M_2 considering the axis of symmetry of the straight tube reference plan:

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} \tag{2}$$

From the above relationships, we can see the difference between the piezometric heights $\frac{p_1}{\gamma}$ and $\frac{p_{12}}{\gamma}$ related to the points M_1 and M_2 (and, implicitly, the pressure drop between the two points) is directly proportional to the square of the fluid flow Q:

$$\frac{p_1 - p_2}{\gamma} = Q^2 \frac{1}{2gA_2}\left(1 - \frac{v_1^2}{v_2^2}\right) = mQ^2 \quad m > 1 \tag{3}$$

In order to estimate the risk of cavitation in a fluid bed, the number of cavitation σ:

$$\sigma = \frac{p_0 - p_{vaporizare}}{\frac{1}{2}\rho v^2} \tag{4}$$

The significance of the magnitude of this relationship becomes clear if we refer to the case of Venturi strangulation discussed above and to Bernoulli's relationship (5.2) and its consequence (5.3). Thus $p_{vaporization} = p_2$ is the minimum value of the static pressure that can be reached at the crack area, and v = the upstream winding speed.

The probability of occurrence of cavitation in the area of cracking is even lower as at higher values. If cavitation occurs, increasing the number of cavitation by correspondingly increasing the static pressure p_0 or by reducing the upstream winding speed v will lead to the disappearance of the phenomenon.[9]

3. Use of cavitational jets to disintegrate materials

In the years that have passed, cavitation jets have had a great deal of attention. This attention being paid to the laboratory to understand how the phenomenon of cavitation occurs and to determine the feasibility of their use in different fields and applications. Recently, these efforts to test cavitation jets have proven some applications that include: cleaning paint and rust on metal surfaces; removing marine biofouling from hull ships; removing explosives from ammunition, increasing the action of mechanical bits with a deep hole used for drilling oil or geothermal energy resources.

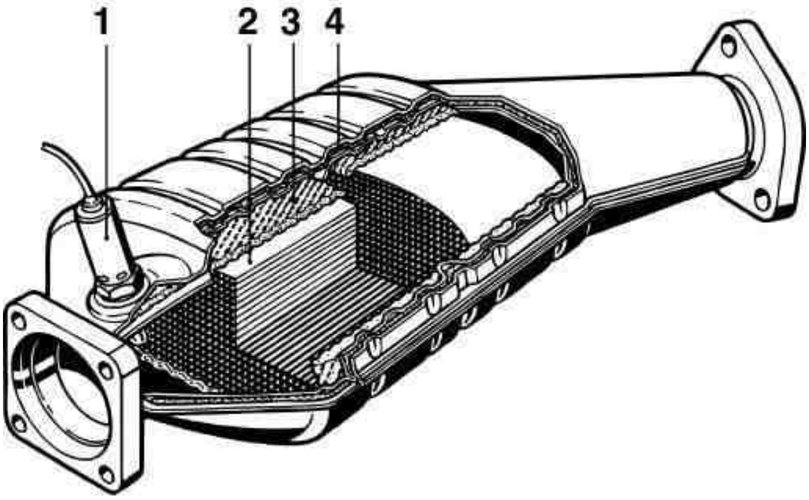
4. The use of cavitational micro-jets for the recovery of noble metals from catalysts.

A beneficial application of the cavitational phenomenon can be the recovery of rare and precious metals from automobile catalysts. Catalysts (catalytic converter) is an element made up of two catalysts that reduce pollutant emissions of the engine. More specifically, they reduce emissions of carbon monoxide, hydrocarbons and nitrogen oxides - being called "three-action catalytic converters".

The role of the catalyst is to modify the chemical content of the exhaust gases by transforming the pollutants (HC, CO and NOx), harmful to the environment into safe, neutral substances. The chemical transformations in the catalyst are carried out with noble metals such as platinum (Pt), palladium (Pd) or rhodium (Rh).
Chemical reactions occurring in a catalyst:

Hydrocarbons (HC) + Oxygen (02) => Carbon dioxide (CO2) + Water vapor (H2O)
Carbon monoxide (CO) + Oxygen (O2) => Carbon dioxide (CO2)
Nitrogen Oxide (NO) + Hydrogen (H2) => Nitrogen (N2) + Water Vapor (H2O)

The catalyst emission reduction system consists of a lambda probe, a ceramic monolith, a flexible protective metal screen, and a heat insulating start.



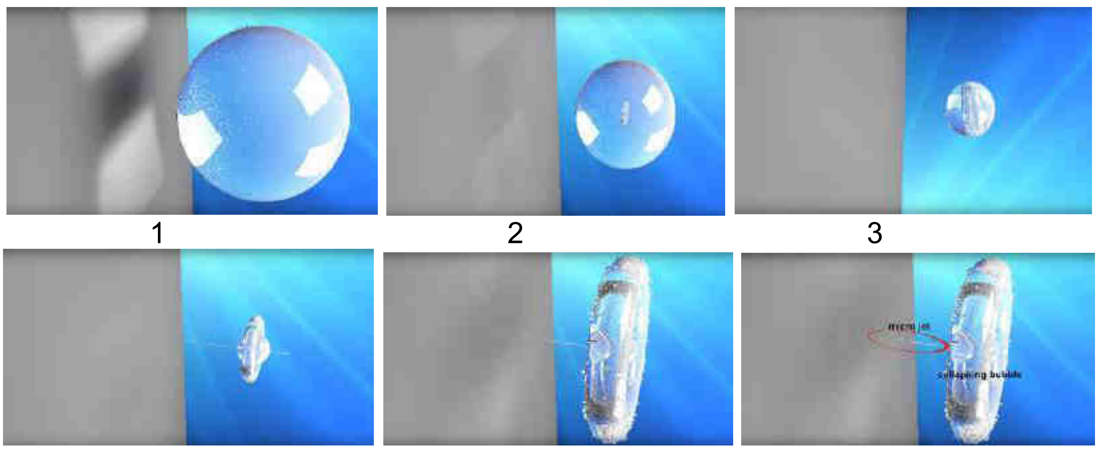
1. lambda probe
2. Ceramic monolith
3. Flexible protective metal screen
4. heat insulating start

Fig. 3. Three-way catalyst with lambda probe

The ceramic monolith is coated with a layer of aluminum oxide (Al2O3) with an irregular surface. The role of this layer is to increase the exhaust gas contact area by approximately 7000 times. This layer also contains noble metals, platinum and / or palladium and rhodium. Platinum and palladium accelerate the oxidation process of hydrocarbons and carbon monoxide while rhodium accelerates the process of reducing nitrogen monoxide. The mass of noble metals in a catalyst ranges from 1 to 5 g and varies according to the engine cylinder and pollutant emission standards to be met.[10]

The process of recovering noble metals from catalytic converters can be done with the help of cavitation micro-jets. These cavitational micro-jets occur when the vapor bubble formed due to pressure differences is transformed from a spherical structure into a toroidal structure, followed by a liquid return of the fluid, creating an ultrasonic speed micro-jet, which has a destructive effect. This micro-jet can be used to disintegrate ceramic powder loaded with noble materials by separating the atoms, followed by a process of separating and recovering precious materials.

Stages of microjet creation:

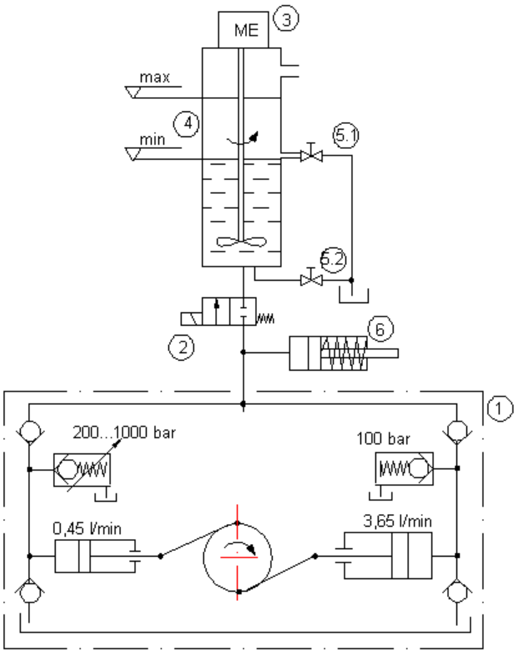


1 2 3

4 5 6

7 [11]

This process consists in the mechanical shredding of the ceramic monolith so that it becomes a powder. This powder is placed in a water container. A jet of water with a pressure greater than 300 bar is introduced into this container. When the jet is released into the container, the phenomenon of cavitation is created, disintegration of the emulsified material.
The experimental structure of the disintegration process:



1. pump
- Pressure 1000 bar
- Theoretical flow (no pressure): 0.47 l / min

The small piston rotates in 0.4 sec and delivers 3.14 cm 3 / well. In 0.4 sec the piston expels 3.14 cm3 without pressure. The technical sheet of the pump does not give the flow rate in the load. The pressure flow diagram should be raised.

2. Electrically controlled valve
- Pressure 1000 bar
- Dn 1 mm
- Switching frequency 1 ... 10 commutations / sec. Adjust so that the flow rate is less than that of the pump at 1000 bar.

3. stirrer

4. Cavitation vessel

5.1. Liquid discharge valve

5.2. Ceramic mud discharge valve

6. Accumulator (piston) 1000 bar; max. 1 litre.

When the level in vessel 4 reaches max. stops the process; after rinsing the water, open the tap 5.1 and recover the water

5. Conclusions

- Cavitation is a very destructive phenomenon from the point of view of the operation of hydraulic systems, but can be controlled and used in various applications such as: cleaning paint and rust on metal surfaces; removing marine biofilm and recovering noble metals with cavitation micro-jets by disintegration of emulsified material.

- This application consists of controlled cavitation formation in a container for disintegration of the ceramic monolith powder in the catalytic cone, followed by separation of elements and recovery of noble metals.

Acknowledgement

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HYDRAULIC EQUIPMENTS TESTING

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Abstract: *This paper proposes to present, in its first part, how to approach organizational the tests of hydraulic equipments for military aviation, taking into account procedures resulted from specific regulations. In its second part, are enumerated technical tests, some with a short presentation. It is wanted to present the experience in aviation industry in Romania, the author having 25 years of experience in the field.*

Keywords*: Testing, hydraulic equipment, test procedures*

1. Forward

The present paper is referring, especially, to specific tests for advanced hydraulic equipments. Presented recommendations for equipments testing are based on stipulations of some aviation standards and normative documents elaborated in Romania and of some renown foreign norms, applied for equipments manufacturing.
For being accepted as military technique, the equipments are subjected to some additional tests, namely, to a greater range of temperatures, vibrations, shocks, storage, tests to be taken with good results for satisfying specific use regime for military technique. Many aspects that will be presented can be also applied for industrial equipments.

2. Classification of tests for equipments

2.1 Categories of tests, detailed on organizational criteria

Most issued papers are referring to technical aspects, but practice demonstrated also the necessity of defining some organizational aspects. Methodological instructions about tests are settling phases and documents, necessary for:

- Scientific research, creation and validation of experimental model;
- Prototype execution, experimentation and homologation;
- Manufacturing and homologation of zero series.

Technical data are settling inspections on manufacturing flow and during final checking on delivery and percentages, also conditions for the tests, duration, test methods, apparatus, materials, devices and inspection instruments.
Generally, during manufacturing and relation with beneficiaries, for hydraulic equipments, are met the situations presented below.
Tests of experimental model. It is made on high complexity equipments, for checking some partial results of own scientific researches or only of some parameters defining the product, for confirming meeting the requirements of research-design theme.
Manufacturing tests are made with every element, hydraulic equipment, after its mounting, manufacturing or capital repair, when the product is to be introduced in storehouse or is to be sent to beneficiary.
Manufacturing tests are represented by enough tests for guaranteeing that hydraulic equipment is respecting minimum admitted parameters.
Batch tests. For hydraulic equipments, is recommended, even in general standards, to be made on every equipment (there are also exceptions, mentioned be the pipes). In some cases, batch tests are defined as tests for finding subtle quality deviations occurred during manufacturing and not found out during manufacturing tests. For that, a number of equipments from a batch defined based on some clear criteria are subjected to a more comprehensive tests program.

Type tests are aiming checking all technical conditions mentioned in technical documentation, so settling the correspondence between manufactured product and main documentation. These tests are the most complex tests made on a product, for determining constructive, dimensional, functional characteristics, about behavior during empty operation, during normal operation, during different mechanical – climatic conditions. The number and type of tests are settled by designer in technical data and homologation program, documents issued based on beneficiary's requirements, requirements in norms and standards.
Type tests are made during:
- Prototype homologation;
- Zero series homologation (it is also accepted unique phase homologation – prototype plus zero series);
- Introducing important constructive changes;
- Introducing major changes about materials nature or quality;
- Devices technology's change;
- Producer's change;
- Periodic, according to frequency settled in technical data (for checking the keeping in parameters of manufacturing preparation).

In some cases, homologation tests are made under surveillance of some official bodies. Homologation ends with a homologation document.
Acceptance tests at beneficiary are made if hydraulic elements were transported in other localities or if their storage time exceeds certain periods settled in technical data. These tests are pursuing to check workability maintaining and are fewer than the manufacturing tests.
Tests before installing on product are made for every stored hydrostatic driving element that will be mounted in less than a month, on a product. Tests, in this case, will not exceed the content of manufacturing tests file.
Expertise tests aim to find the causes of some incidents or for preventing some incidents during exploitation. These tests can determine the remaking of homologation tests.
Restoring tests are represented by equipment's setting up after years of storage.

2.2 Categories of tests for settling performances

Tests for determining hydraulic performances determination are usually including:
- Checking exterior aspect and dimensional control;
- Control of inside and outside tightness;
- Electrical parts working inspection;
- Determination of performances: force, couple, course, speed, flow, pressure falls, endurance hysteresis, fatigue etc.

Tests are made static and dynamic. Tests programs are issued based on beneficiary's requirements and norms and regulations for tests.
Endurance test, destined for finding how are affected performances of a device and wear resistance of parts during relative movement, during a period of time, according to endurance tests, called working period, are included in type tests. Prototype and zero series homologation process needs to be run the total number of cycles even, sometimes, passing to series manufacturing can be made before ending the endurance. About the number of working cycles and loading range, there are some evaluation possibilities, mentioning now:
- Respecting stipulations of norms and regulations;
- Their settling by designer.

As it is, MIL-H-8775 (American Military Standard) indicates for endurance test of equipments on military airplanes, to be run a greater number of cycles than the one estimated for the entire life cycle of equipments, but no less than:
- 20,000 cycles for components operated less than 10 times during a flight;
- 50,000 cycles for components operated more than 10 times during a flight;
- 5,000 cycles for components in fault circuits.

According to airplane's type, average flight time is considered 0.5 hours for a school airplane and 1 hour for other categories of fight airplanes.
For equipments on rockets, the number of cycles indicated to be run during endurance test will be 4 times the number of working cycles estimated for an equipment during rocket's working period including the occasional ones during periodical exercises, but no way is accepted less than 2,000 endurance cycles.
Norm MIL-C-5503 for cylinders is indicating 2,000,000 cycles for mechanical-hydraulic servomechanisms and 5,000,000 for electrical-hydraulic servomechanisms, with courses and forces ranging from ± 2% to ± 100%.
For components working in extreme temperature conditions, at least 25% of cycles included in endurance cycle will be made at these temperatures. Accelerated endurance test supposes a developed mathematic apparatus, benefiting of well-done hypotheses or special experience.
Fatigue tests are made for settling fatigue resistance of some parts included in hydraulic equipment.
The number of fatigue tests cycles is of millions, so, for a servomechanism in airplanes driving commands, were run 7 million elongation-compression cycles of execution rod, with different forces, inclusive forces greater than the nominal force.
Accelerated test is a special reliability test during which the level of run strains is over the settled level in reference conditions, for decreasing the time necessary for observing strain effect on equipment.
Real time tests are made for completing endurance and fatigue tests. Real time tests are performed during several years, pursuing a batch of products in concrete exploitation conditions.
Destructive tests aim to check the safety coefficient taken into account during design and to find equipment's behavior in unexpected situations. These tests include:
- Mechanical tests – traction, compression etc.;
- Behavior during overpressure – exploitation of plastic deformations range and destroying mechanical parts of fittings.

Based on experience, on requirements of some norms and methodological instructions, in table 1 is presented an informative synthesis, about tests.

Table 1

Tests	On experimental model	Homologation	Reliability	Acceptance at beneficiary	Acceptance on batch
Performances determination	YES partial		YES	YES (low)	YES
Mechanical-climatic	YES partial	YES	YES	At request (low)	At request
Endurance	Desirable	YES	YES	NO	At request running
Fatigue	NO	Often necessary	NO	NO	At request
In real time	Sometimes	Sometimes	Sometimes	NO	NO
Destructive during strains	Sometimes, desirable	YES sometimes	NO	NO	At request for some problems

3. Recommendations for performing hydraulic tests

The fluid used for tests will be the one mentioned in documentation as working fluid. Use of other fluids can have unwanted results by damaging some fittings or even some hydraulic parts. Fluid's purity when are started the tests should respect the limits settled for every equipment. The environment has to meet requirements about cleaning, quantity of impurities in air, temperature and humidity.

General tests for confirming performances can be grouped in:
- product examination;
- pressure tests;
- fluid loses determination;
- pressure falling determination;
- extreme temperature tests.

Product's examination consists in thorough checking of equipments about existence of label, security corks, orifices and electrical couples integrity and cleaning etc.
Pressure tests are made for several pressure values, for low pressure, nominal pressure, test pressure, breaking pressure.
Most working tests are made at nominal pressure.
Test pressure, in most norms, is settled as 1.5 times of nominal pressure. Test pressure will be applied at specified temperature, at least 2 times, for 2 minutes.
Breaking pressure has different values: minimum 4 times the nominal working pressure for pipes and 2 – 2.5 times for equipments.
During breaking pressure, should not be destroyed parts or losses should not be greater than the ones allowed as maximum limit at nominal pressure.
Tightness test. During all tests, are not accepted fluid losses, only slight moisturizing (for static fittings) insufficient for forming a drop. For dynamic seals, losses through tightening areas will not be greater than the ones specified in detailed documentation.
Pressure falls are determined according to flow, between limits 0 ÷ 150% of nominal flow's value.
After reaching maximum temperature, it is maintained enough time for allowing all equipment's parts to reach that temperature. The equipment will be driven at least twice for demonstrating workability.

4. Climatic and mechanical tests

Tests programs will mention:
- performed tests;
- severity of every test;
- tests succession;
- sampling of tested element;
- sizes, construction and performances of necessary devices for correct tests performing, in case are not mentioned in the standard afferent to test method;
- technical conditions stipulated during and after test.

Severity degree of a test corresponds to different climatic and mechanical conditions to which can be subjected elements, differentiated by time variation, temperature or other determined parameters, taken separate or combined. Severity degrees settling allows, for example, covering climatic demands due to climatic area differences.
In norms, are settled:
- weather conditions for return and preconditioning;
- standard weather conditions for forced drying.

Further, will be approached aspects specific for hydraulic elements tests. We mention that the test needs also to be consulted the specific norm and test documentation.

4.1 Climatic tests

Most hydraulic plants equipping mobile plants have to perform diverse missions in most diverse climatic and field conditions, geographical areas etc. For this purpose, plants' components are checked before products final manufacturing, in laboratory conditions, for settling their behavior in some of below mentioned conditions:
- dust and sand deposit;
- working in environment with sand and dust;
- working in environment with saline fog;

- exposure in hot and high humidity environment;
- temperature variations; different thermal regimes;
- ice creation;
- water sealing (rain);
- exposure to radiations;
- flameproof;
- fungus;
- electromagnetic interference;
- deactivation;
- fire;
- mold;
- storage;
- moist heat etc.

Among previously mentioned tests, are selected those considered to occur normal or accidental. Hydraulic equipments, generally, have few moving parts coming in direct contact with air. Such parts are at hydraulic cylinders, hydraulic locks, manual taps, distributors with manual command possibility etc. The same equipments, subjected to water action, are checked if during working are not affected by ice formation.

5. Mechanical tests

Shock tests are determining components capacity of resisting to shocks. Shock is represented by outer forces applied for milliseconds or microseconds. Often is the impulse type “tooth” (20g and 11ms) with greater frequency, including a larger range of resonance frequencies of the tested equipment. Together with equipment's testing, are also checked equipment's fixing systems, together with it or separate.
It is also mentioned a **falling test** of equipments packed as to be transported. According to equipments weight and sizes, are varied the heights (450 – 1,200 mm) from where they are left to fall, usually on a corner, for the edge to angle 45º from horizontal.
Testing equipments resistance to transportation. The test is made for checking hydraulic device's capacity to resist o destroying actions of mechanical strains during transportation.
Mechanical vibrations test. This test is checking equipment's behavior to a range of frequencies susceptible to be found during use, monitoring damages or degradations of functional characteristics.
Devices test to centrifuge accelerations. For airplanes, generally, hydraulic devices are manufactured for proper working, in conditions of accelerations of 8g. It is possible for some greater acceleration to open valves or to commutate drawers. Accordingly, are introduced placing restrictions, for on some axes the acceleration to be less than certain values or the moving parts to move perpendicular on acceleration's direction.

6. Conclusions

This paper is based on 25 years of experience in designing and testing hydraulic equipments, in most endowed testing laboratory in Romania, INCREST, in cooperation with laboratories in IAv (AEROSTAR) Bacau, Avioane Craiova, Aeroteh. An example is equipping IAR 93 with 141 Romanian equipments, not being managed to end only assimilation of rotary hydraulic engines. There were used most exigent regulations / standards, existing at this moment, worldwide.

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DISTRIBUTED INFORMATIC SYSTEM FOR CONTROLLING HEAT-TREATING PROCESSES

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Abstract: *The system, presented in this paper, was designed for process computerization within heat treating department of SMEs and comes into the current context in which the industry makes progress in the development and implementation of intelligent manufacturing technologies. The system contains an integrated set of components for collecting, storing, and processing data and for providing information, knowledge, and digital products. The system contains two data bus, one of it is a serial bus, master/slave type, MODBUS-RTU that integrates temperatures controllers and the other one is an Ethernet bus that interconnected PCs and database management server. A programmable logic controller links the buses. The software designed is based on client-server architecture and is a multitier application developed on three levels: Client tier, Enterprise Information System tier and PLC tier.*

Keywords*: Temperature, controller, monitoring system*

1. Introduction

The advantages of computerization of the production process are related to the possibility of monitoring and integrated control of the technological processes, centralized at the level of the database management system of the enterprise. The concept of the distributed information system for process control is original and is based on experience gained in the development of various applications in the industrial environment. The hardware equipment are interconnected through two data buses. The serial bus is a master-slave type that has the Modbus-RTU protocol and connects the heat-treatment furnaces with the programmable logic controller. The Ethernet allows connection of the PLC to the beneficiary's local area network. All the computers that are part of the informatics system are interconnected through beneficiary local area network. The control of heat-treating process for each furnace is realized on the computer situated in heat treating department. The monitoring application could be installed in various computers from beneficiary network, and this one allows real-time monitoring or viewing process from the archive. On the IT manager computer there is the application that allows configuring the software and the database server.

2. Informatics system - Hardware structure

The hardware structure, shown in fig. 1, integrates into the informatics system, the heat-treating furnaces existing in the beneficiary heat treating department, via a serial communication line Master Slave type. The *Master* equipment is a programmable logic controller and the *Slave* equipment is the temperature controllers of each heat-treating furnace. The PLC is the communication bridge, between the BUS in which the heat-treating furnaces are connected and the LAN network of the enterprise in which the other equipment of the system are connected.
The computer of the heat-treating department allows the control of the technological process of each furnace. The computer system allows real-time monitoring of the process or archive via the LAN linking to the network that has the monitoring application installed. Also, the IT manager has the possibility to configure the information system through the administration application. Another component of LAN is the database management server that allows the recording of heat-treating technological process data, as well as obtaining various reports related to them.

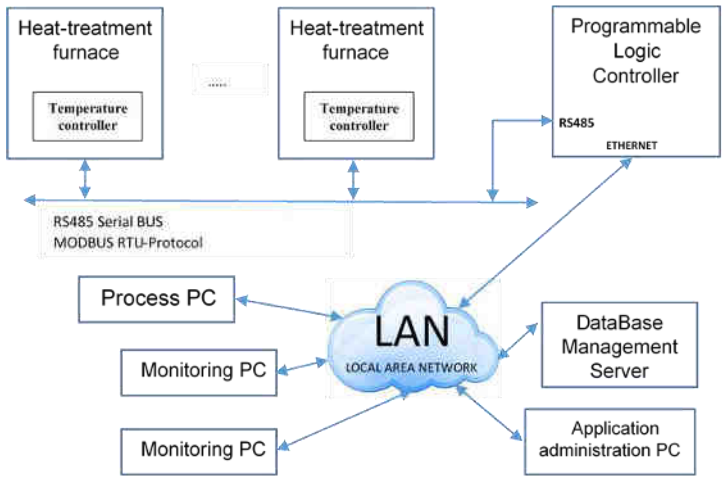

Fig. 1. Informatics system - Hardware structure

3. Informatics system - Software structure

The software application implemented is based on client-server architecture and is a multitier application developed on three levels: Client tier, Enterprise Information System (EIS) tier and Programmable Logic Controller (PLC) tier as is shown in figure no.2.
On the **Client tier** structure, are developed the client applications: process application, monitoring applications and management system application. Process application controls each heat-treatment furnace existing in the beneficiary heat-treating department. The monitoring applications allows real-time or archive process viewing and generating reports about heat-treating process. The administration application allows the IT manager of the enterprise to configure the communication parameters of the system elements and to configure the DBMS connection parameters.
The **Enterprise Information System** (**EIS**) **tier** contains software implemented on beneficiary informatics system like database management system (DBMS) and network services. These allows database access and LAN beneficiary management.

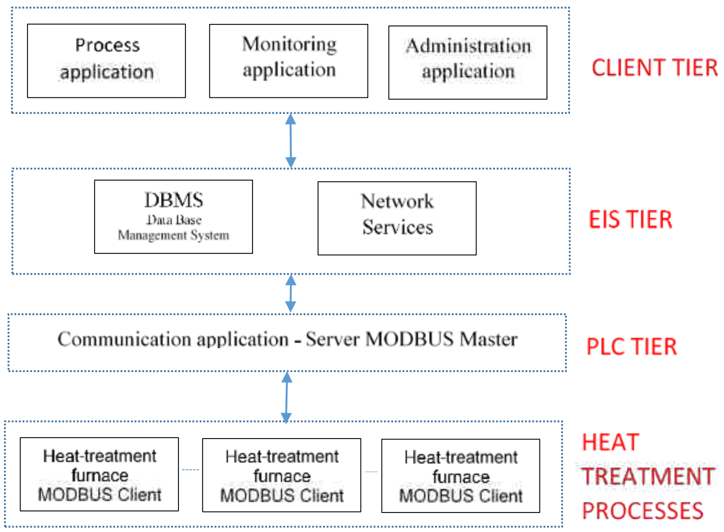

Fig. 2. Informatics system- software structure

The **Programmable Logic Controller** (**PLC**) **tier** consists of application implemented on PLC that is developed on dedicated PLC software- Ladder diagram. This application manages communications functions between PLC and temperatures controllers periodically at the time intervals specified in the configuration files. Also, at this level, the application ensures primary data processing and packing/unpacking of data in accordance with the requirements of the communication protocols.
At the level of the communication controllers there is a client for the Modbus protocol that has the configurable equipment addresses.
The application developed on the client tier is presented in figure 3. This are showing all data about a heat-treating process starting with temperature, the real one and the set point value, data about communications between PLC and controllers, data about parts.

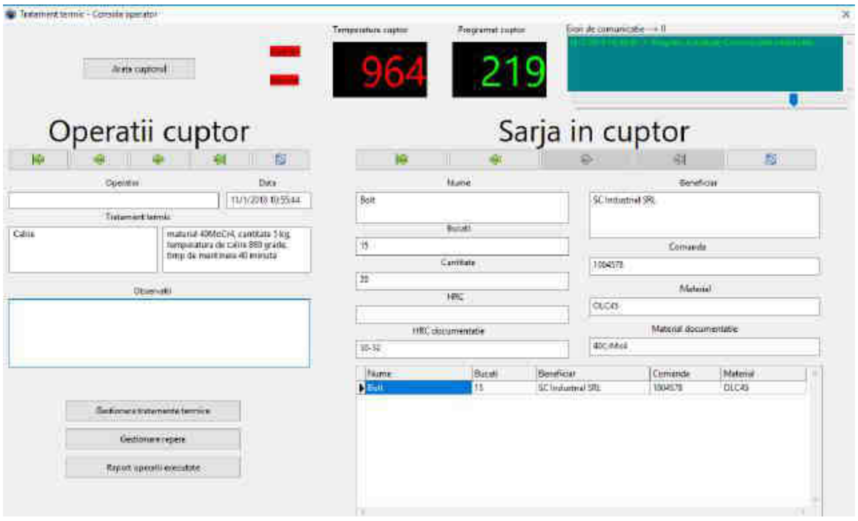

Fig. 3. Operation panel

There is a simple data recording panel that allows to record commercial data about parts into the database (figure no. 3). In figure no.5 is shown the panel that allows to record data about heat treating process like, name, short description and time and temperature values. Entering data about time and temperature automatically generates the heat treatment curve.

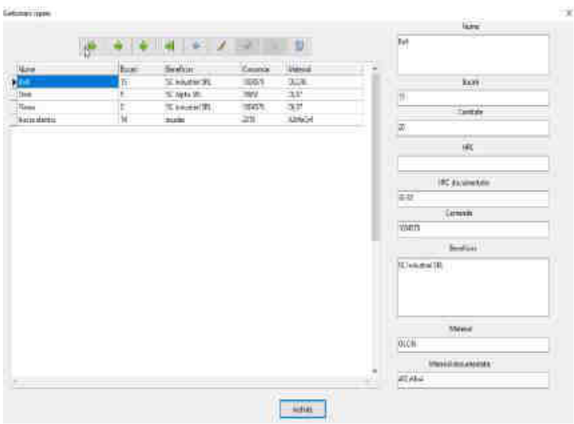

Fig. 4. Parts recording panel

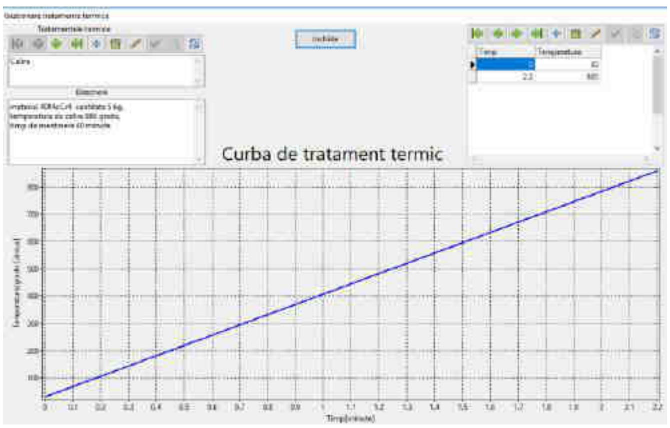

Fig. 5. Heat treating recording panel

With the panel shown in figure no. 6 the operator creates the batch introduced in heat-treating furnace. The application described the real batch and the heat-treating features. It allows to be added one or more parts, from different customers that are need the same heat-treating, also could

be entered the name of the person in charge with the current operation and any other details about it. The report generated based on this batch will be printed for each customer.
On the monitoring panel, presented in figure no.7, the operator or anyone interested about the current heat-treating is able to see the real-time progress.

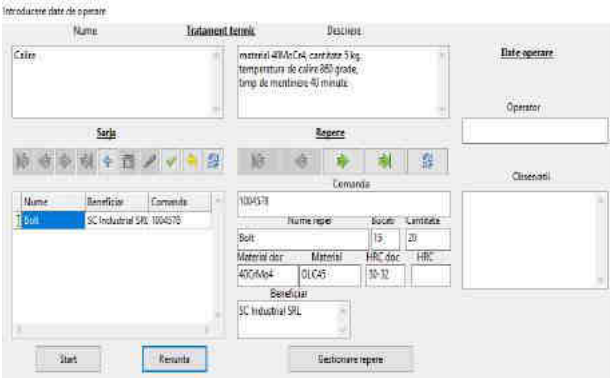

Fig. 6. Batch data

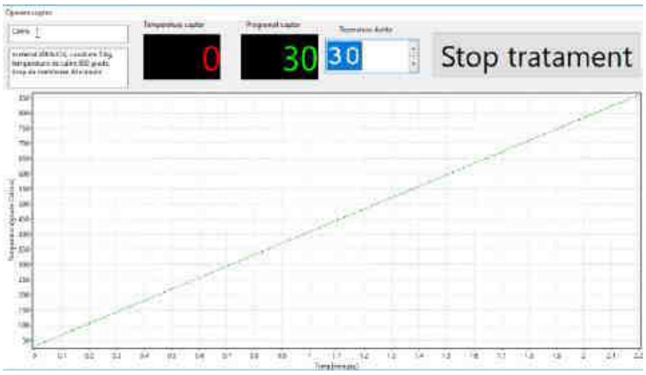

Fig. 7. Heat-treating furnace function

4. Conclusions

The system allows the unitary computerization of existing heat-treating process in beneficiary heat-treating department, using the already existing hardware infrastructure, data networks and DBMS. That ensures an easy implementation with minimal material and training costs.
The distributed computer system, described above, has a flexible and scalable configuration, both hardware and software. It is flexible because, with low changes it could be implemented on different computer systems and is scalable due to the fact that the number of existing equipment can be increased or reduced without influencing functionality. The system has been already implemented on demand in a small company.

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DESIGN OF HYDRAULIC VIRTUAL LOAD SIMULATOR USING PROPORTIONAL PRESSURE RELIEF VALVE

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Abstract: *In this paper, we introduce an effective way to apply virtual load to hydraulic valve control system using proportional pressure control valve (PPRV). By installing the PPRV in return line of the hydraulic valve control system, it is able to realize the effect of force disturbance from conventional hydraulic load simulator (HLS). The pressure in the return line determines the velocity of the actuator and it works virtual load as if an actual load is acting on the actuator. The modelling of hydraulic valve control system with the actual and virtual load is conducted for different actuators: single-rod cylinder and double-rod cylinder. Secondly, the simulation is conducted by using AMESim to verify the control performance of virtual load simulator. The simulation results indicate that the virtual load simulator can generate the effect of force disturbances to an actuator.*

Keywords: *Hydraulic load simulator, Proportional pressure relief valve, Force disturbance*

1. Introduction

When it needs to test a position control system under force disturbance or configure hardware-in-the-loop simulation (HILS) of hydraulic valve control system, a conventional hydraulic load simulator (HLS) can be used [1-2]. The conventional HLS basically consists of a power unit (hydraulic pump, tank and a relief valve), a directional control valve (DCV) and an actuator to give a load to another actuator to be tested. However, the HLS takes up much spaces and costs a lot because it needs additional hydraulic parts. In the case that the load from HLS is given to the actuator of another hydraulic valve control system, the flow through DCV is reduced compared to the case that the load doesn't exist. Considering the concept, the flow through DCV can be controlled if a pressure between the DCV and a tank (i.e., return line) can be accurately controlled. Then, the velocity of the actuator is controlled as if the actual load is acting on the actuator.

2. Hydraulic system modelling

Because the flow through the DCV is different with two cases: double-rod cylinder and single-rod cylinder, the pressure in the return line for the velocity control should be derived for each case.

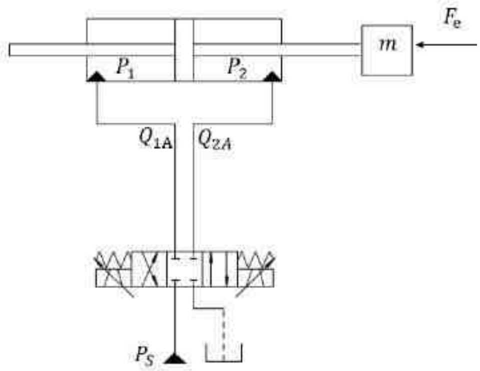

Fig. 1. Hydraulic valve control system with actual load (Double-rod cylinder)

2.1 Double-rod cylinder (Case. 1)

In the case of the hydraulic valve control system with actual load as shown in Fig. 1., the pressure difference ($P_{LA} = P_1 - P_2$) is generated when the external force (F_e) is acting on the actuator and the load flow is expressed as below. [3]

$$Q_{LA} = \frac{Q_{1A}+Q_{2A}}{2} = C_d \omega x_{sv} \sqrt{\frac{P_S - sgn(x_{sv})P_{LA}}{\rho}} \tag{1}$$

$\rho[kg/m^3]$ – density of the hydraulic fluid
$P_S[Pa]$ – system pressure
C_d – discharge coefficient of DCV
$x_{sv}[m]$ – spool displacement
$\omega[m]$ – area gradient of opening area with respect to spool displacement

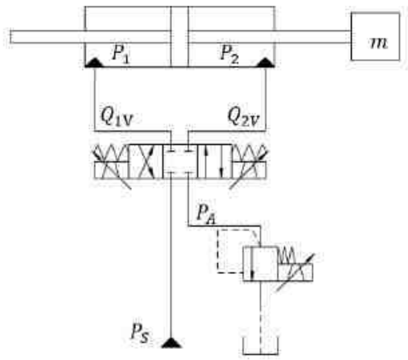

Fig. 2. Hydraulic valve control system with virtual load (Double-rod cylinder)

In the case of the hydraulic valve control system with virtual load as shown in Fig. 2., the pressure difference ($P_{LV} = P_1 - P_2$) is almost zero because there is no external force. Only small amount of the pressure difference is generated because of the friction of the actuator and the inertia load of a piston and rods. The load flow through the DCV is expressed as below.

$$Q_{LV} = \frac{Q_{1V}+Q_{2V}}{2} = C_d \omega x_{sv} \sqrt{\frac{P_S - P_A}{\rho}} \tag{2}$$

Then, the pressure in the return line should be controlled as expressed by the pressure difference as below using the relation $Q_{LA} = Q_{LV}$.

$$P_A = sgn(x_{sv}) \cdot P_{LA} \tag{3}$$

2.2 Single-rod cylinder (Case. 2)

The case of actual load with single-rod cylinder is shown in Fig. 3., The single-rod cylinder has asymmetric piston areas with the ratio of $\eta(= A_2/A_1)$. Because of the asymmetry, the load flow can't be determined as the case of double-rod cylinder. The flow through the DCV is expressed as below.

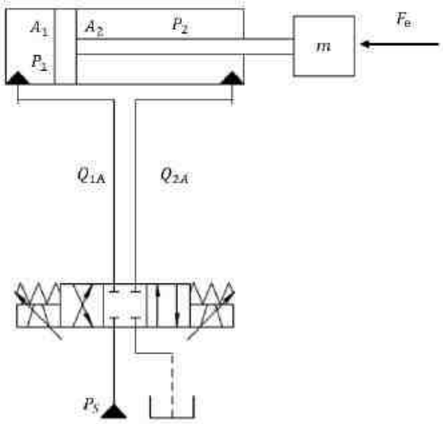

Fig. 3. Hydraulic valve control system with actual load (Single-rod cylinder)

$$Q_{1A} = \begin{cases} C_d \omega x_{sv} \sqrt{\frac{2(P_S - P_1)}{\rho}} & x_{sv} > 0 \\ C_d \omega x_{sv} \sqrt{\frac{2P_1}{\rho}} & x_{sv} < 0 \end{cases} \tag{4}$$

$$Q_{2A} = \begin{cases} C_d \omega x_{sv} \sqrt{\frac{2P_1}{\rho}} & x_{sv} > 0 \\ C_d \omega x_{sv} \sqrt{\frac{2(P_S - P_2)}{\rho}} & x_{sv} < 0 \end{cases} \tag{5}$$

The pressure difference ($P_{LA} = P_1 - \eta P_2$) is generated when the external force (F_E) is acting on the actuator, then the flow from each chamber to/from the actuator is reduced.

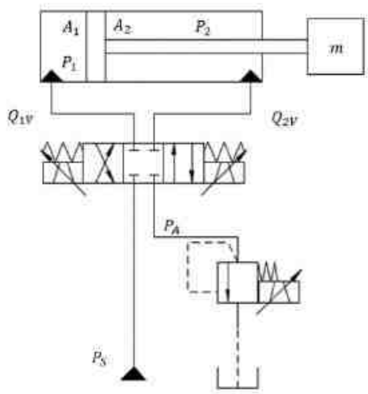

Fig. 4. Hydraulic valve control system with virtual load (Single -rod cylinder)

The case of virtual load with single-rod cylinder is shown in Fig. 4. The flow through the DCV is expressed as below.

$$Q_{1V} = \begin{cases} C_d \omega x_{sv} \sqrt{\frac{2(P_S - P_1)}{\rho}} & x_{sv} > 0 \\ C_d \omega x_{sv} \sqrt{\frac{2(P_1 - P_A)}{\rho}} & x_{sv} < 0 \end{cases} \quad (6)$$

$$Q_{2V} = \begin{cases} C_d \omega x_{sv} \sqrt{\frac{2(P_2 - P_A)}{\rho}} & x_{sv} > 0 \\ C_d \omega x_{sv} \sqrt{\frac{2(P_S - P_2)}{\rho}} & x_{sv} < 0 \end{cases} \quad (7)$$

Then, from the relation of $Q_{1A} = Q_{1V}, Q_{2A} = Q_{2V}, Q_2 = \eta Q_1$ and similar mathematical process in the Case 1, the pressure to be controlled in the return line to have a same effect of the external force can be described as below

$$P_A = \begin{cases} \frac{P_{LA}}{\eta} & x_{sv} > 0 \\ -P_{LA} & x_{sv} < 0 \end{cases} \quad (8)$$

3. Simulation

As shown in Fig. 5, the simulation is conducted by using Amesim. Firstly, the input of the DCV is set to constant in both case and the external load is acting on the cylinder in the actual load case. The input signal to PPRV is calculated using the pressure difference in the cylinder of the actual load case. To verify the effectiveness of the research, the velocity of the cylinder in both cases is compared. The motion of the cylinder in the virtual load case should be same in another case when the pressure in the return line is controlled according to Eqn (3), (8). The parameters for the simulation are shown in Table 1.

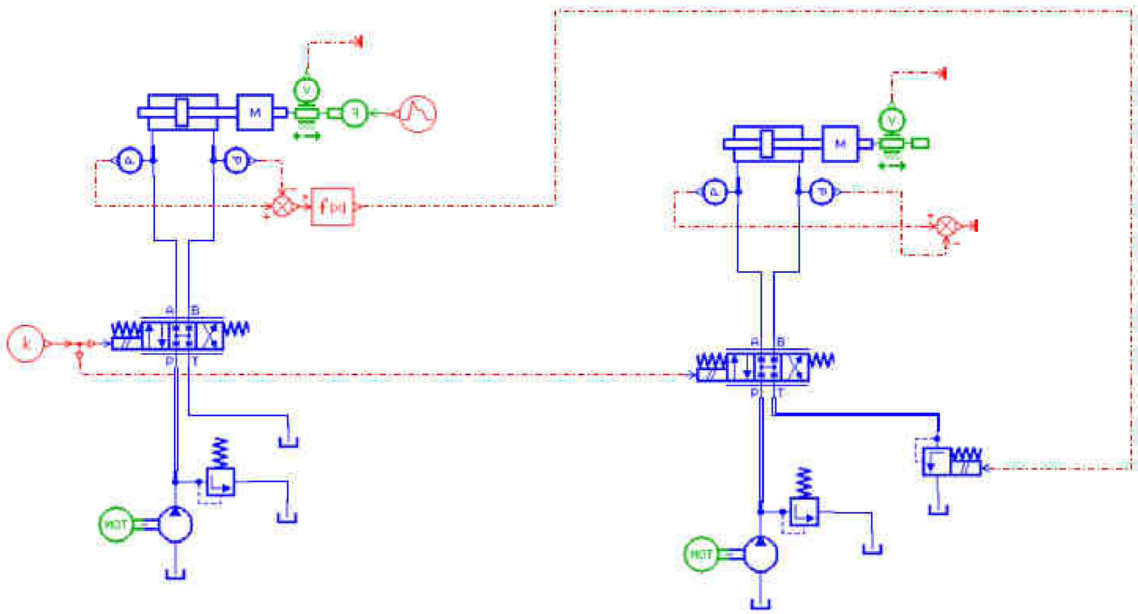

Fig. 5. Simulation paragraph in AMESim

Table 1: Parameter setting for simulation

Item	Value
Flow rate at maximum valve opening at $\Delta p = 70\mathrm{bar}$	12 L/min
Valve natural frequency (DCV)	55 Hz
Valve damping ratio (DCV)	0.7063
Piston diameter	50 mm
Rod diameter	28 mm
Length of cylinder stroke	300 mm
System Pressure	140 bar

3.1 Simulation results

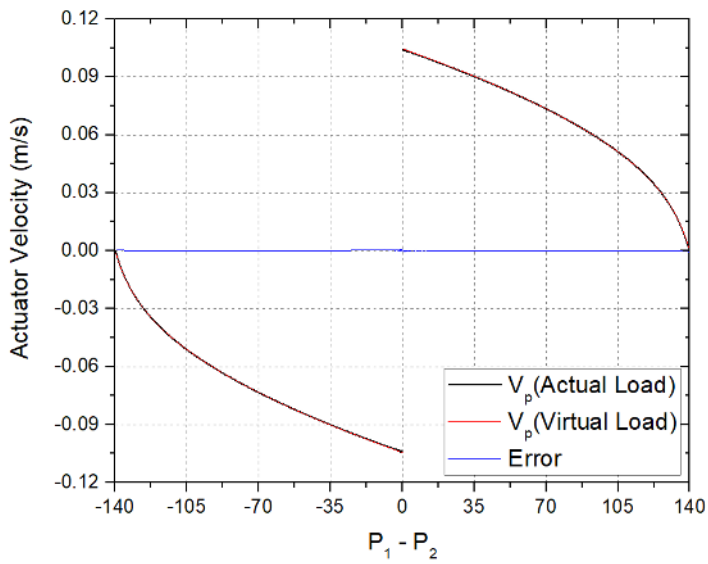

Fig. 6. Simulation result of Case 1

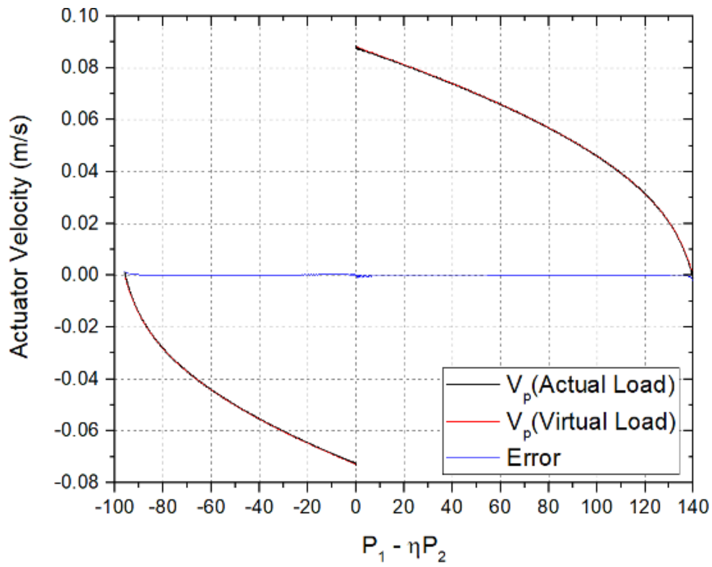

Fig. 7. Simulation result of Case 2

Fig. 6~7 shows the results of the simulation. The velocity of the cylinder in the case of an actual load is reduced when the pressure difference $P_1 - P_2(P_1 - \eta P_2$ in Case 2) is increasing. Then, the velocity of the cylinder in the case of virtual load is close to another case as if the external load is exerted to the actuator. However, the error is bigger when the pressure difference is closer to the full-load condition and no-load condition. Because the PPRV itself acts the orifice to return line even though the input signal is zero, the velocity of cylinder is different with that of the actual load case.

5. Conclusion

Based on the simulation results, it is verified that the designed hydraulic virtual load simulator can be used as the hydraulic valve system under the external force disturbance by simulation. The motion of the hydraulic actuator is controlled as if the load is exerted in two case: single-rod cylinder and double-rod cylinder. It is expected that the simulator can be used in hydraulic position control system in various load condition and haptic application, etc. Follow-up experimental research should be conducted in near future to verify the effectiveness of the virtual load simulation in real system.

Acknowledgments

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ASPECTS REGARDING THE ANALYSIS OF A CRUDE OIL EXTRACTION SYSTEM WITH HELICAL PROGRESSIVE CAVITY PUMPS

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Abstract: *Increased global crude oil demand, correlated with the escalation of commercial disputes, political issues in the key-emerging economies of the major exporting countries, inevitably lead to a reduction in production. This calls for the implementation of more stringent markets, increased prices for crude oil and derivatives, which bay be merged with increased production through technical solutions that maintain the extraction quota, one of which is increasing the recovery factor. Stimulating the productivity of the probes, cojugated with the extraction of high flow rates when the reaction probes are flooded, contributes to the increasing of the recovery factor. In this respect, the paper analyzes problems regarding crude oil extraction with helical progressive cavity pumps. An analysis of the helical pump extraction system is carried out, showing the pumping plant, which includes bottom equipment and surface equipment, a mechanical calculation of the pumping unit depending on a series of initial data. Also, an analysys of stability loss be presented by comparative calculation using two finite element modelling softwares, Ansys and Cosmos, for a sucking rod pumping unit, which was loaded with a torque and, in turn, with three compression forces.*

Keywords: *Crude oil extraction, helical PCP, sucker-rod pumps, finite element analysis (FEA)*

1. Introduction

The growing energy requirements of the future, especially those related to the hydrocarbon extractive industry, require the best technical management decisions, as well as the development and use of state-of-the-art technologies for the best possible global exploitation quota to reduce energy consumption and without affecting the environment [1, 2], which is also achievable by increasing the crude oil recovery factor from deposits [3].

Current crude oil extraction technologies involve multiple pumping technologies, the most common ones being: piston pumping, centrifugal pumping, pumping with hydraulic jet pumps, and helical pumping [4, 5, 6]. Piston pumping is carried out using surface pumping units with or without beam (pneumatic, hydraulic or mechanical) inserted into the probe and driven from the surface through the pump seal, Figure 1 [7].

Centrifugal pumps are built for a wide range of flows, ranging from 30-40 m3 / day to 6000-8000 m3 / day, depending on the diameter of the column into which it is inserted. Submersible centrifugal pumps are especially used for large fluid flows and recommended for highly-viscous crude oil [8, 9]. The jet pump is a hydraulic pump without a rotating piston or other moving parts that works on the principle of the ejector - pumps the fluid produced by the probe to the surface due to an energy transfer from the drilling fluid to the fluid produced by the probe. The high-pressure drilling fluid enters the pump at its top and then passes through a nozzle, where the entire pressure of the fluid is converted into kinetic energy, the fluid gaining a very high velocity and consequently a low static pressure. The aspiration of the fluid in the probe is produced due to this depression, Figure 2 [10].

Fig. 1. Balanced pumping unit [7]

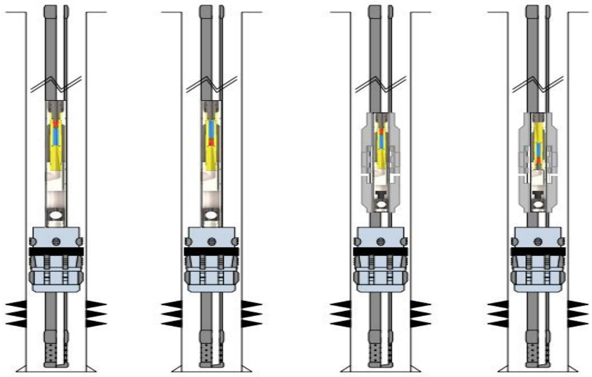

Fig. 2. Jet Pumps for Oil Production [10]

The helical pump plant comprises bottom equipment and surface equipment.

Bottom equipment consists of the submersible helical pump, extraction pipes and sucker-rod pumps, and the surface equipment comprises the actuation system of the sucker-rod pumps, the rotor of the pump, the coupling between the actuation system and the drive-head, the drive-head and support system for all bottom equipment [11, 12, 13, 14].

2. The helical PCP plant

The helical PCP is composed of an elastomeric stator and a PCP rotor, usually made of stainless steel or high alloy.

The rotors of these pumps are bodies of work whose composite profiles include circular arcs, line segments, cycloidal curves, and often non-analytical curves.

Such a geometry of the profiles confer the gear processes superior characteristics, to reduce friction and improve sealing conditions.

The efficiency of the helical pumps requires a specific profile for the rotors, allowing a maximum flow section, the shortest gear line, and a leakage section as small as possible, all to achieve a high flow rate for the same PCP rotor and speed.

This results in a high volumetric yield, which also leads to an adiabatic yield increase, because the power losses are lower during the compression process through internal recirculation.

Most of the time, the helical pumps are provided with two helical channels, hence it is double-headed, and the PCP rotor is provided with a single helical channel, hence it is single-headed, the length of the PCP stator step being twice the length of the rotor pitch, Figure 3 [15].

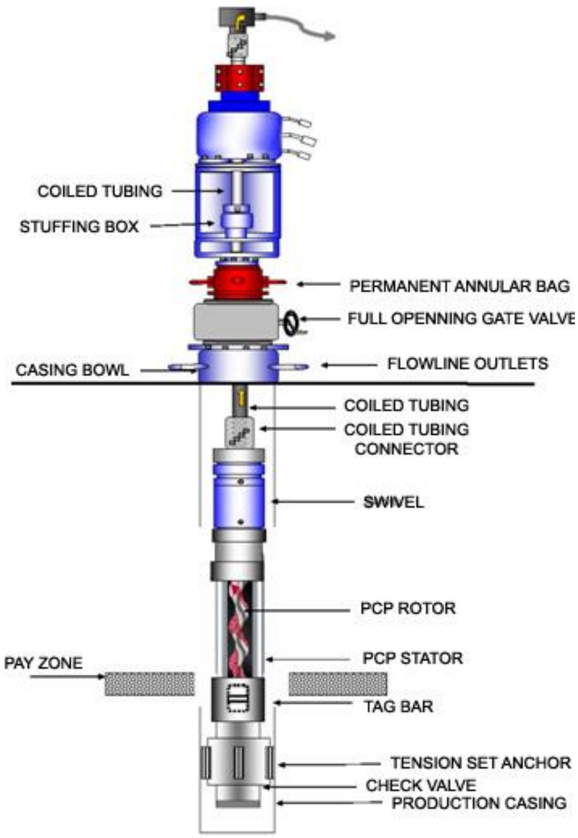

Fig. 3. Scheme of helical pumping plant [15]

3. The helical pumping plant

In order to provide a correct definition of a helical pump extraction plant, the following steps shall be taken: defining the positioning depth of the pump inside the probe, H_p, based on the dynamic liquid level in the probe, which depends on the bottom pressure and the Q - flow rate, expected to be extracted; defining the dynamic H_d level in the probe and calculating the pressure losses in the H_{fric} extraction pipes due to friction; defining the pressure in the pumping head H_{cp} and calculating the total lifting height, H; establishing the pump model, according to the total lifting dynamic height, the expected Q - flow rate to be extracted; defining the reduction of the speed ratio: $i = n_{motor} / n_{pump}$ and choosing the pump characteristics: length of the PCP stator; the PCP rotor length; number of levels; determining, by calculation, the resistance to the stability of the sucker-rod pump.

By comparison, it shall be submitted the way to choose the helical pump for the extraction system of the two probes (S1 and S2), starting from different dynamic levels, H_d = 1700 m and H_d = 2000 m. The primary calculation elements for the two probes are presented in Table 1.

Table 1: Initial data for S1 and S2 probes

Date	Probe S1	Probe S2	Date	Probe S1	Probe S2
Diameter of the fluid [mm]	127 + 114,3	177,8 + 114,3	Water density, ρ_w [kg/m^3]	1040	1040
At-rest bottom-hole pressure (BHP) [bar]	252	272	Oil viscosity, *cP*	2,5	2,5
Ram bottom-hole pressure (BHP) [bar]	205	172	Water viscosity, *cP*	1	1
Presure in the swivel head flow p_{cp} [bar]	4	4	Percent impurities [%]	20	28
Pump flow, Q [m^3/day]	25	16	Difference in level probe-ground [m]	10	15
Oil density, ρ_t [kg/m^3]	815,5	850	Nominal diameter of the extraction pumps [mm]	73,02	73,02

For S1 Probe, there shall be determined:

- The dynamic level: H_d = 1700 m;
- Horsehead: $H_{fix} = H_d + h_{sub}$ = 1700 + 100 = 1800 m;
  where h_{sub} - pump submergence;
- Pumping height: $H_p = H_{fix} + H_{fric} + H_{cp}$ = 1800 + 0,22 + 47,4 = 1848 m;
- Pressure into the pumping head:

$$H_{cp} = \frac{p_{cp}}{\rho_l \cdot g} = \frac{4 \cdot 10^5}{860{,}4 \cdot 9{,}81} = 47{,}5\,\mathrm{m} \tag{1}$$

- Density of the fluid:

$$\rho_l = (1-i) \cdot \rho_t + i \cdot \rho_w = (1-0{,}2) \cdot 815{,}5 + 0{,}2 \cdot 1040 = 860{,}4\,\mathrm{kg/m^3} \tag{2}$$

- Pressure loss:

$$H_{fric} = \frac{\Delta p_{fr}}{\rho_l \cdot g} = \frac{0{,}019}{860{,}4 \cdot 9{,}81} = 0{,}22\,\mathrm{m} \tag{3}$$

$$\Delta p_{fr} = \lambda \cdot \frac{H_{fix} \cdot v^2}{2 \cdot d_i} \cdot \rho_l = 0{,}037 \cdot \frac{1800 \cdot 0{,}069^2}{2 \cdot 73 \cdot 10^{-3}} \cdot 860{,}4 = 0{,}019\,\text{bar} \tag{4}$$

- Hydraulic loss coefficients:

$$\lambda = \frac{64}{\text{Re}} = \frac{64}{1737} = 0{,}037 \tag{5}$$

$$\text{Re} = \frac{\rho_l \cdot v \cdot d_i}{\mu} = 1737 \tag{6}$$

- Flow velocity:

$$v = \frac{4 \cdot Q}{\pi \cdot d_i^2} = \frac{4 \cdot 25}{3{,}14 \cdot (73 \cdot 10^{-3})^2 \cdot 86400} = 0{,}069\,\frac{\text{m}}{\text{s}} \tag{7}$$

KUDU 60TP2000 shall be chosen (rotational speed: n = 231 rpm); drive power: N = 10 kW [15]. Its characteristics are extracted from the pump data sheet: the number of levels: 43 levels; the PCP rotor length: 5.7 m; the PCP stator length: 5.55 m; the rotor thread: 33 mm; the outer diameter of the pump: 89 mm. When calculating the resistance of the sucker-rod pumps, proceed as follows:

- There shall be determined the weight of the column of the fluid:

$$P_l = \left(A_t - a_p\right) \cdot H_{fix} \cdot g \cdot \rho_{am}\,\text{N} \tag{8}$$

$$P_l = (4{,}185 \cdot 10^{-3} - 6{,}424 \cdot 10^{-4}) \cdot 1800 \cdot 9{,}81 \cdot 860{,}4 = 53810\,\text{N}$$

- There shall be determined the buoyancy factor:

$$b = 1 - \frac{\rho_{am}}{\rho_{OL}} = 1 - \frac{860{,}4}{7850} = 0{,}89 \tag{9}$$

- There shall be determined the weight of the sucker-rod pumps in the air:

$$P_p = q_p \cdot H_{fix} = 49{,}455 \cdot 1800 = 89019\,\text{N} \tag{10}$$

- There shall be determined the normal stress, by means of the formula:

$$\sigma_t = \frac{P_l + b \cdot P_p}{a_p} = \frac{53810 + 0{,}89 \cdot 89019}{6{,}424 \cdot 10^{-4}} = 207\,\frac{\text{N}}{\text{mm}^2} \tag{11}$$

- There shall be determined the torque:

$$M_t = 9550\frac{\text{N}}{\text{n}} = 9550\frac{10}{231} = 413{,}4\ \text{N} \cdot \text{m} \tag{12}$$

- There shall be determined polar modulus of strength:

$$W_t = \frac{\pi \cdot d_p^3}{16} = \frac{\pi \cdot 0{,}0286^3}{16} = 4593{,}3\,\text{mm}^3 \tag{13}$$

- There shall be determined tangential stress:

$$\tau_t = \frac{M_t}{W_t} = \frac{413{,}4 \cdot 10^3}{4593{,}3} = 90\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{14}$$

- There shall be determined the equivalent stress in the case of compound demand:

$$\sigma_{ech1} = \frac{1}{2} \cdot \left(\sigma_t + \sqrt{{\sigma_t}^2 + 4{\tau_t}^2} \right); \quad \sigma_{ech1} = \frac{1}{2} \cdot \left(207 + \sqrt{207^2 + 4 \cdot 90^2} \right) = 241\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{15}$$

$$\sigma_{ech2} = 0{,}35 \cdot \sigma_t + 0{,}65 \cdot \sqrt{{\sigma_t}^2 + 4 \cdot {\tau_t}^2}; \quad \sigma_{ech2} = 0{,}35 \cdot 207 + 0{,}65 \cdot \sqrt{207^2 + 4 \cdot 90^2} = 251\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{16}$$

- There shall be determined the withstand stress, corresponding to the 1530M-steel:

$$\sigma_a = \frac{\sigma_c}{c_s} = \frac{744}{1{,}9} = 391{,}6\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{17}$$

The dimensioning is correct because the resistance condition is met.

For S2 Probe, there shall be determined:

- The dynamic level: H_d = 2000 m;
- Horsehead: H_{fix} = 2000 + 100 = 2100 m;
- Pumping height: H_p = 2100 + 0,016 + 45,2 = 2146 m;
- Pressure into the pumping head:

$$H_{cp} = H_{cp} = \frac{4 \cdot 10^5}{903{,}2 \cdot 9{,}81} = 45{,}2\,\mathrm{m} \tag{18}$$

- Fluid density:

$$\rho_l = (1 - 0{,}28) \cdot 850 + 0{,}28 \cdot 1040 = 903{,}2\,\mathrm{kg/m^3} \tag{19}$$

- Pressure loss:

$$H_{fric} = \frac{0{,}014}{903{,}2 \cdot 9{,}81} = 0{,}157\,\mathrm{m} \tag{20}$$

$$\Delta p_{fr} = 0{,}037 \cdot \frac{2100 \cdot 0{,}044^2}{2 \cdot 73 \cdot 10^{-3}} \cdot 903{,}2 = 0{,}014\,\mathrm{bar} \tag{21}$$

- Hydraulic loss coefficients:

$$\lambda = \frac{64}{\mathrm{Re}} = \frac{64}{1167} = 0{,}055; \quad \mathrm{Re} = \frac{\rho_l \cdot v \cdot d_i}{\mu} = 1737 \tag{22}$$

- Flow velocity:

$$v = \frac{4 \cdot 16}{3{,}14 \cdot (73 \cdot 10^{-3})^2 \cdot 86400} = 0{,}044\,\frac{\mathrm{m}}{\mathrm{s}} \tag{23}$$

KUDU 180TP3000 pump shall be chosen (n = 110 rpm); drive power: N = 15 kW [15]. Its characteristics will be extracted from the pump data sheet: the number of levels: 47.4 levels; the PCP rotor length: 9,25 m; the PCP stator length: 8.73 m; the rotor thread: 33 mm; the outer diameter of the pump: 120 mm.

When calculating the resistance of the sucker-rod pump gasket, proceed as follows:

- There shall be determined the weight of the fluid:

$$P_l = (4{,}185 \cdot 10^{-3} - 6{,}424 \cdot 10^{-4}) \cdot 2100 \cdot 9{,}81 \cdot 903{,}2 = 65901\,\mathrm{N} \tag{24}$$

- There shall be determined the buoyancy factor:

$$b = 1 - \frac{903{,}2}{7850} = 0{,}885 \tag{25}$$

- There shall be determined the weight of the sucker-rod pumps in the air:

$$P_p = 49{,}455 \cdot 2100 = 103856\,\mathrm{N} \tag{26}$$

- There shall be determined the unitary tensile stress, by means of the formula:

$$\sigma_t = \frac{65901 + 0{,}885 \cdot 103856}{6.424 \cdot 10^{-4}} = 246\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{27}$$

- There shall be determined the torque:

$$M_t = 9550\frac{\mathrm{N}}{\mathrm{n}} = 9550\frac{15}{110} = 1302{,}3\ \mathrm{N \cdot m} \tag{28}$$

- There shall be determined polar modulus of strength:

$$W_t = \frac{\pi \cdot 0{,}0286^3}{16} = 4593{,}3\,\mathrm{mm}^3 \tag{29}$$

- There shall be determined tangential stress:

$$\tau_t = \frac{1302{,}3 \cdot 10^3}{4593{,}3} = 284\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{30}$$

- There shall be determined the equivalent stress in the case of compound demand:

$$\sigma_{ech1} = \frac{1}{2} \cdot \left(246 + \sqrt{246^2 + 4 \cdot 284^2}\right) = 432\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{31}$$

$$\sigma_{ech2} = 0{,}35 \cdot 246 + 0{,}65 \cdot \sqrt{246^2 + 4 \cdot 284^2} = 488\,\frac{\mathrm{N}}{\mathrm{mm}^2} \tag{32}$$

The dimensioning is correct because the resistance condition is met.

The test pump data (KUDU 180TP3000) is shown in Table 2.

Table 2: Technical characteristics of the KUDU 180TP3000 pump [15]

d_R [mm]	***e*** [mm]	***h_{St}*** [mm]	***Q*** [m^3 / h]	***n*** [rot/min]	Δ***p*** [bar]	***N*** [kW]
18	3	189	0÷5,6	110	0÷12	15

where: d_R – diameter of the PCP rotor; e – excentricity; h_{St} – height of the PCP stator.

4. Finite element analysis of a sucker-rod pump

Sucker-rod pumps are designed to transmit the rotation motion from the drive-head to the PCP rotor.

The loads acting on the sucker-rod pumps, in the case of helical pumping, are given by the weight of the submerged sucker-rod gasket, the weight of the fluid column acting on the cross section of the PCP pump, the torque expected to be transmitted to the pump and the bending momentum (after loss of stability).

It follows that, in the case of helical PCP, the sucker-rod pumps are subjected to compression, torsion and bending, thus to a compound load. The compression stiffens the sucker-rod gasket increasing the speed at which the loss of stability occurs, while torsion has a contrary effect.

The normal stress occuring from the axial load has a maximum value at the top of the sucker-rod gasket and is given by the relation (11), in which the P_l - weight of the column of liquid in the extraction pipes (8) is defined; b - buoyancy factor (9); P_p - the weight of the sucker-rod pump, in the air (10); a_p - the inner cross-sectional area of the sucker-rod pumps; d_p - sucker-rod pump diameter.

The transmission of the torque required to rotate the PCP rotor leads to the development of tangential stresses along the entire length of the sucker-rod pump. The mean torque is determined by the relation (12) and the tangential voltage is determined by the relation (14). The two stresses, axial compression and torsion, give rise to a compound stress. In order to determine the equivalent stress specific to the compound stress σ_{ech}, one of the resistance theories (15) and (16) is adopted and the condition of checking the resistance of the sucker-rod gasket is imposed, where $\sigma_{ech} \le \sigma_a$, where σ_a is the allowable stress $\sigma_a \le \sigma_c / c_s$, with c_s – safety coefficient (c_s = 1,5).

Finite element analysis method for the solid model of the sucker-rod pump is performed using the finite element analysis software, Ansys Academic R15.0 [16], compared to the finite element analysis software, Cosmos / M [17]. The material of the workpiece is a 1530M-steel, low in carbon, easy-welding, resistance against intergranular corrosion, low temperature resistance.

a. Modeling the landmark using the ANSYS Academic Software R15.0

In the first stage, there shall be determined the units of measurement, then geometric characteristics of the solid landmark Sucker-rod pump shall be introduced, Tables 3 ÷ 4.

Table 3: Geometry elements of a sucker-rod pump

Bounding Box		Properties		Statistics	
Length X	22.2 mm	Volume	2.9495e+006 mm³	Nodes	50792
Length Y	22.2 mm	Mass	23.154 kg	Elements	9625
Length Z	7620. mm	Scale Factor Value	1	Mesh Metric	None

Table 4: Geometry elements of the solid

Properties					
Centroid X	1.6837e-016 mm	Moment of Inertia Ip1	1.1147e+008 kg·mm²	Volume	2.9495e+006 mm³
Centroid Y	-2.1648e-016 mm	Moment of Inertia Ip2	1.1147e+008 kg·mm²	Mass	23.154 kg
Centroid Z	3810. mm	Moment of Inertia Ip3	1412. kg·mm²		

For the sucker-rod pump, the following are known: d = 22,2 mm; l = 7620 mm; G = 24.384 kg. The PCP rotor was loaded with torque and, in turn, with three compression forces. In the first stage, the axial force F1 = -171675 [N] and a torque M = 610 [Nmm] shall be applied on the Z-axis, Figure 4 and Figure 5.

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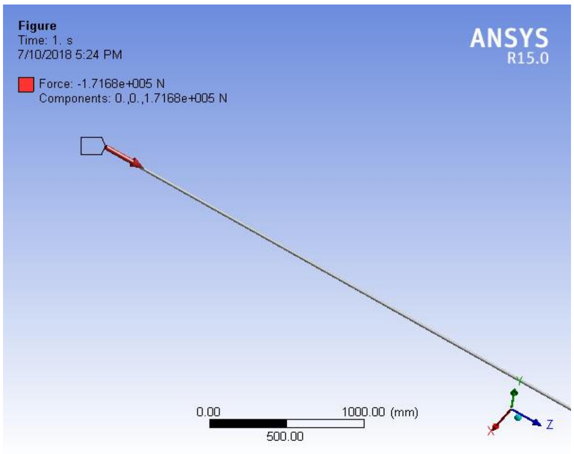


Fig. 4. Model loading with F_1 axial force

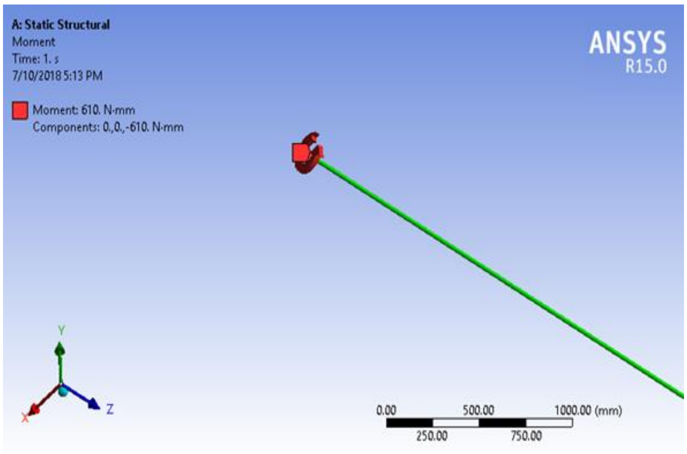


Fig. 5. Model loading with torque

The procedure shall be repeated, applying other two axial forces to the Z-axis, F2 = -190314 [N] and F3 = -208953 [N], but the torque M = 610 [Nmm] remains unchanged. The modeling factor determines the multiplication factor, as defined in Table 5. With this multiplication factor, the critical load can be determined, by which the sucker-rod pump can be loaded so that the landmark can withstand.

Table 5: Values of the *K* multiplication factor - Ansys Academic R15.0

F1 [N]		**F2** [N]		**F3** [N]	
Load Multiplier	5.8932E-4	Load Multiplier	5.3159E-4	Load Multiplier	4.8418E-4

b. Modeling using the COSMOS/M software

For finite element analysis using the COSMOS / M software package, the landmark was created by defining elements used for discretisation BEAM3D (three-dimensional), material properties. The cross section in Figure 6 was defined, starting from the definition of points and curves, Figure 7.

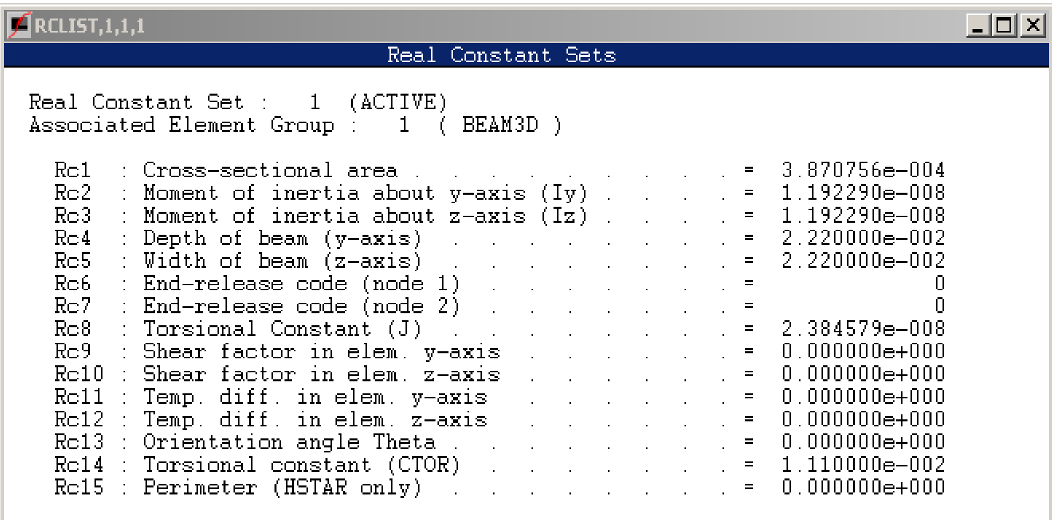
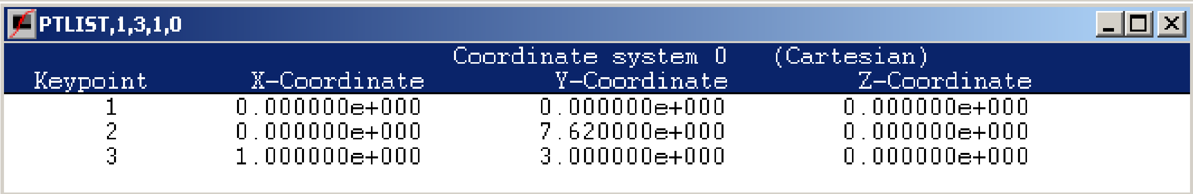


Fig. 6. Defining cross-section (*PropSets>Beam Section*)



PTLIST,1,3,1,0

Coordinate system 0 (Cartesian)

Keypoint	X-Coordinate	Y-Coordinate	Z-Coordinate
1	0.000000e+000	0.000000e+000	0.000000e+000
2	0.000000e+000	7.620000e+000	0.000000e+000
3	1.000000e+000	3.000000e+000	0.000000e+000

Fig. 7. Creating key points by defining coordinates (*Geometry>Points>Define*)

The model was loaded with axial force and torque *(LoadBC>Structural>Force>Define by Points (by Node)*, Figure 8, and the model ws deprived of degrees of freedom *LoadBC>Structural>Displacement>Define by Points>* All6DOF.

Following the finite elements analysis, the multiplication factor was determined with this software, Table 6.

In Table 7 and Figures 9 and 10, the comparative values obtained under the same loading conditions for the *K* multiplication factor are presented using the two finite element analysis software packages Ansys Academic R15.0 and COSMOS / M.

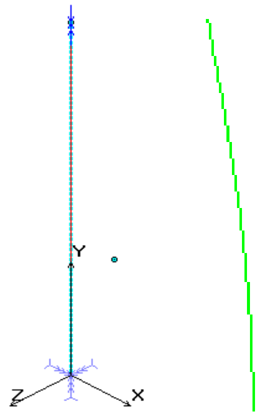


Fig. 8. The appliance of compression force and torque

Table 6: Values of the multiplication *K* factor - COSMOS/M

F1 [N]		**F2** [N]		**F3** [N]	
Load Multiplier	5.90248E-4	Load Multiplier	5.3244E-4	Load Multiplier	4.84945E-4

Table 7: Comparing the results from the two softwares

Compression force [N]	***K* multiplication factor (COSMOS)**	***K* multiplication factor (ANSYS)**
171675	5,90248E-4	5,8932E-4
190314	5,3244E-4	5,3159E-4
208953	4,84945E-4	4,8418E-4

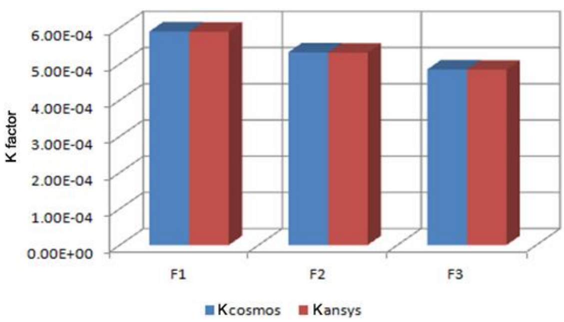


Fig. 9. Variation of *K* vs. F1, F2, F3

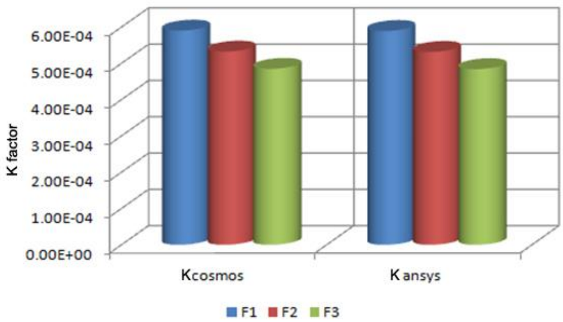


Fig. 10. Variation of *K* vs. Ansys and COSMOS

Conclusions

Progressive helical PCPs are widely used in the industrial field, especially in crude oil extraction, as their constructive and functional characteristics correspond to the severe operating conditions specific to this field, where the aggressiveness of the chemicals involved is a problem. Their construction allows the transfer of high viscosity fluids and the achievement of relative speeds with required precision. They are easy to install and characterised by a high reliability and maintainability, much more convenient than a beam pumping units or hydraulic jet pumps. For work surfaces that come into contact with the fluid to be delivered, stainless steel or anticorrosive material shall be used, while the non-metallic parts are made of rubber, plastics, the essential advantage being the normal displacement of the fluid through the conjugated PCP rotor, with continuous opposite displacement-opposing force inside the pumping chamber. Helical pumps use energy only to lift the fluid, not the sucker-rod pumps, thus eliminating ruptures of the sucker-rod pumps, caused by the weight of the fluid. However, given the long length of the sucker-rod pumps and the operating conditions, their loading must be taken into account, in terms of the forces and moments applied.

In this paper, the correct choice of the helical pumps was demonstrated by a comparative resistance calculation of the sucker-rod pumps, starting from the physical characteristics of the extraction fluid, respectively from the specific operating conditions.

Following modeling with finite elements, a multiplication K-factor has been obtained, similar to modeling with Ansys Academic R15.0 and COSMOS / M softwares, an essential factor in determining critical loads for loss of stability.

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SCANNING ELECTRON MICROSCOPY (SEM): A REVIEW

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Abstract: *In the present study, definition of scanning electron microscopy (SEM) was presented in terms of the main component of the instrument and step-by-step the process of SEM system. Schematic drawings with SEM components pictures were provided for understanding the procedure of work in easy and true way. Also, types of SEM were presented and discussed. The capability of energy-dispersive spectrometer (EDS) was also presented; this included historical background of EDS and how it works in accordance with SEM. The existence of EDS capability with SEM instrument is very essential for qualitative and quantitative analysis for any specimen. In the absence of EDS only information on surface topography of the specimen can be produced through SEM. The two most powerful features of SEM image are introduced and discussed namely secondary electron imaging and backscattered electron imaging. Understanding principle of work of both features is very important to have a complete knowledge on how SEM instrument works. SEM is characterized by its easy operation. Having that knowledge one can manage to perform the analysis and imaging very smoothly.*

Keywords*: Backscattered electron imaging, Energy-dispersive spectrometer, Scanning electron microscopy, Secondary electron imaging.*

1. Introduction

In general, two types of microscopy are available: optical microscopy (OM) and scanning electron microscopy (SEM). The former is the oldest one, which has been used since the last two centuries in the form of simple device with limited capabilities. It is also called light microscopy. OM differs from SEM in the following properties and features: (a) the main principle of work in OM is the light unlike SEM, which depend upon electron emission. (b) simple OM has only one lens while compound OM has two lenses. The lenses depend on bending the light to magnify the images. (c) magnification of modern OM reaches to the range between 400-1000 times the original sizes, which is very low compared to SEM having magnification reaches to 300,000x. (d) both living cells and solid materials can be examined by OM. (e) however, very few small organics can be visible and small solid pieces can be observed. This is due to the capability of the OM to small and thin samples only. (f) conversely, SEM provides a more detailed field with gray-scale images. (g) therefore, it can be said that SEM is more expensive than OM and cannot easily be maintained. (h) images produced from OM show the true colors of the examined object. Fig. 1 displays optical microscopy with compound lenses. There are three commercial types of OM: the stereo zoom optical microscope, the petrographic microscope and automated optical microscope [1].
Scanning electron microscopy (SEM), which is also recognized as SEM analysis or SEM technique, has been used worldwide in many disciplines. It can be regarded as an effective method in analysis of organic and inorganic materials on a nanometer to micrometer (μm) scale. SEM works at a high magnification reaches to 300,000x and even 1000000 (in some modern models) in producing images very precisely of wide range of materials. Energy Dispersive X-ray Spectroscopy (EDS) works together with SEM to provide qualitative and semi-quantitative results. Both techniques, together, have the potential to introduce fundamental information on material composition of scanned specimens, which could not be provided by the common laboratory tests. The analysis is done through SEM equipment, as shown in Fig. 2, which is a very developed SEM Quanta device for materials science [2]. The device consists of variable pressure system with the ability to hold any samples (even wet or samples with minimum preparation). The device allows to analyze samples with diameter up to 200 mm and height of 80 mm. Magnification of the device

range from 5x to 300,000 x. Materials that can be used in SEM is organic and solid inorganic materials including metals and polymers [3].
This paper presents an overview of SEM analysis in terms of background development of SEM, definition, types and work process. Energy Dispersive X-ray Spectroscopy (EDS) is introduced with their historical development and its effectiveness in SEM system. Best SEM instrument properties with available models for purchasing are very important to be included in this study.

Fig. 1. Optical microscopy with compound lenses [1]

Fig . 2. SEM Quanta device [2]

2. Background Development of SEM

The idea of SEM is back to the thirteenth of the last century at which a first electron microscopy was constructed based on the works that were conducted by two physics scientists Ruska and Knoll in 1933. The instrument is called transmitted-electron microscope (TEM) shown in Fig. 3 with electrons pass only through thin specimens, and magnification beyond that of the well-known optical microscope [4]. Subsequently, in 1938, Von Ardenne added scan coil to (TEM) constructing scanning transmission electron microscope (STEM) using voltage of (23 kV) at magnification of (8000x) and resolution of (50-100 nm). The laboratory instrument by Ardenne included many features, which become a standard since then to invent any SEM system [5]. However no commercial instrument was invented based on Ardenne SEM principle results due to explosion in his Lab [6]. Zworykin, Hillier and Snyder in 1942 presented a new description of SEM for thick specimens examination. The role of secondary electron emission for topographic contrast was identified [7]. Oatley in 1952 with the corporation of his student McMullan developed the electrostatic lens SEM with using voltage of (40 kV) for the electron gun. McMullan followed by Smith, who added other principles to McMullan work in his research. Smith recognized that the micrographs could be improved by signal processing and nonlinear signal amplification was introduced. Also, he produced double deflection scanning in order to upgrade the scanning system [5]. Both students' research laid the foundation for other in instrumentation. A new stereoscopic pairs were designed by O. Wells in 1953 for examining the third dimension in the micrographs [6]. Another two research students (Everhart, T. and Thornley, R.) developed the operation of scintillator detector (secondary detector) in electron conversion to light, which was transmitted to more efficient photomultiplier. This led to increase the collected signals and improving the signal to noise ratio [8]. In 1963, Pease built SEM V system with three magnetic lenses. This became the first instrument commercially under the name of “Stereoscan” Cambridge Scientific Instruments Mark 1, which was available in markets since 1965 [6]. After that many advances have been recorded such as sophisticating of electron sources for emission of more electrons and improving resolution. The invention of energy-dispersive spectrometer (EDS) was of great benefit. The system used successfully with SEM since 1968 to measure the x-rays by solid-state detector [5]. Development of SEM continued with producing more modern commercial equipment. During 1991-1993, Danilatos conducted a study on the effects of environment on the examined specimens. As a result a new instrument was developed which examine the surface of any specimen wet or dry. The most recent evolution of SEM is the process of generating the images digitally. Followed by displaying the images on computer screen. The majority of available commercial SEMs are equipped with (EDS) system and modern software to analyse the received data [5]. The EDS added the advantages of evaluating the composition of various elements in the sample with the aid of computer program. The latter facilitate the whole operation process; it converts the intensity of x-ray ratio to chemical compositions in a few seconds besides increasing quantitative analysis performance [3].

3. Components and Working System of SEM

3.1 Main Components of SEM

The SEM machine consists of the following components:

a- A source to generate electrons of high energy, it is called electron gun, as in Fig 4.
b- Column down for travelling the electrons through two or more electromagnetic lenses, as in Fig 5.
c- Deflection system consists of scan coils.
d- Electron detector for backscattered and secondary electron, as in Fig 6.
e- A chamber for the sample, as in Fig. 7.
f- Computer system consists of viewing screen to display the scanned images and keyboard to control the electron beam, as in Fig. 7.

Fig. 3. First Electron microscope [4]

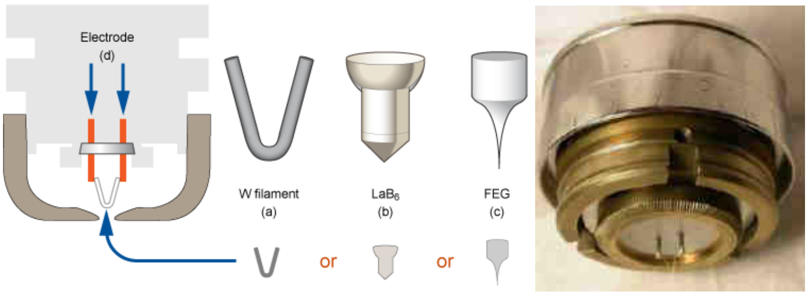

Fig. 4. Electron gun [9]

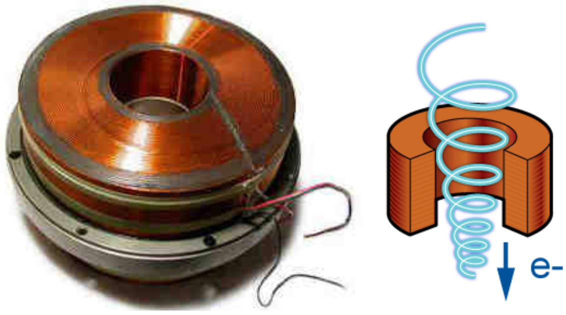

Fig. 5. Electromagnetic lenses [9]

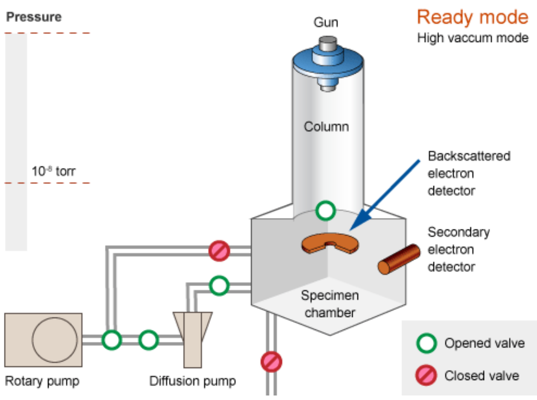

Fig. 6. Electron detectors in the SEM system [9]

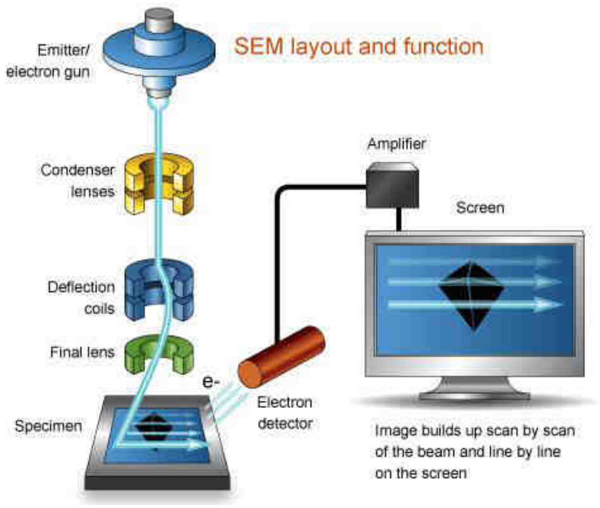

Fig. 7. All SEM components [9]

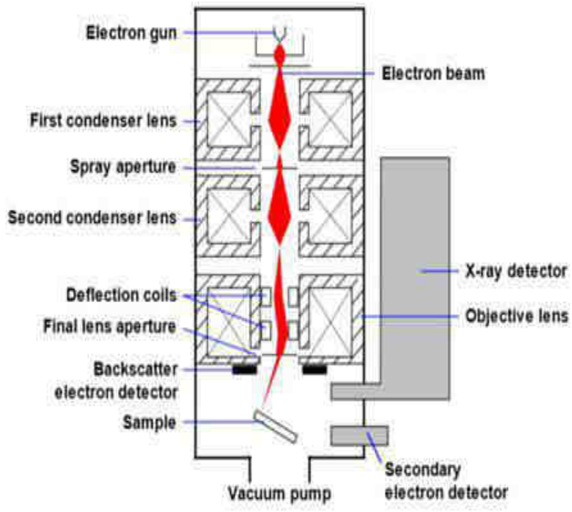

Fig. 8. Schematic of scanning electron microscope (SEM) [9]

3.2 SEM Analysis Process

SEM is a tool at which invisible worlds of microspace and nanospace can be seen. Details and complexity that is inaccessible by light microscopy can be revealed by SEM. This is all can be achieved through the following process, which is well descripted by Goldstein et al. [5] and both Fig. 7 and 8 can be used for more clarification:

a- The analysis will be done through applying a beam of electrons (having high-energy) in the range between (100-30,000 electron volts). Usually a thermal source is used for electron emission.

b- The spot size produced from the gun is too large to generate a sharp image therefore the SEM equipped with the lenses to compress the spot and direct the focused electron on the specimen. The spot size of most SEMs is less than (10 nm) with electrons collected from the final lens interact with the specimen and penetrate to a depth of (1μm) to generate the signals used to produce an image.

c- The image of the specimen is formed point by point depending on the movement of the scan coils, which cause the electron beam to move to discrete locations in a form of straight lines until a rectangular raster is produced on the surface of the specimen. All the process depends on magnification required. In case when the operator requests a higher magnified image, the scan coils make the beam to deflect a cross a smaller area. It is worth mentioning that the working distance, which is the distance from the last lens to the surface of the specimen, has an effect on the magnification, in which in the modern SEM this is solved by automatic adjustment.

d- Electron detector is to detect the emitted electrons (signals) from the scanned sample. In the absence of the detectors each signal generated due to the interaction between the electron beam and the surface of the sample can generate an image alone, which is un-understandable. Both secondary electrons (SE) and backscattered electrons (BSE) are used in SEM image production. When a positive voltage is directed to the collector screen, both SE and BSE will be collected. However, only BSE will be collected in case of negative voltage applied on the collector screen. Fig 9 shows Scintillator detector, which can be used for both secondary and backscattered electrons [10].

e- The signals then are displayed on the viewing screen and the operator will control the brightness and the intensity until a reasonable clear image is obtained. In case where small details are required within the specimen, magnification beyond (10,000x) should be applied.

f- The electron voltage mode (emitted from the gun) has influence on the provided details. The scanned image will be rich in surface information if low accelerating voltages used less than (5 kV). In contrast, the high accelerate voltages, which range between (15-30 kV), which penetrate underneath the surface, will make the reflected signal from the surface carry details about the interior of the sample. Fig. 10 is presented to show different penetration level of electrons through the sample and the reflected signals [11].

g- The partly three-dimensional image obtained from SEM depends on visualization of the topography of the sample in terms of (shape, size and surface texture). And this depends on number of BSE and SE. Surprisingly, angle of inclination of the sample surface has a direct effect on increasing both aforementioned numbers and as a result on topographic contrast. An inclination (or it is called tilt angle as well) more than 50° up to 70 raises number of BSE and SE signal to the peak.

Fig. 9. Scintillator detector for both secondary and backscattered electrons [10]

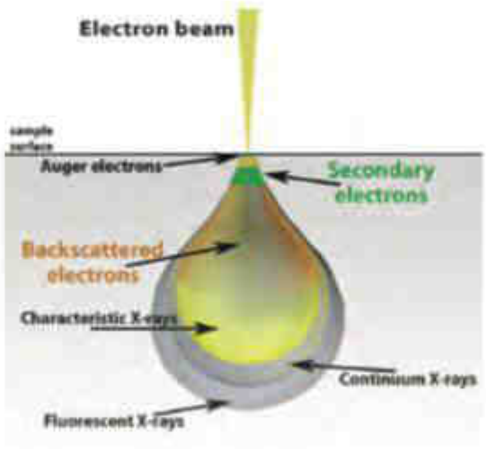

Fig. 10. Different penetration level of electron through the sample [11]

4. Types of SEM

There are three types of SEM, conventional SEM (CSEM), environmental SEM (ESEM) and low vacuum SEM (LVSEM) [12].

a- In a conventional SEM (CSEM), the interaction of electron beam with specimen occurs in a high vacuum (10^{-6} torr), at which torr is a unit measure of pressure (1 torr = 133.32 Pascal). Thus low energy secondary electrons will be emitted from the sample with minimum collisions with gas molecules in the chamber. However, dehydration and cracking of concrete will occur due to this high vacuum, which will obstacle the ability to make direct observations on crack propagation. But it can be smoothly applied in other cases such as identifying Alkali Silica Reactivity (ASR) or aggregate constituents in concrete, which are unaltered by the vacuum.

b- The second type is environmental SEM (ESEM). In this type the interaction between electron beam and specimen occurs at elevated pressures (0.2 to 20 torr), this has positive and negative effects.

Positive effects:

i- Lessen or eliminates dehydration (generally, the minimum pressure to sustain liquid water is 4.6 torr).

ii- The elevated gas pressure has another benefit; discharging of any surface charge will occur by ionization of the gas molecules. This reduces the need for conductive coatings and an improved concrete imaging will be obtained.

iii- The ionization of gas molecules is the result of collisions between beam electrons and the emitted electrons from the sample. This ionization will increase the strength of electron signal and this is appositive effect.

Negative effect:

i- Such collisions lead to scattering and defocussing of the electron beam, which in turns lead to uncertainty of the position of electron beam on specimen.

ii- This is not a problem for imaging but it is a serious problem in x-ray microanalysis because the considered element in the analyzed spectrum may truly not be present at the assumed analysis point.

In conclusion, it can be said that ESEM can be successfully used for concrete imaging but of limited ability for performing x-ray microanalysis.

iii- The third type of scanning electron microscope is the low vacuum SEM (LVSEM), which is similar to a CSEM but also adapted to operate at elevated pressures (0.2 to 2 torr). In such environment, any liquid water cannot be sustained and will dissipate very slowly in the vacuum. Effect of this type of SEM on cracking will be very slow and not seen during a typical analysis. Similar to CSEM, LVSEM eliminates surface charging and the need for coating.

5. Energy Dispersive X-Ray Spectroscopy (EDS)

X-ray generates when the electron beam, which is emitted from the gun, penetrate and interact with volume beneath the surface of the sample. The principle is defined very well in physics, when electrons inter the coulomb field of a specimen it will decelerate and the loss of electron energy emits as a photon. So, the same principle works in SEM analysis and x-ray photons will be emitted. Those photons have energies particular to specimen elements; these will provide the SEM the capabilities and called characteristic x-rays [5], as shown in Fig. 10.

Measuring the intensity of x-ray gives the quantification scheme; Heinrich illustrated this in his publication (Quantitative Electron Probe Microanalysis) in 1968 [13]. It became a standard for the developing x-ray field. What was missing at that time was the identification of several things: 1. Determination of correction factors when electron penetration and scattering is measured was essential. 2. X-ray absorption. 3. Conversion of x-ray intensity to relative concentration. The development of energy dispersive spectrometer (EDS) solved many problems associated with Electron Probe field. Heinrich participated in the process of introducing EDS to x-ray field. Many studies and works were implemented in this field to develop the x-ray field or electron probe field. Most efficiently are development of computer software and a reference to microanalysis standard materials [14].

A schematic picture is presented in Fig. 11 for showing the x-ray detecting system (solid state detector). The EDS detector takes the responsibility of separating the x-ray characteristic of various elements within the sample into energy spectrum. Then the spectrum will be analyzed by EDS system software to determine the amplitude of specific element (photon energy will be converted into electrical signals). Finally, the chemical composition maps of the elements can be determined both qualitatively and quantitatively [5]. The complete scanning instrument SEM equipped with EDS capability is presented in Fig 12. The procedure of quantitative analysis of the scanned sample using SEM instrument equipped with EDS involves the following steps:

- a- Determining the problem; in other words what exactly the purpose of the analysis (composition gradient measurement or just chemical composition of the sample).
- b- A qualitative analysis on the sample to determine different elements within the sample.
- c- Preparation of the sample: the sample must be flat and polished with thickness less than (0.1 μm), this will not appear under the microscope.
- d- The polished sample should be kept before the analysis in a dry environment to lessen any built up contamination on its surface.
- e- Conduct the quantitative analysis by measuring x-ray intensities of each element in the sample.

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f- Performing quantitative corrections to produce numerical concentration through the software.

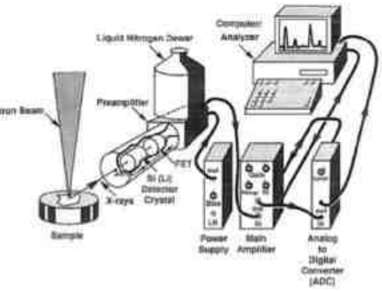

Fig. 11. Schematic picture of energy-dispersive spectrometer [5]

Fig. 12. A high SEM performance instrument, equipped with EDS system and a chamber room to analyze and navigate large specimens [2]

6. Purchasing SEM Instrument

First, there are differences among different instruments and the three mentioned SEM types could be used for analyzing concrete material. The best microanalysis data and highest possible resolution can be obtained when using CSEM instrument. However, cracking and dehydration exist and coating of the specimen with conductive media is important to eliminate surface charging. ESEM has the ability to function as LVSEM and CSEM but design restrictions should be applied which lead to optimum performance. LVSEM functions very well as CSEM with little to no hydration cracking. Thus, each instrument has their capabilities; so for purchasing SEM several points should be kept in mind [1]:

a- The instrument has the capability of largest possible specimen size and stage travel.
b- Most of SEM chamber area allow for specimens with diameter over (200 mm).
c- Choosing an instrument with a high detector take-off angle between (35- 40°). This is the inclination angle between the surface of sample and the x-ray detector.
d- Evaluation of the seller is very important by calling the customers who bought the instruments to have information on field service cost and performance.
e- The sellers should also provide information on maintenance cost. Usually, it varies between (1%-5%) of instrument total price per year. For instance, if the cost of the SEM instrument with EDS system is ($300,000), the maintenance cost will be between (£ 3000-$15,000).

Fig. 13 is a modern SEM device called Q250 Analytical SEM for Materials Science. It has a flexible sample characterisation enabling of high vacuum, low vacuum, and ESEM for any sample. This is available online from Thermo Scientific site. The instrument equipped with UltraDry EDS detector, which enable surface and compositional analysis with images therefor it is very suitable for labs.
Fig. 14 is Hitachi High Technologies SEM called The SU3500 Scanning Electron Microscope. This type is designed for a wide range of applications, (biological and advanced specimens are also included). The SU3500 SEM has the following features: 1. It has a high image quality. 2. Wide screen and fast auto image optimization process (need only 7 seconds). 3. Equipped with ultra-variable pressure detector. 4. It has a Stereoscopic image function with "3D" image observation. The product can be purchased from Hitachi High Technologies America, Inc. (“HTA”) company [15].

7. Conclusions

Basic concepts about scanning electron microscopy technique have been presented in this paper. The following concluding remarks can be drawn.

1. It can be concluded that both CSEM and LVSEM might be the best choice for analyzing concrete material as they both work at lower pressure than ESEM. This concept prevents

too much scattering of the electrons, eliminates defocusing of the electron beam and thus, high resolution images will be produced.

2. The existence of EDS capability with SEM instrument is very essential for qualitative and quantitative analysis for any specimen. In the absence of EDS only information on surface topography of the specimen can be produced through SEM.
3. Two industrial companies was selected, who produce SEM with various models and capabilities, Thermo fisher Scientific and Hitachi Company. They have very large selling and through reviewing the costumers' comments on their purchased product, very satisfactory comments were provided online. The contact with both companies revealed that they have good deals with discounts on most of their SEM products.

Understanding principle of work of both secondary electron imaging and backscattered electron imaging features is very important to have a complete knowledge on how SEM instrument work. SEM is characterized by its easy operation. Having that knowledge one (engineer) can manage to perform the analysis and imaging very smoothly.

Fig. 13. Q250 Analytical SEM for Materials Science [2]

Fig. 14. SU3500 Scanning Electron Microscope [15]

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TEST STAND WITH SPECIFIC SENSORS FOR DIGITAL HYDRAULIC CYLINDERS

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Abstract: *This article discusses the testing capabilities of the INOE 2000 - IHP digital hydraulic cylinders stand. It presents the functional scheme and the devices in the structure of the stand, as well as the working methods for the realization of the main tests that it can provide. Although the stand is for research, it can meet the general conditions of internal and international norms to determine the functional performance of hydraulic cylinders with the necessary adaptations for digital hydraulic cylinders.*

Keywords*: Test stand, digital hydraulic cylinders, tests, electronic control, data acquisition.*

1. Introduction

Hydraulic cylinders, also known as linear hydraulic motors or power cylinders, are designed to perform. They convert energy from hydrostatic energy into mechanical energy, characterized by two parameters, force and speed.
The use of linear hydraulic motors in hydraulic systems is a current practice and is often specific to each system designed to meet certain requirements. These engines have a wide spread due to the simplicity of construction and the possibility of achieving large and very large driving forces.

2.Tests and check methods for standardized hydraulic cylinders according to national norms of standardization

The checking of the minimum pressure for the uniform and shock-free movement of the piston and starting pressure is carried out when idling. The working chambers are filled with oil having the ambient temperature at which the test is carried out, the kinematic viscosity v = 35 cSt. Connect a pressure oil source at one end. There is the lowest pressure at which the piston moves at minimum speed and the piston has a smooth and shock-free stroke throughout the stroke. Uniformity of the piston displacement speed is checked with a recorder.
The maximum admissible value of these pressures is specified in the technical documentation of the product.
The checking of the minimum, maximum piston speed, is performed at pressures ranging from 0.2-1.5 p_n but not more than 1.1 p_{max}; the displacement must be carried out under load, smoothly and without shocks throughout the stroke.
The checking of the pushing force and traction force is performed at pressures ranging from 0.2-1.5 p_n and at three speeds (minimum, middle, maximum) of the piston. The force is measured with dynamometers or force transducers with the class precision at least 1 per stroke interval corresponding to pressure and force stabilization. The mechanical resistance load is created with a load cylinder powered by a separate, low pressure hydraulic system and can be continuously varied in both directions by the adjustable pressure valve. The measurements are made for 5-8 values of pressure at three gears, within the mentioned ranges. The test speeds are obtained by varying the flow in the cylinder under test, with an adjustable flow pump.

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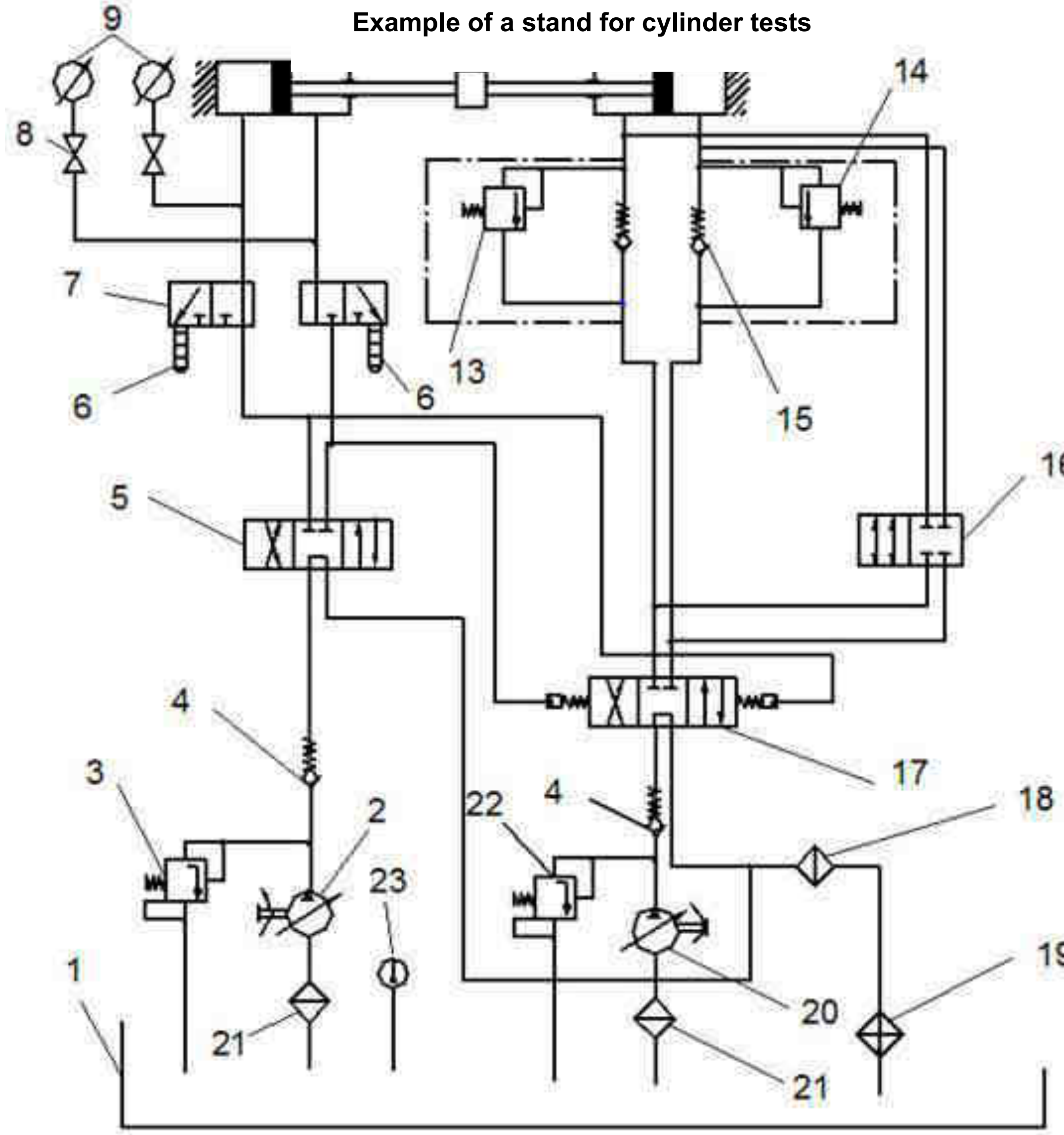
2.1 Test scheme for standardized hydraulic cylinders



No	Furniture	No	Furniture
1	Tank	10	Hydraulic cylinder to be tested
2 ; 20	Pumps	11	Force transducer
3 ; 22	Pressure relief valve	12	Load cylinder
4 ; 15	Check valve	13 ; 14	Counter-pressure valve
5;7;16;17	Directional valves	18 ; 21	Filters
6	Graduated vessels	19	Heat exchanger
8	Tap	23	Termometer
9	Manometers		

Fig. 1. Scheme recommended by STAS 8535-83

2.2 Digital hydraulic cylinders

In a conventional hydraulic cylinder, a fluid at a certain working pressure acts on a piston with a particular working area, resulting in a specific linear output force in accordance with the load to be displaced. If another output force is required, the fluid pressure must be changed because the piston area remains unchanged. From a hypothetical point of view, if the active area of the piston could be changed or only part of the area could be used, the fluid pressure could remain constant and the output force could vary. Unfortunately, there is no means by which the liquid can only act on a portion of a piston, since the pressure fluid acts equally on the entire area containing it.
Hydraulic digital technology is a solution to this new approach. In the case of digital hydraulic cylinders, it has been found that it is more cost-effective to vary the surface than to vary the pressure or flow for active cylinder control. By dividing the work area of a piston into annular zones with binary multiple sizes or according to other criteria, the selective pressurization of the annular chambers results in a cumulative output force that can be actively controlled in relation to the requirements of the system. The permutation of individually or cumulatively selectable combinations of zones / sections leads to a wide range of constant output flow / pressure outputs / speeds. Hydraulic digital drive is a new approach to linear drive. The basic principle is to divide the active surface of the cylinder. The result is an energy-efficient actuator that has a high maximum output but only needs a medium power output from the outside.

3. Stand for testing of digital hydraulic cylinders

The stand for testing the digital hydraulic cylinders (fig.2) consists of the equipment shown in the block diagram, fig. 3.

Fig. 2. Test stand

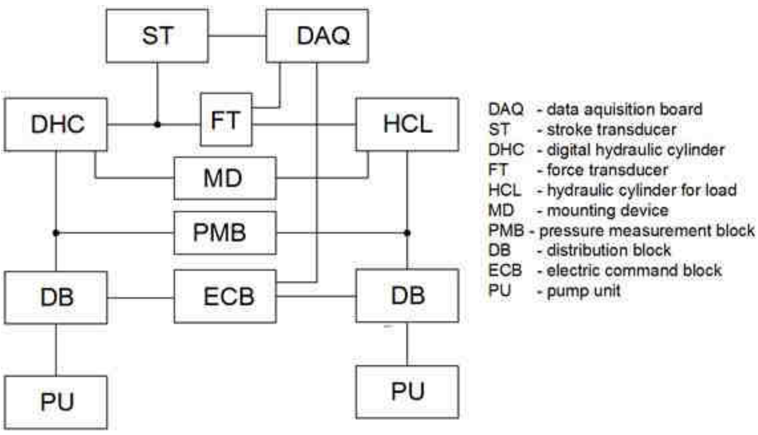


Fig. 3. Block diagram of test stand

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Figure 4 shows the hydraulic diagram of the digital hydraulic cylinder test stand.

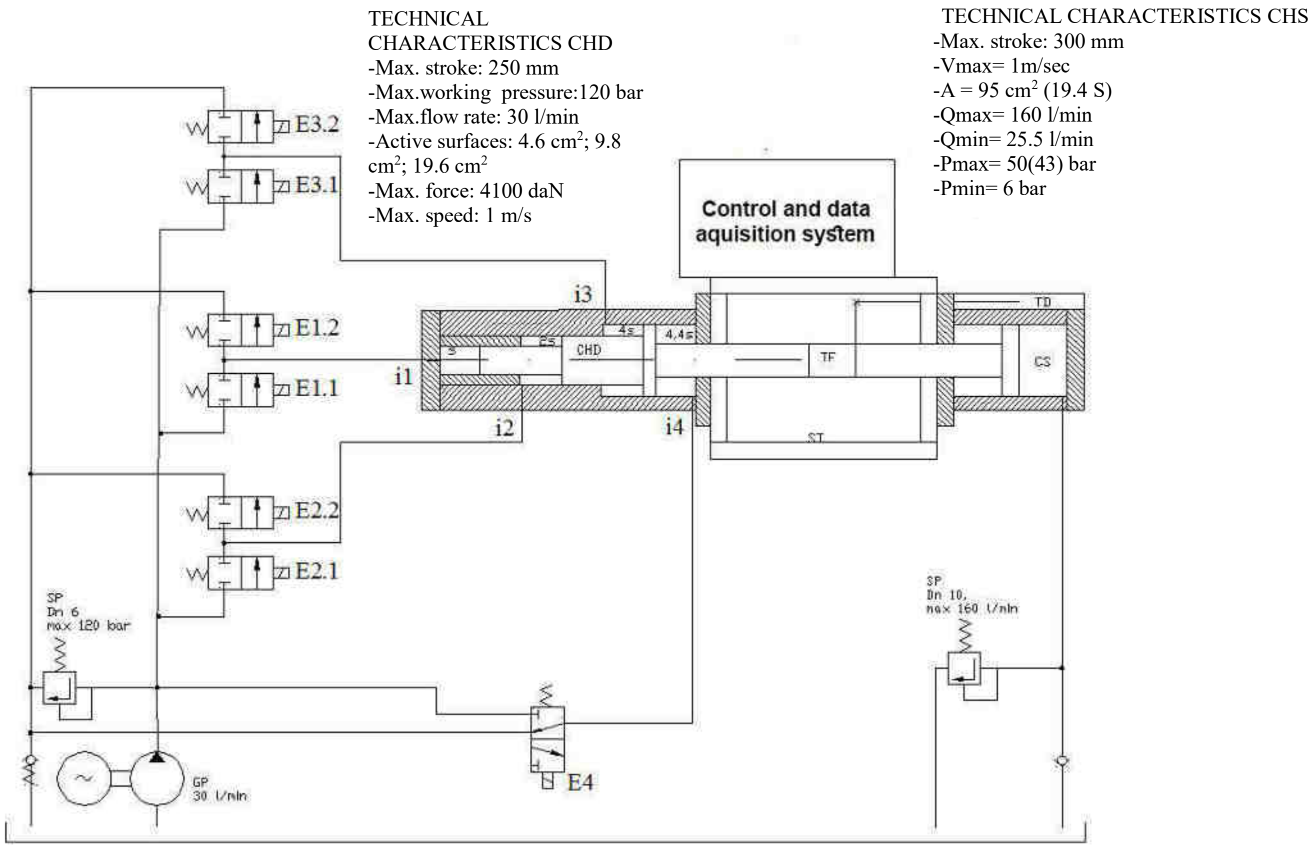

Fig. 4. Hydraulic diagram of the research stand for digital hydraulic cylinders

The stand includes a fixing device, fig. 5 on which the digital hydraulic cylinder for testing, fig.6 is mounted and the hydraulic cylinder for simulating the load, fig.7 at the rod of the digital hydraulic cylinder.

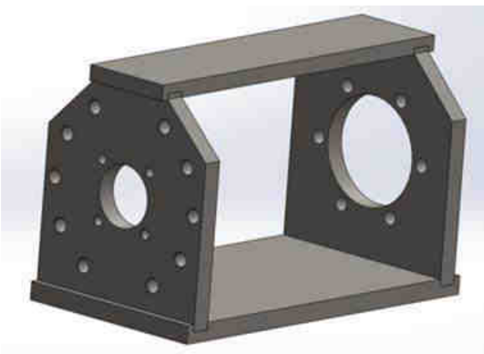

Fig. 5. Fixing device

Fig. 6. Digital hydraulic cylinder

Fig. 7. Load hydraulic cylinder

Fig. 8. Pumping station

The mounting device is fixed to the cover of an oil tank. Next to the stand are the pumping units (fig. 8) for the digital hydraulic cylinder and the load hydraulic cylinder.
The fixing device consists of a force transducer (TF) and a traction transducer (TD) (fig. 9), whose signals go to a given acquisition plate (fig. 10).

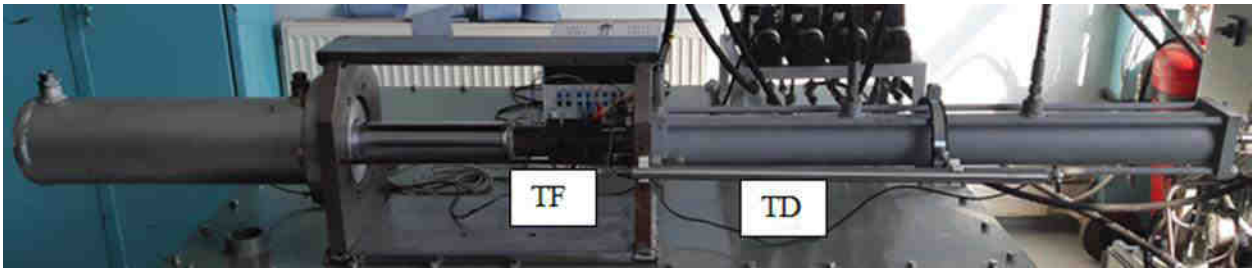

Fig. 9. Research device for digital hydraulic cylinders

Fig. 10. Data acquisition plate

The same data acquisition plate is used to give commands to the distribution block of the stand from fig.11 for different speed and force regimes of the digital hydraulic cylinder.


Fig. 11. Distribution block

A virtual instrument application (fig. 12) has implemented command logic for feeding the digital hydraulic cylinder chambers and the data acquisition system for the measured signals. The electric control block diagram (fig. 13) consists of 8 transistors which control the relays coils that feed the solenoids of the hydraulic directional control valves. The commands for the different working regimes of the hydraulic cylinder are given by the virtual instrument application via an electric control block (FIG. 14) which interfaces the digital outputs of the DAQ board with directional valves.

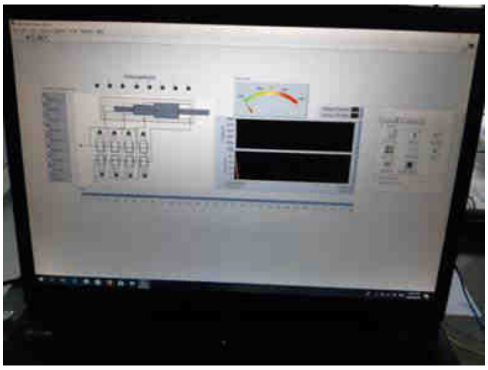

Fig. 12. Graphic interface of application

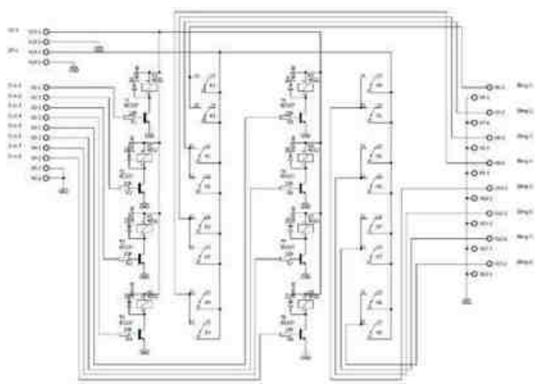

Fig. 13. Electronic diagram for electric command block

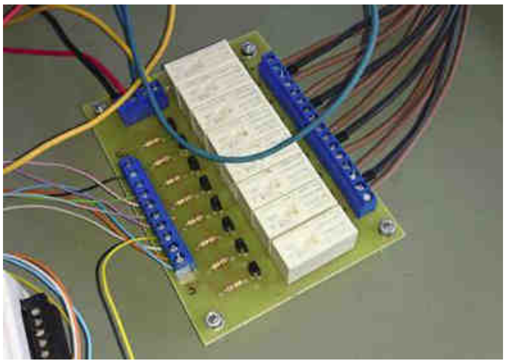

Fig. 14. Board with electric command block

The interface of the application is shown in fig.15. Figure 16 shows the schematic diagram for making the 7 advancement modes for the hydraulic cylinder rod and one for pulling out the rod.

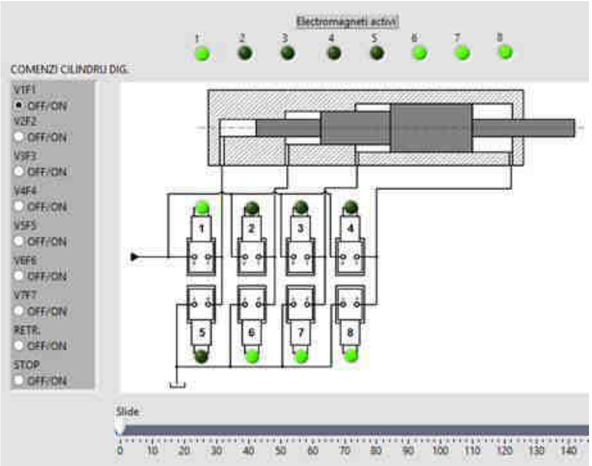

Fig. 15. Virtual instrument command interface

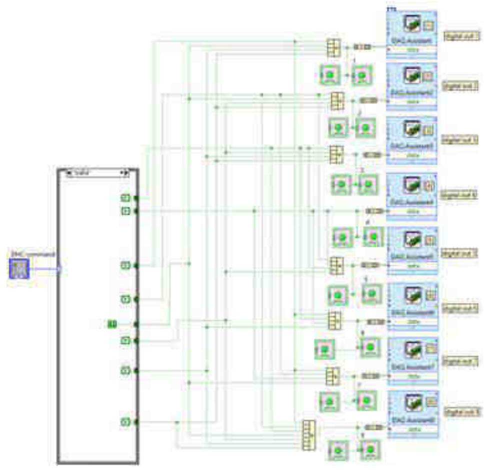

Fig. 16. Solenoids selection block in VI

4. Presentation of the main tests for achievement of the research papers

Table 1 shows the control cyclogram for plotting F = f (Ai) to p = ct and V = f (Ai) to q = ct. for digital hydraulic cylinders with three surfaces.
Where F corresponds to the force obtained with the lowest area at constant pressure and V corresponds to the speed achieved with constant flow for the smallest section, s represents the surface of the smallest piston, the control code represents the combination of active surfaces selected by the control of electromagnets E.

Table 1: Control cyclogram for three-dimensional digital cylinders

Command code	**Input commands to electromagnets**							**Cylinder with technologically optimized diameters**	
	E1.1	**E1.2**	**E2.1**	**E2.2**	**E3.1**	**E3.2**	**E4**	**Force**	**Speed**
0	0	0	0	0	0	0	0	0	0
1	1	0	0	1	0	1	0	1F	1V
2	0	1	1	0	0	1	0	3F	0.33V
3	0	1	0	1	1	0	0	3.975F	0.251V
4	1	0	1	0	0	1	0	4F	0.250V
5	1	0	0	1	1	0	0	4.975F	0.201V
6	0	1	1	0	1	0	0	6.975F	0.143V
7	1	0	1	0	1	0	0	7.975F	0.125V
Withdrawal	0	1	0	1	0	1	1	4.4F	0.227V

Where:

- The control code is the combination of electromagnets controlled for a pressure stage.

- S is the surface of the smallest piston.
- E1-E4 are electromagnets.
- F is the force with the smallest surface at the supply pressure.
- V is the speed obtained with the lowest section at the supply flow.

Expected results for rod advance:

- For variance of force: F = f (Ai)
- F = PxS

Where:

- F- The resulting force with the smallest surface
- P-Pressure (constant)
- S-Surface (variable)

4.1 Hydraulic cylinders specific tests

The checking of the minimum pressure for the uniform and shock-free movement of the piston and the starting pressure for the three-dimensional digital hydraulic cylinder is performed in idle. The working chambers are filled with oil having the ambient temperature at which the test is carried out, the kinematic viscosity v = 35 cSt. Connect all surfaces of the cylinder to a pressure oil source according to the test scheme. The lowest pressure at which the piston moves at the minimum speed and for which the piston has a smooth and shock-free stroke for each surface of the multi-surface cylinder and all the summed surfaces is recorded over the entire length of the stroke. For the three-dimensional cylinder, commands corresponding to command code 1,2,4 and 7 are executed in the control cyclogram. Uniformity of the piston displacement speed is checked with a recorder. The measurement result is added to the test sheet.

The checking of the pushing force is made at constant pressure by selecting the combinations of sections of the multi-surface digital cylinder over the entire length of the stroke. Force is measured with force transducers with precision class at least 1 per stroke interval corresponding to pressure and force stabilization. The load of strength-type is created with a hydraulic cylinder powered by a separate, low-pressure hydraulic system and can be continuously varied through the adjustable pressure valve. The measurement is made to determine the force variation according to the combination of selected surfaces, F = f (Ai) at constant pressure. Check controls are made in accordance with the control cyclogram, successive for all combinations during the rod forward stroke. The measurement result is added to the test sheet and compared to the expected result.

The checking of the piston speed is made at constant flow rate; the displacement must be carried out under load, smoothly and without shocks throughout the stroke. The check is made for each surface combination of the multi-surface cylinder and all the summed surfaces, during the rod forward stroke. The measurement is made to determine the velocity variation according to the combination of selected surfaces, V = f (Ai) at constant flow. Check controls are made according to the control cyclogram. The measurement result is added to the test sheet and compared to the expected result.

5. The results obtained in the research activity

At the test, the commands to the distribution block were applied according to the control cyclogram in table 1 and the force graph corresponding to the combination of active surfaces fed with 120 bar pressure was obtained.

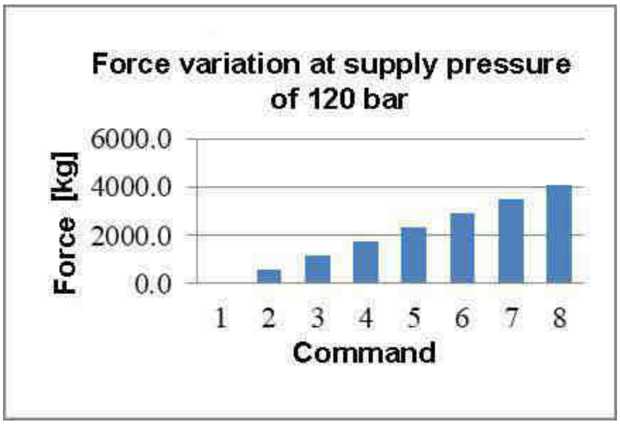

Fig. 15. Example of force variation for the supply pressure of 120 bar to the cylinder with three binary multiplied surfaces

Also under the same test conditions (according to table 1), the graph of the variation of the displacement speed of the cylinder rod was obtained at a constant supply flow of 30 l / min.

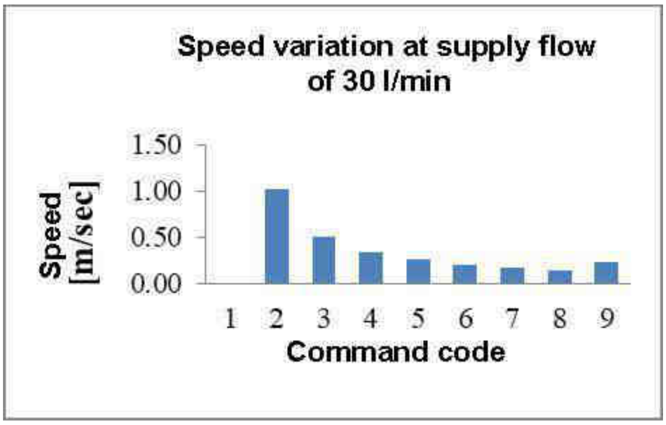

Fig. 16. Example of speed variation for supply flow of 30 l/min in the cylinder with three binary multiplied surfaces

6. Conclusions

The research stand for digital hydraulic cylinders is the first achievement in the field of Digital Hydraulics from the institute and from the country and enables full testing for normal working regime, to determine key parameters and dynamic regime for tracing the response diagram to step signal.
The tests results of the digital cylinder behavior in dynamic regime of response to step signal will be used to formulate conclusions on the performance of the tested digital cylinder and to formulate proposals for new research directions in the studied field.

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THE HYDRAULIC OIL HEATED UP EVEN WHEN THE SYSTEM RAN SLOW: A CASE REPORT

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Abstract: *The hydraulic system is the backbone of industrial, construction, and agricultural machines. The hydraulic system is still the preferred choice for high-energy applications over electronic systems because of their higher power density and efficiency. "Whenever the system runs to its full capacity, hydraulic oil heats up more as compared to partial loads" is a myth. In this paper, a study report on higher oil temperatures for a lower system loading case has been presented.*
The subject system is an example of Industrial hydraulics which comprises of precision valves. The system could deliver excellent performance due to its high precision parts. The concern started when the machine at lower speeds was resulting in frequent shutdowns. This paper presents a systematic approach using the system engineering principles to diagnose the problem and develop a mathematical model to arrive at the design change to resolve the issue entirely. This learning can be equally deployed for the other field of interest, as care should be taken to understand the system idle losses which can result in elevated temperatures. This paper is concluded with an approach to find the self-balancing system (in relation to a case wherein the rate of heat addition is higher than the rate of heat ejection, thus, the temperature increase was a must.)

Keywords*: Hydraulics, Heat, Radial Piston Pump, Variable Pump, Case drain, Check Valve*

1. Introduction

If the hydraulic system needs to be at its best, the self-balancing system needs to operate in equilibrium. In the fluid power system, more flow always results in more pressure drop. Heat generation in the fluid power system is a result of the pressure drop. The more the pressure drop, the more is the heat addition. If adequate cooling arrangements are not made, the fluid power system temperature can rise above the recommended levels. Operating the fluid power system in the recommended temperature range always results in the extended life of the system and provides optimum efficiency. The Industrial hydraulic systems usually run within a narrow range of operating temperatures to ensure the functioning of machines in the optimum viscosity range. This paper focuses on a customer complaint wherein the threshold temperatures were often broken resulting in the production stoppage even when the hydraulic system was used at lower speeds.

2. System Description and Problem Details

Following sections focus on hydraulic system architecture, performance specifications, and problem details.

2.1 System Details

The system here refers to an Injection Molding Machine (IMM) consisting of an electronic radial piston pump which operates the clamping unit with a proportional valve and the Injection unit with on/ off valves. Figure 1 and Figure 2 show a typical IMM which indicate a clamping unit which holds the mold in place and the injection unit sends the homogenized plastic mixture into the mold resulting in the molded part which will be ejected through the ejection system. For a Hydraulic IMM, two types of clamping units can be used: toggle and ram type. The projected area of the part and the number of components per mold, decide the size of the IMM.

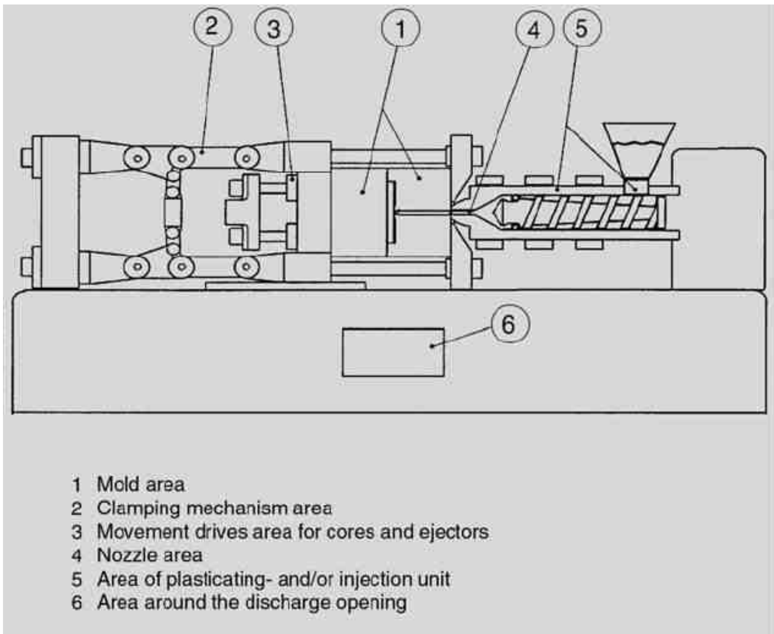

Fig. 1

Figure 2 explains the system architecture which shows the flow of energy, signal, and noise. The central control system monitors the idle conditions of the system and takes commands from the operator input device. The system discussed here is a typical 150T machine with a radial piston electronic variable displacement pump operating the clamping unit with a proportional valve and the Injection unit with on/off valves. Such machines typically have cycle times in the range of 5 to 15 seconds based on the type of parts and their complexity. The subject has a 22kw motor, 80cc pump, and 8kW cooler (water based.) The case drain is connected directly to the reservoir with a maximum allowed flow of 3% of pump rated flow.

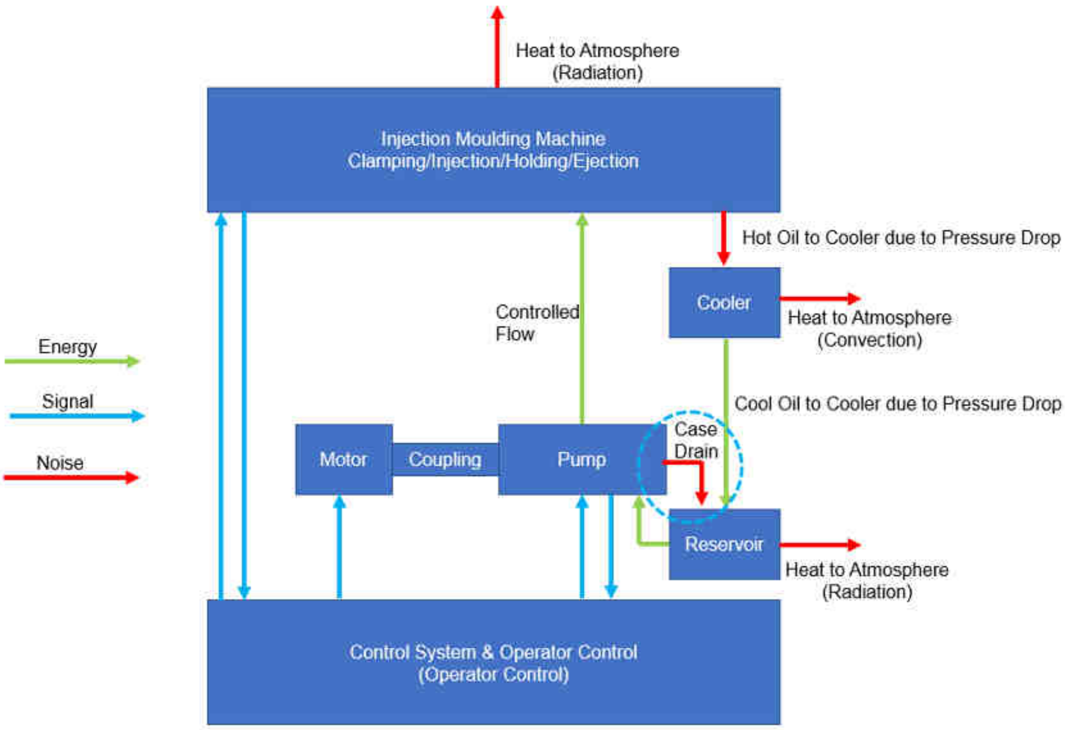

Fig. 2

2.2 Cycle Time versus Temperature rise

IMM is operated at 70% of the speed setting in one of the molds (pet bottles) and 30% of the speed setting in the second one (bottle cap). When IMM was used at 70% of the speed setting, there was expected performance, and there was no oil heating. The concern started when the new part which was selected needed a slower operation of the IMM. IMM was used for making pet bottles (Figure 3) and it normally works with a cycle time of 6 seconds (Clamping: 1.2 seconds+ Injection: 1.8 seconds+ Holding: 1 second+ Mold open: 1 second+ Ejection: 1 second).

Fig. 3

IMM was producing bottle caps with a cycle time of 10 seconds (clamping 3 seconds+ injection 3 seconds+ holding 2 seconds+ mold open 1 second+ ejection 1 second). In this case, the IMM working temperature started from 40°C and reached 60°C in 80minutes (Figure 4) prompting the "oil temperature high alarm." These factors prompted for the system temperature mapping.

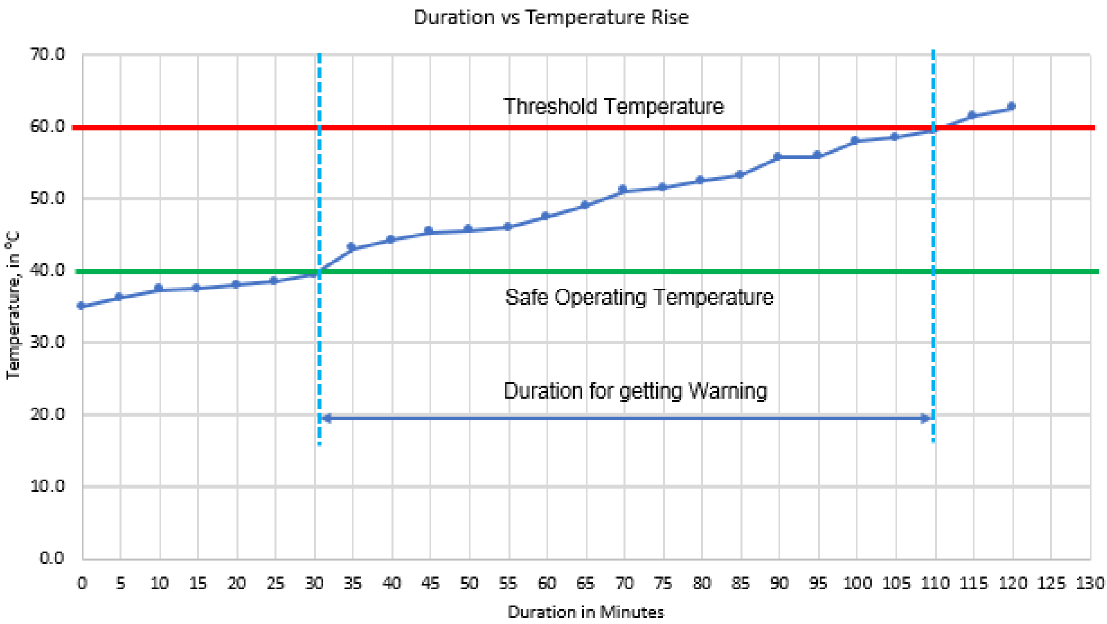

Fig. 4

2.3 Temperature Measurements

The temperature was measured via a temperature gun at every hydraulic plumbing/ valve/ manifold. Due to the efficient water-cooling system, external temperatures were well within the normal range in most of the areas except the pump surface, which indicated that the system had a case drain flow which was not passing through the oil cooler and was steadily heating up the reservoir.

3. Heat calculations

The hydraulic power loss results from the pressure drop and is proportional to the amount of oil flow/ density. Equation 1 indicates the relationship between hydraulic power loss, temperature rise, and the volume of oil.

$$P = \frac{\Delta T \cdot V \cdot \rho \cdot c}{t \cdot 3600} \tag{1}$$

Legend:

P: Power loss in kW
ρ: density of oil in kg/dm^3
c: Specific Heat Capacity in kJ/kgK
(for mineral oil c=1.67 kJ/kgK)
V: tank volume in liters
ΔT: Temperature increase in °C
t: Operating time in hours

Equation 2 calculates the Hydraulic power in relation to the flow of oil and its pressure.

$$P = \frac{p \cdot Q}{600} \tag{2}$$

Legend:

P: Power in kW
p: Hydraulic Pressure in kg/cm^2
Q: Flow in Liters Per Minute (lpm)

Equation 1 measures the rise in oil temperature per hour in relation to the operating condition. The power which is required for creating the leakage can be calculated from equation 2. Below calculation assumes that net heat increase due to the return line of the machine operation is compensated by the cooling effect of the oil cooler. Below table gives us the different flow scenarios and the resultant temperature increase due to uncooled oil going to the reservoir directly from the case drain. Generally, the case drain flow is assumed to be around 3.5 lpm (3% max) which is coming out of the pump and getting added to the reservoir steadily. According to the Piston pump catalog, 4~6 lpm case drain flow is possible for an 80 cc radial piston pump. Following cases helped to find the range of temperature rise per hour (Table 1.)

Table 1: Temperature Increase per hour

Pressure in Bar	Case Drain Flow in lpm	Hydraulic Power in kW	Tank Volume in liters	Operating time in Hrs	Specific Heat Capacity In kJ/kgK	Density ρ kg/dm3	ΔT in °C
150	6	1.5	250	1	1.67	0.86	15
75	5	0.63	250	1	1.67	0.86	6.3
20	4	0.13	250	1	1.67	0.86	1.3

From the table, it is evident that the perceivable temperature increase is possible when the case drain temperature reaches the reservoir without going through the cooler. The cooling effects by the reservoir area have been excluded in the above calculations.

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4. Root Cause Identification and Solution

Methodology shown in Figure 5 is followed in the identification of root cause. Based on the temperature mapping, the results were processed to get the desired output.

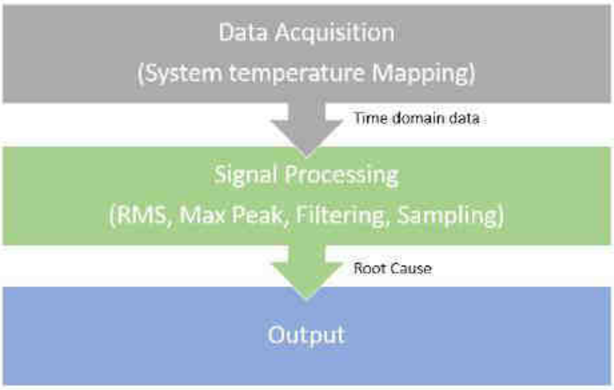

Fig. 5

In Six Sigma, QFD helps to prioritize actions to improve the process or product to meet customers' expectations. QFD tool (Table 1) is used here to identify the top contributing root cause and pareto is used to prioritize the same.

Table 2

Quality Function Deployment for Low Load Temperature Raise Root Cause							
	Importance Rating	Improper Cooler Size	Improper Water IN Temperature	High Ambient Temperature	Excess case drain	Radiation from Injection Unit	Excess system leakage
Improper Cooler Size	3	3	3	3	3	0	3
Improper Water IN Temperature	3	3	3	3	9	3	3
High Ambient Temperature	1	1	1	1	3	1	1
Excess case drain	5	3	3	3	3	0	9
Radiation from Injection Unit	3	1	1	3	9	1	1
Excess system leakage	3	3	3	3	9	3	3
Raw score		46	46	52	108	22	76
Relative %		13%	13%	15%	31%	6%	22%
Importance Rank		2	2	2	5	1	4

Importance Rating:
1 = Low Importance
3 = Moderate Importance
5 = High Importance

Relationships:
9 = Strong
3 = Moderate
1 = Weak
0 or Blank = No Relationship

Pareto was indicating the excess case drain, excess system leakage, and high ambient temperatures as the top contributing parameters.

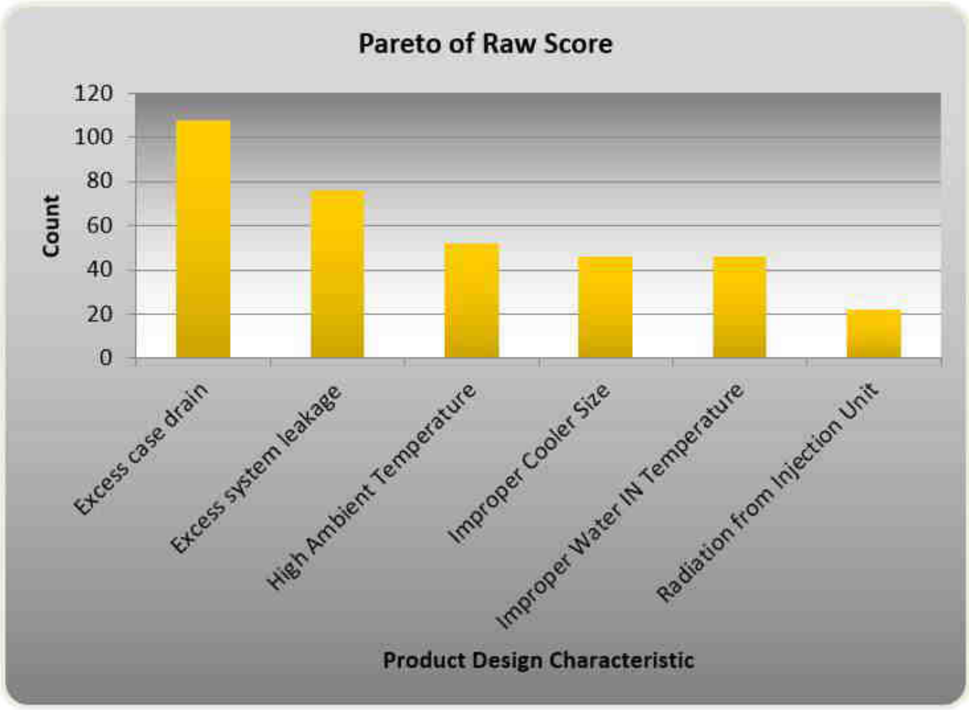

Fig. 6

Few of the vital control parameters were identified to corelate the performance of the system. Following DOE was designed, and the transfer function was developed. Regression was done on the acquired data and R^2 value was 0.9, which was indicating a good significance of the data. The main effect and the interaction plot (Figure 7) were generated to see the impact of each variable on system performances resulting in the optimized performance of the system.

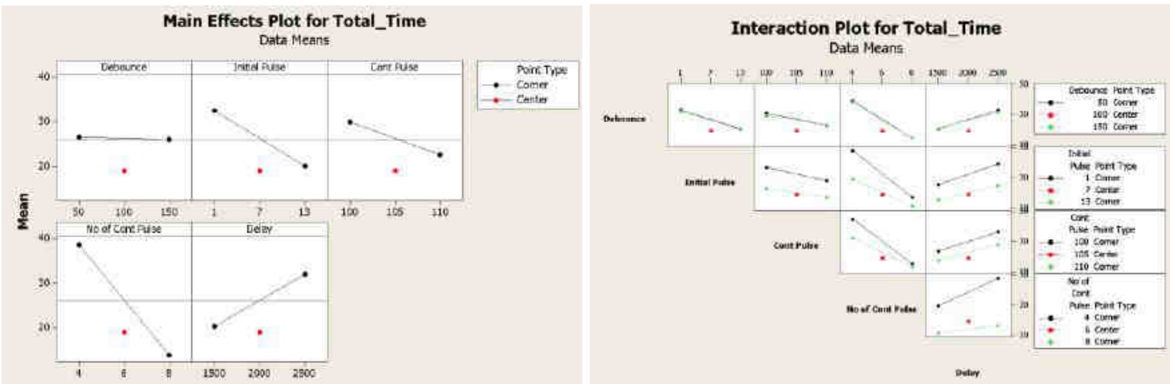

Fig. 7

Based on the heat calculations and above analysis, it was concluded that there was a need to add a pump case drain to the oil cooler. Since the oil cooler inlet could experience some amount of back pressure, a direct connection of the case drain to the oil cooler was not possible. Also, according to the inherent design of the radial piston pump, it cannot have a case pressure of more than 1 Bar. Thus, there was a need to have a bypass valve arrangement as shown in the updated system architecture (Figure 8.) A Check Valve (CV) with a cracking pressure of 0.2 bar was added in the case drain, and the oil was routed through the oil cooler. The new arrangement ensured a steady flow of hot oil from the pump through the oil cooler avoiding the temperature elevation.

Since the pump is sensitive to back pressure, an additional bypass check valve of 0.5 bar was added. So, any surge pressure in pump case was sent directly to the reservoir. A pump case pressure of higher than 1 Bar can result in the pump shaft leakage. We designed a robust solution which won't hamper any of the functions of the machine. Since the maximum case drain pressure was kept under 1 bar with a proposed design change, there was a violation of the pump manufacturer's recommendation to avoid using the check valve in the pump case drain. Post-implementation the IMM was made to run for eight hours, and the system was running in the temperature range of 45~50°C for the identified operation (Figure 9.) Some of the other learnings which were gathered from the supplier catalog [3][4] were as below:

1. A pump running with a low pressure and low flow, needs a pump case flushing with an external flow of 4 to 6 lpm.
2. The pump suction should not have sharp angles and screwed pipes to avoid excessive pressure drop. There is a need to use pipe bends or hoses for the connection.
3. There is a need to refer the pump manufacturer catalog for the maximum possible case drain pipe/ hose length as it directly impacts the pump case pressure when there is a higher leakage.
4. The fluid temperature in the tank must not exceed the temperature of the pump by more than +25°.

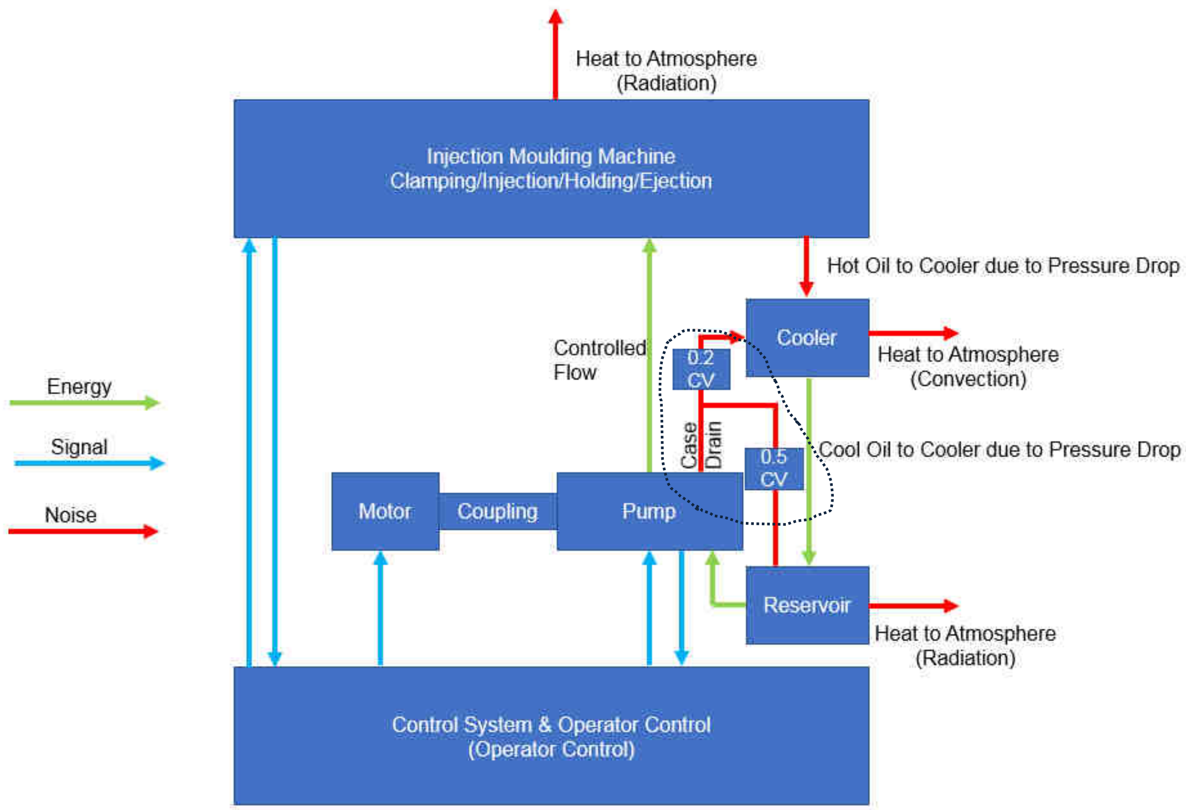

Fig. 8

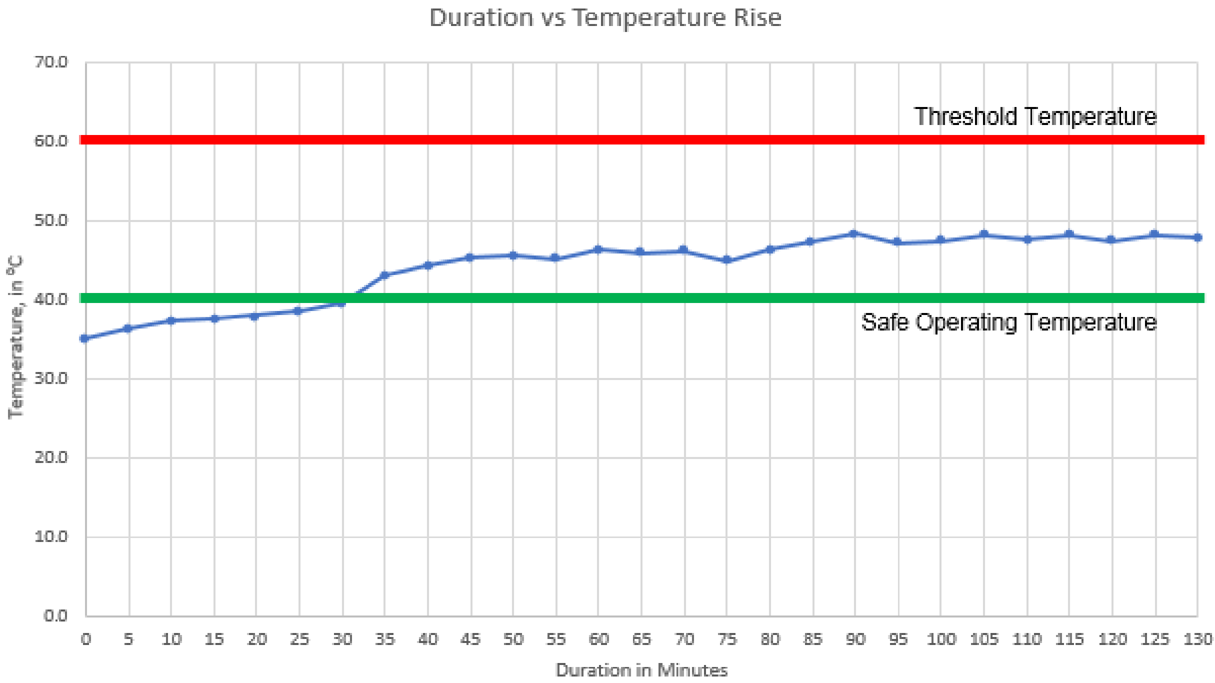

Fig. 9

5. Conclusion

It is uncommon to see any hydraulic system heating up at lower loads. In this report, the authors have discussed a rare case of IMM, wherein the system had heated up at lower loads. Here, the system leakage flow was responsible for the higher system operating temperatures. Via this report, the authors stress the importance of ruling out the possibility of a system leakage, whenever the system heats up, though it's a rare possibility. The authors also convey that this learning applies to all hydraulic systems and is not limited to IMM.
It is crucial to maintain the right recommended temperature range throughout the life of the hydraulic machines. It ensures the optimum performance and life of the system. There is a need to follow the user manual judiciously to avoid underperformance and breakdown of hydraulic systems.

Acknowledgments

I would like to thank my manager Mr. M P Saju (Head Design, Toshiba Plastics Machinery) for mentoring me in the field of Hydraulics and making me capable of dealing with complex Hydraulics systems. I would also like to thank Dr. Kamakshi G Mahale (Wife) who is supportive and instrumental in making this case report.

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DIGITAL HYDRAULIC CYLINDERS

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Abstract: *The basic principle in digital hydraulics is section meshing and active control of split sections, and with constant supply pressure and flow, variable forces and velocities are obtained at the execution element. In the case of digital hydraulic cylinders, it has been found that it is more cost-effective to vary the surface than to vary the pressure or flow for an active control. But since, for a long time, the surface variation solution seemed impossible, research in this regard was out of the question.*
The paper presents several classic solutions of hydraulic schematic diagrams for speed (flow rate) control or force control at hydraulic cylinders, a digital hydraulic cylinder parameters calculation model and two constructive options (one technologically optimized and the other functionally optimized) of digital hydraulic cylinders with three surfaces.

Keywords*: Multiple-area cylinders, digital cylinders, digital hydraulics, actuator, digital hydraulic cylinder parameters calculation model*

1. Introduction

Digital Hydraulics is an alternative, recently developed, to replace hydraulic drives with servo valves or proportional directional control valves. Digital Hydraulics means hydraulic systems that comprise at least one hydraulic element which ensures discrete, precisely and actively controlled output values. This involves, besides the digital hydraulic elements, an adequate electronic control, so a good computerization of the system.
The name of the digital hydraulics comes from the fact that in all cases the operation of digital hydraulic devices with parallel distribution is based on the on / off principle, meaning that the flow, the pressure, the surface can have two states: active or inactive (0 and 1), and, by using an intelligent controller, an active speed or force control is obtained at the output.
Although the principles of Digital Hydraulics have been applied hundreds of years ago, since 2000, the foundation of Digital Hydraulics research has been established in prestigious universities. For example, the version of the Digital Hydraulics with parallel distribution developed by Professor Lindjama from Tampere University of Technology is based primarily on high-speed on-off simple directional control valves, which, electrically controlled, can get into one of the two states, close or open, providing in the system actively controlled flow steps. [1]
The classic alternatives of force and speed variation in hydraulic cylinders by varying the pressure or flow are made with significant energy losses because the required power of the system that includes hydraulics must be ensured in all working conditions, that is for low forces or speeds but also for the maximum values of working regime. Thus, more complicated working flow or pressure control systems are required, or the voluntary spillage of unused energy surplus into the reservoir through the safety valve and transforming it into heat, which often requires additional energy consumption for cooling the working fluid. [2]

2. Examples of force and speed control at a hydraulic cylinder

An example of controlling the force and speed of a hydraulic cylinder by means of a proportional directional valve is shown in figure 1. The diagram has a fixed flow pump (1), filtration systems (2) imposed by the working conditions for the proportional hydraulic devices, safety valve (3), proportional hydraulic device (4), force transducers (5), pressure transducers (6), flow transducers (7) and displacement transducers (8).

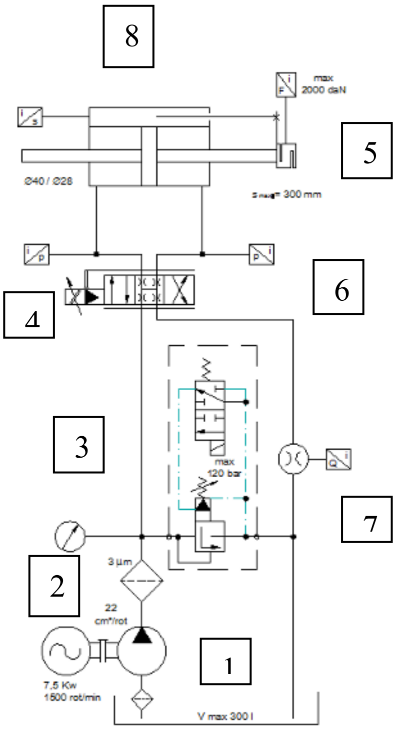
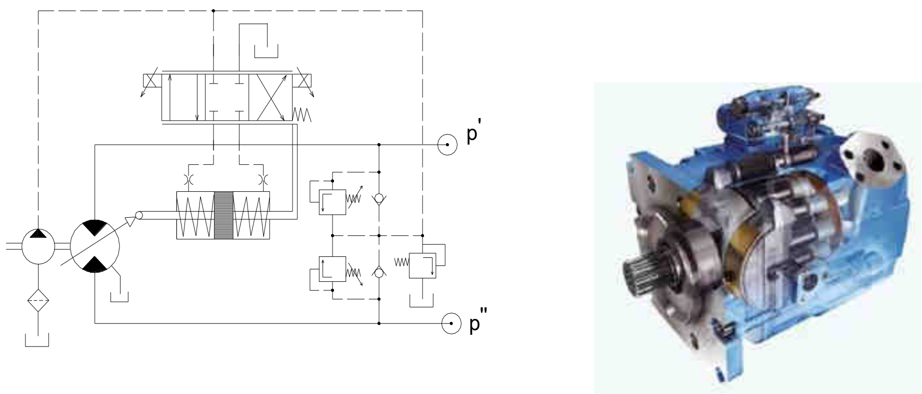


Fig. 1. Classic schematic diagram of hydraulic drive with servo-cylinder

The direct flow rate control from pump with flow rate servo controller is shown in figure 2. Flow control is done by changing the angle of inclination of the pistons block by means of a directional servo-valve. For a correct operation of the system, regardless of the working pressure of the main pump, there has been provided a secondary control pump because the control flow of proportional directional control valve must be ensured at low flow rate.

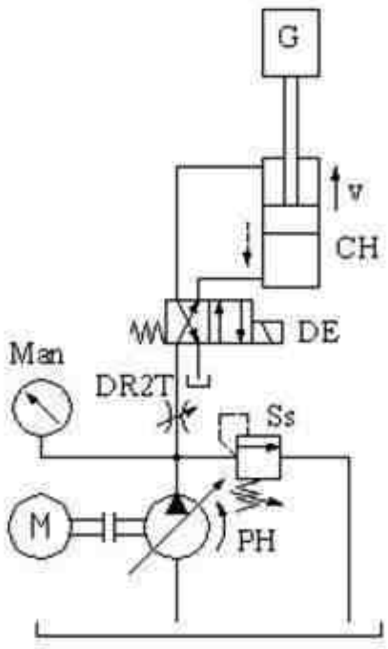


(a) (b)

Fig. 2. Pump with flow servo regulator [3]

Figure 2 (a) shows a schematic diagram of the A11VG Rexroth pumping system, in which an inclined disc main pump (b), in closed system, in tandem with an auxiliary pump, has as a flow control device a linear servomotor electrically controlled proportionally.
Regulators do not require human operator intervention during operation, and the capacity adjustment is made under the effect of the piloting pressure that can be taken from the outside or even from the discharge of the adjusted pump.

Regulators represent a wide range of hydromechanical devices in which pressures applied on certain surfaces determine forces that are balanced by springs, and flows passing through certain hydraulic resistors cause differential pressure that occur on the adjusting devices.
Another variant of speed control at hydraulic cylinders by means of throttles is shown in fig. 3. On the direction in which speed control is desired a throttle (DR2T) is provided, and the flow difference is discharged to the basin by means of the safety valve (Ss).



Components of the hydraulic schematic diagram
PH - hydraulic pump
Ss - safety valve
DR2T - route throttle
DE- hydraulic directional control valve with electric drive
CH - hydraulic cylinder
Man - manometer
G - weight
M - electric motor

Fig. 3. Adjusting the speed with a throttle [4]

Digital flow control by means of parallel connection pumps, shown in figure 4, which Dr. Heinrich Theissen from IFAS Aachen [5] calls digital pumps, is made with a pumping group made up of three pumps (1) which are introduced into the hydraulic circuit according to the flow required at a given time. The combination of active pumps is selected using simple on / off directional control valves (2) and can be done by several methods, of which the German specialist considered to be of interest to select them using the binary system.

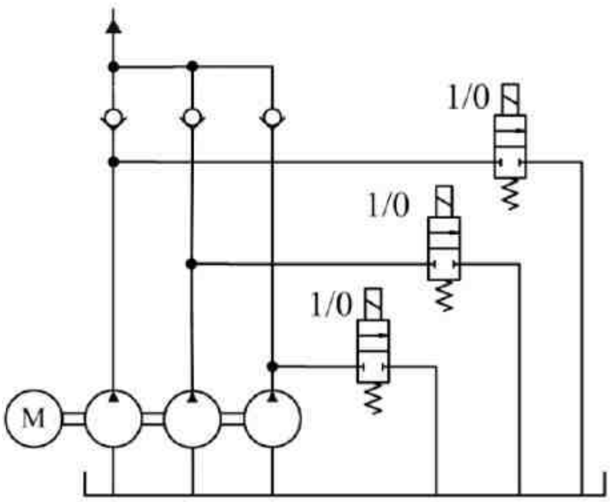


Fig. 4. Parallel distribution flow adjustment schematic diagram [6]

A speed and force digital control solution in a system that includes hydraulics is by using a multi-surface cylinder.
The literature gives some examples of theoretical drive solutions that use multi-surface cylinders:

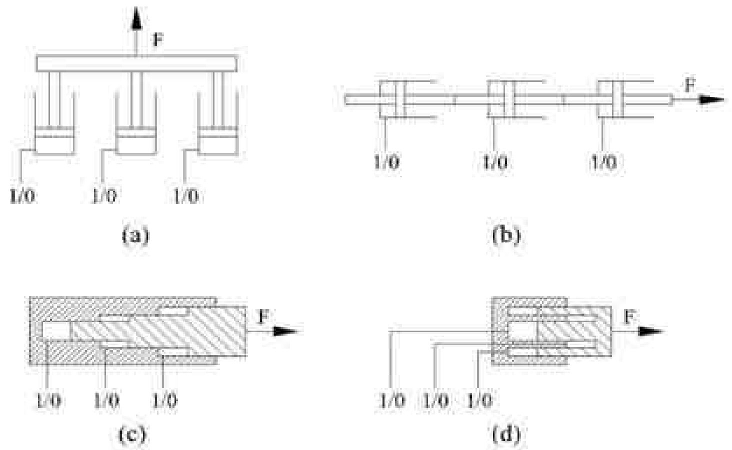


Fig. 5. Examples of solutions for multi-surface cylinders [7]
a) cylinders in series; b) inline cylinders; c, d) cylinders with concentric surfaces.

An alternative of surface variation can be made by dividing the active surface of the piston into several concentric, annular surfaces (Figure 5. c) or d)) which are supplied separately or cumulatively, with constant pressure and flow, according to well-established rules in order to achieve combinations of supplied areas with which a movement with variable speed or force is obtained.
An example of multi-surface cylinder application is the one in the press and punching machine, where the high speed of rapid feed is performed with the small area of the piston and the high pressing force with its large area.
In order to obtain a larger range of forces with this digital cylinder, several pressure stages provided by the hydraulic installation (Fig. 6) can be used, for example, with a three-pilot valve fitting there can be obtained at the rod 21 levels of force (7 selectable values x 3 pressure values).

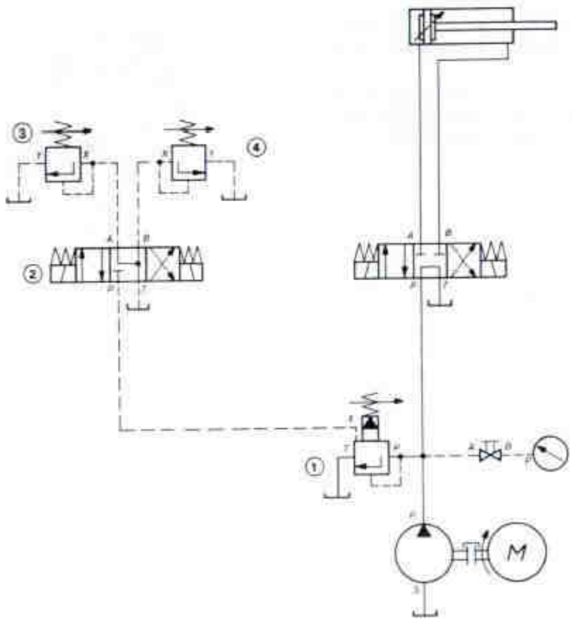


Fig. 6. Hydraulic diagram for three working pressure steps. [8]

3. Model for calculating the parameters of digital hydraulic cylinders

The surfaces of the digital hydraulic cylinders are in a geometrical progression with the ratio q = 2, where S is the surface size. They can be calculated with the relations:

$S_1 = S_{min}$
$S_2 = q \cdot S_1$
$S_3 = q^2 \cdot S_1$
$S_4 = q^3 \cdot S_1$
.
.
.
$S_i = q^{i-1} \cdot S_1$
.
.
.
$S_n = q^{n-1} \cdot S_1 = S_{max}$,
where n is the number of surfaces;
i = 1...n

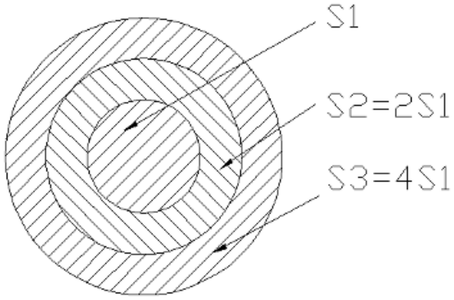


Fig. 7. Concentric surfaces binary multiplied

The minimum surface of the digital hydraulic cylinder can be calculated if the minimum or maximum force and the pressure p in the hydraulic system are imposed (pre-set):

$$S_{min} = \frac{F_{min}}{p}$$

$$F_{max} = p \cdot S_{max} = p \cdot q^{n-1} S_{min} \rightarrow S_{min} = \frac{F_{max}}{p \cdot q^{n-1}}$$

If the minimum surface (S_{min}) is imposed, the pressure in the hydraulic system can be calculated:

$$p = \frac{F_{min}}{S_{min}}$$

$$p = \frac{F_{max}}{q^{n-1} \cdot S_{min}}$$

If the ratio of the surfaces is according to the binary code presented then for a number *n* of surfaces there results a number of combinations 2^n-1.

Table 1: Number of steps of forces or speeds obtained according to the number of surfaces.

n (no. of the surfaces)	**2^n-1 (no. of the combinations)**
1	1
2	3
3	7
4	15
5	31
6	63
7	127
8	255
9	511
10	1023
.....	.....

The values of the forces will be:

$F_1 = p \cdot S_{min} = F_{min}$

$F_2 = 2 \cdot F_1$

$F_3 = 3 \cdot F1$

.

.

.

$F_N = j \cdot F_1$ $\qquad$ $j = 1... N$

The speeds depend on the flow Q of the hydraulic system. The minimum speed (v_{min}) or the maximum speed (v_{max}) can be imposed and then the flow is calculated with the relations:

$$v_{min} = \frac{Q}{S_{max}} = \frac{Q}{q^{n-1} \cdot S_{min}} \quad \rightarrow Q = q^{n-1} \cdot S_{min} \cdot v_{min}$$

$$v_{max} = \frac{Q}{S_{min}} \quad \rightarrow \quad Q = v_{max} \cdot S_{min}$$

The obtained speeds are:

$$v_1 = \frac{Q}{S_{min}} = v_{max}$$

$$v_2 = \frac{Q}{2\,S_{min}} = \frac{v_1}{2} = 0.5\, v_1$$

$$v_3 = \frac{v_{max}}{3} = 0.33\, v_1$$

.

.

$$v_j = \frac{v_1}{j}$$

.

.

$$v_N = \frac{v_1}{N},$$

where j = 1... N.

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4. Solutions for digital hydraulic cylinders with three surfaces

The solution for a digital hydraulic cylinder with three surfaces shown in fig. 8 resulted following the use of semi-finished parts of standard pipes, special for cylinder liners, with a minimum of mechanical processing in order to obtain a lower manufacturing cost.

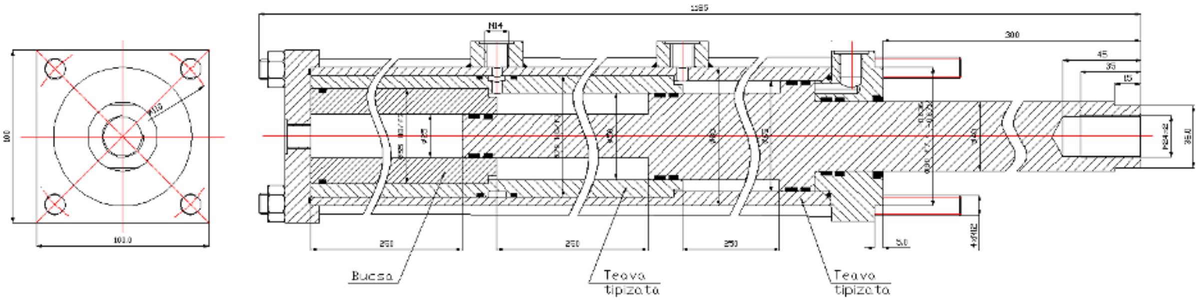

Fig. 8. Hydraulic cylinder with three surfaces technologically optimized. [9]

Table 2 shows the calculated values of the surfaces of the digital hydraulic cylinders for the two constructive variants and the corresponding diameters:

Table 2: Calculated values for surfaces and diameters of digital hydraulic cylinders with three surfaces

Cylinder with three binary multiplied surfaces		Cylinder with three standard-diameter surfaces	
Surface [cm²]	Diameter [mm]	Surface [cm²]	Diameter [mm]
4.906	25	4.906	25
9.812	43.3	14.712	50
19.624	61.24	19.503	65

The cylinder with three surfaces technologically optimized is made up of several standard components, which reduces the manufacturing price. The power and speed steps are not linearly increasing but this is not necessarily a disadvantage because it can increase the fineness of the adjustment in a more intensive work area.
In INOE 2000-IHP was designed and developed an experimental model of a hydraulic cylinder with three surfaces technologically optimized, shown in fig. 9.

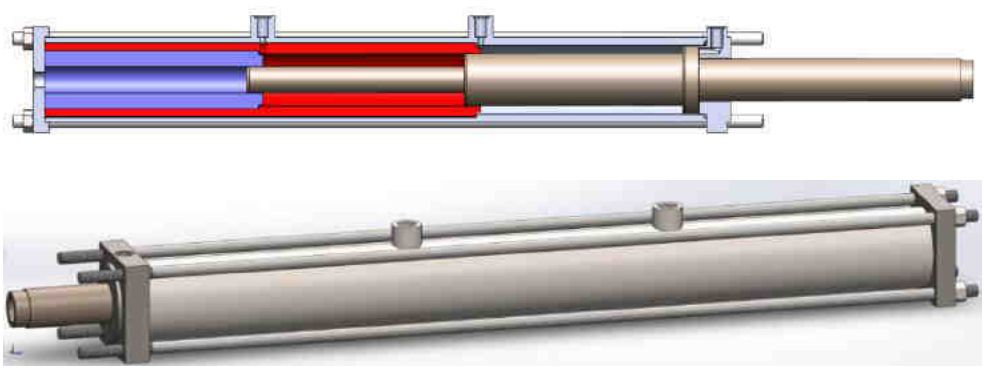

Fig. 9. Digital hydraulic cylinder

For the pressure of 120 bar and the flow rate of 30 l / min, the force variation is shown in fig. 10, and the velocity variation for the two construction variants of digital hydraulic cylinders with three surfaces is shown in fig. 11.

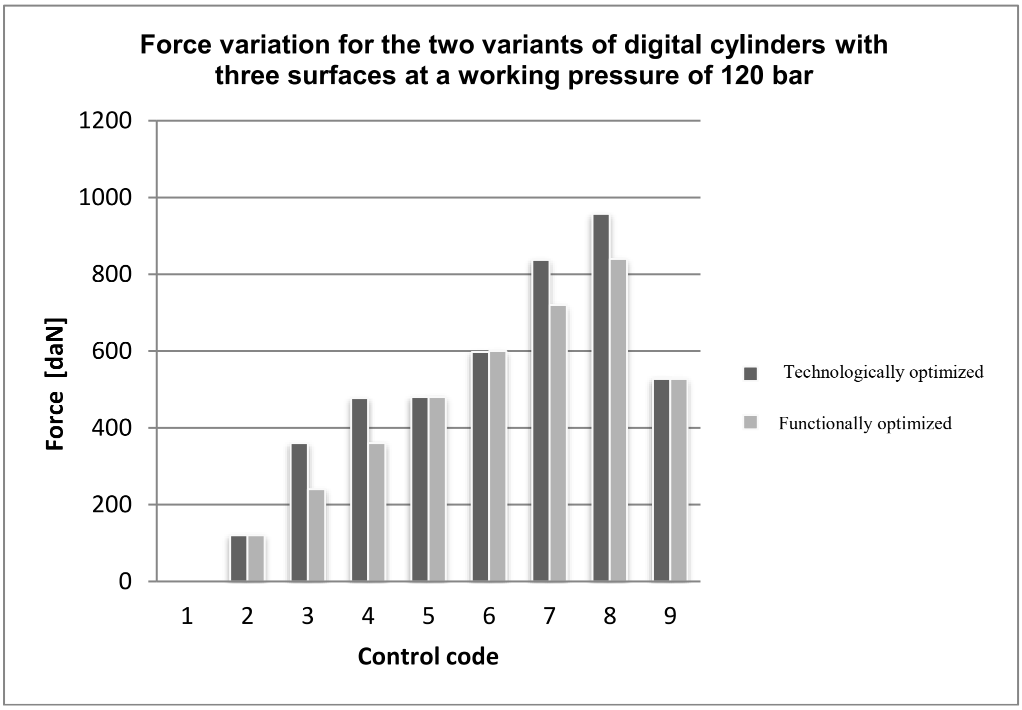

Fig. 10. Force variation for the hydraulic cylinder with three surfaces technologically optimized and the functionally optimized cylinder at a working pressure of 120 bar

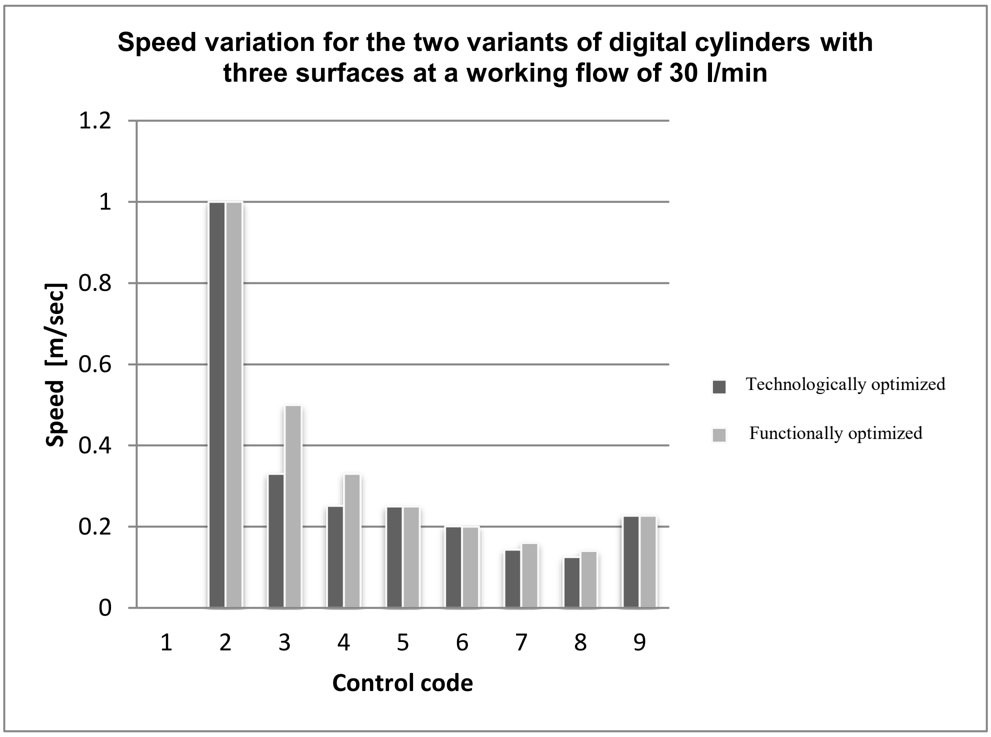

Fig. 11. Speed variation for the hydraulic cylinder with three surfaces technologically optimized and the functionally optimized cylinder at a 30 l / min supply flow rate

5. Advantages of implementing the solutions of digital hydraulics

Compared to state-of-the-art analogue technology, the concept of Digital Hydraulics has many proven practical and theoretical advantages, such as:

- *Energy efficiency*, by sizing the installation to the average installed power, using less and simpler hydraulic devices.
- *Reliability* due to on / off valves that allow for greater contamination of the working oil compared to proportional appliances and can function correctly up to an oil temperature of 75°C.
- *Flexibility* due to on / off valves that allow most classic hydraulic distribution diagrams to be achieved.
- *Performance* due to the simple and robust construction of digital solenoid valves that are very reliable and can work well even in the range of 300 million - 1 billion cycles, thus avoiding unscheduled stops.
- *Fault tolerance and operational safety* due to the parallel connection which, in the event of a valve failure, does not require immediate intervention because the system is self-adaptive and works well and in an emergency. This eliminates the possibility of deadly damaging a servomotor or even the entire system that includes hydraulics.

6. Conclusions

Adjusting the force and speed on hydraulic cylinders requires expensive and complex equipment, and most of the time the classic adjustments are made with significant energy losses.
When using digital hydraulic cylinders in installations that include hydraulics, the adjustment of force and speed can be done strictly on the desired range by dimensioning the active surfaces.
Digital hydraulic cylinders are an alternative for the actuation with servo-cylinders and although at first view they seem to be more technologically complicated, in fact in some applications they can successfully replace classical servo-cylinders, with the above outlined advantages.
The presented solutions for digital hydraulic cylinders can successfully replace classical speed or power control solutions in a system that includes hydraulics. The use of digital hydraulic cylinders results in the simplification of drive schematic diagrams by eliminating complicated and expensive working flow or pressure control devices, as well as reducing power consumption, which is an important indicator for further research in the field of Digital Hydraulics.

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ANALYSIS OF SMART CONTROL INTERFACE IN PRESSURIZED LIQUID INJECTION SYSTEMS FOR COMPETITIVE TECHNICAL SOLUTIONS

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Abstract: *In the recent decades, the intake port fuel injection equipment have been updated and calibrated for multiple types of systems in combustion engines and industrial applications. For increasing performances of injection and to improve dynamic output when changing inertia mass it must be thoroughly researched and electronically managed. Further developments made in the injection system field increase the potential of internal combustion engines. These improvements are to be realized in order to control the emissions and fuel consumption as the final objective. Computational Fluid Dynamics (CFD) and electronic control is yet to be studied and applied for reaching the higher hydraulic control and management of the power machine. Controlling the real operation as well as symptomatic phases is close related to quantifying the amount of fuel, coolant and fuel temperatures and timings for ignition and injection, creating thus the opportunity to outline the optimal poles for electronic intervention in the hydraulic injection system. A rally car like Mitsubishi Lancer has a worldwide impact, which makes that any improvement in hydraulic (fuel) and gaseous mixture formation and ignition (burning) efficiency a good step forward and a basic protocol in energy saving and pollution control for reaching complex market requirements. Complex industrial hydraulic systems and injection processes for internal combustion generators for electric power-plants are also working in a similar protocol methodology and impacting the environment in a much extended manner, thus influencing the society development and life in general.*

Keywords: *Automotive, diagnostics, electronic fuel injection system, hydraulic*

1. Introduction

Managing engine's digital evaluation and all the functions of fuel injection procedures in electronic management of the operation highlights the optimal regime definition with the main characteristics which facilitates fuel saving and increased efficiency a given working condition. The present paper presents an applied research with high tech equipment regarding electronic control of hydraulic processes of injection and flammable fluid mixture ignition in operation for Mitsubishi rally engine. The analysed hydraulic system is an electronically controlled model, which was detailed monitored regarding the fuel injection duty and fluid mixture ignition characteristics. Using modern technologies were made some innovative achievements in scientific research and engineering, being thus brought to light innovative components and features in electronic control and management. The contribution of latest software applications in fluid fuel injection management and in engine's operation control offers new possibilities in electronic module calibration and definition. The present research paper use the Engine Control System (ECS) for outlining the fluid dynamic performances of more than twelve operating scenarios or crankshaft speed regimes on the Mitsubishi Lancer EVO9 rally car, at different air pressures measured inside the intake manifold. Also were experimentally determined the fuel injection duty and ignition advances. A post processing study of result was conducted. Were analysed the trend lines and system variables. They were drawn to outline the rally ICE's (internal combustion engine) operational markers and to design the optimal area with corresponding air intake pressure, better fluid burn rate and controlled pollution risk factors. Air pressure at the intake manifold determines the initial status of air-fuel mixture formation and for lambda coefficient. Prior to air intake stroke there is a gasoline spray in

the port fuel injection (PFI) system. Fuel injection duty expresses the operational sequence time in relation with a base parameter in the engine working process. Ignition advance is adapted to the hydraulic-fuel charge, as well as engine load and speed so it is analysed. In this work we introduce a model for estimating fuel injection duty on the basis of ignition advance value, engine speed, manifold pressure, as well as the air pressure in the intake manifold on the basis of the same parameters. Applied research results were collected through computation and experimental testing. Some features and improvement possibilities are pointed out. After studying the actual values and drawing at least ten operational characteristics in order to trace the trend lines, than the final conclusive ideas consisting in optimal regime and practical conditions are stated and discussed. There are shown the incremental steps between reference operational points of hydraulic injection system with electronic control module and the ignition advance defined for Mitsubishi engine. Optimizing the engine's hydraulic injection process with electronic management application, as well as proper trend-line estimation and ignition advance control in working conditions, is facilitated by engineering evaluation regarding fluid mechanics. These improvements of engine's hydraulic system controlled with electronic management capabilities are closely created and influenced with software applications in a cluster type environment (which has electro-mechanical and software components for regulation). The adequate calibration and proper definition of fuel injection duty (as well as mixture formation and ignition) require advanced engineering methods applied in controlling and testing the fuel injection and ignition systems.
Digital evaluation and Computational Fluid Dynamics (CFD) contribute to injection optimization and combustion improvement [1-5].
Electronic management of injectors and ignition system operation lead to the power output increase. By designing engine operational strategies, the efficiency is improved in some regimes [4-9].
Fuel injection system with port valve spray is designed from multiple parts, that consist from a sensor group, digital control unit and actuator components.
With digital testing management and research of the injection system, consisting of particular operational parameters, system variables, electronic devices and signal mapping indicators [5-8] are used to evaluate the applied digital management strategy model for particular motor-load charge.
The primordial target or aim of the present work is to define and express the correlation in the hydraulics, mechanics and digital control between the fuel injection duty, manifold pressure, ignition advance and the engine speed, throttle position etc. Digital mapping of the engine's behavior to track the tendency of the phenomena is useful for researching the topic. Specific objectives of the present study are as follows: investigation of values recorded for fuel injector duty, air intake pressure in the manifold, ECU auxiliary duty and ignition advance versus crankshaft speed, throttle position and manifold pressure.

2. Research methodology

For realising the research (concerning digital control of the fluid in the manifold and fuel injection hydraulic performances of the supply system applied to the Mitsubishi Evo rally powertrain operated in motor-sport competition which has been investigated) there was implemented in the first place a hardware package with devices and applications. This package facilitated the application of the research methodology. The later one is based on analyse and practical determinations and testing, as well as trend-line evaluation. Tracking the actual values and the methodology protocol, regarding input/output parameters, is realized in a practical endeavour of inspecting and investigating the Mitsubishi Evo power-train with diagnostic equipment (figure 1).
The injectors assembly and other operated components (such as spark plugs) are instrumented by the digital control equipment (DCE). DCE records and use the sensor data from input devices, process all the acquired information and then creates the corresponding decisions to actuate the injectors' opening and fuel pressure regulator.

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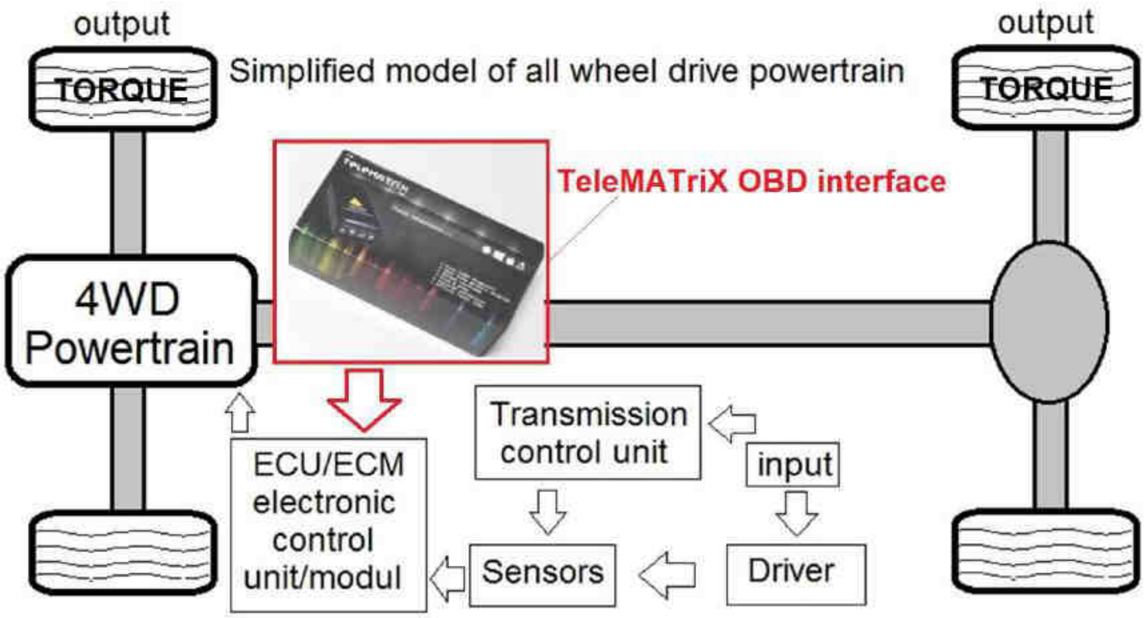

Fig. 1. Structural design of electronic management system for hydraulic injection in the powertrain's control

The research method, based on the connections and exploitation of the TeleMATriX devices (figure 1), achieving the goals of the specific documentation and practical measurements on the Mitsubishi rally vehicle facilitates the interpretation and post-processing of the actual values determined after multiple rewinding of tests and use of digital applications is also versatile.

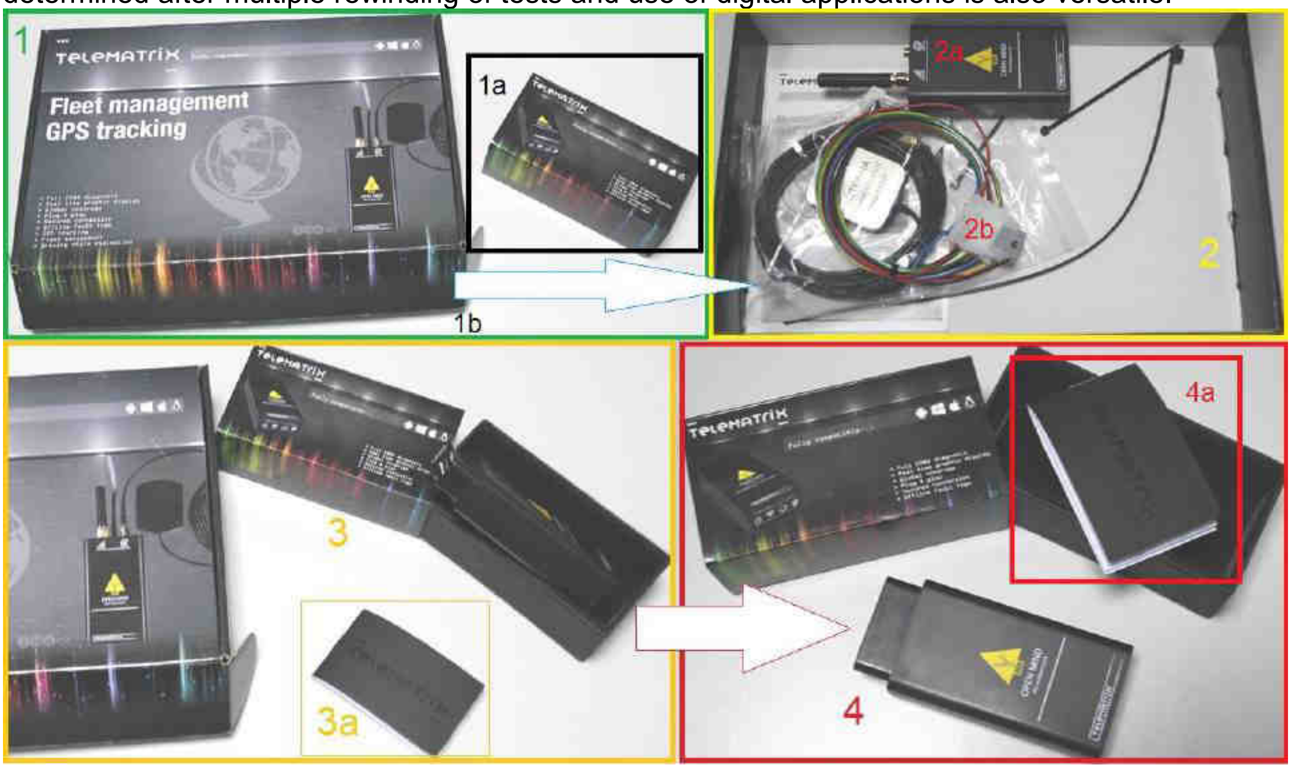

Fig. 2. Structural assembly of management system for hydro-mechanical components in the vehicle's spark ignited engine
1-initial state of equipment; 1a-OBD interface package; 1b-transmition and receiver package; 2-detailed components of the transmitting and reception package; 2a-comunication interface; 2b-wire interface connector; 3-actual OBD interface; 3a-instruction manual; 4-16 pin connection rack; 4a-documentation.

2.1 The study at specific temperature value for engine and air intake

The engine and powertrain is prepared and properly calibrated for testing before starting the applied determination during the experimental research (figure 3). The indicator/pointer on display graph is placed at 24:12:10 minutes from start.

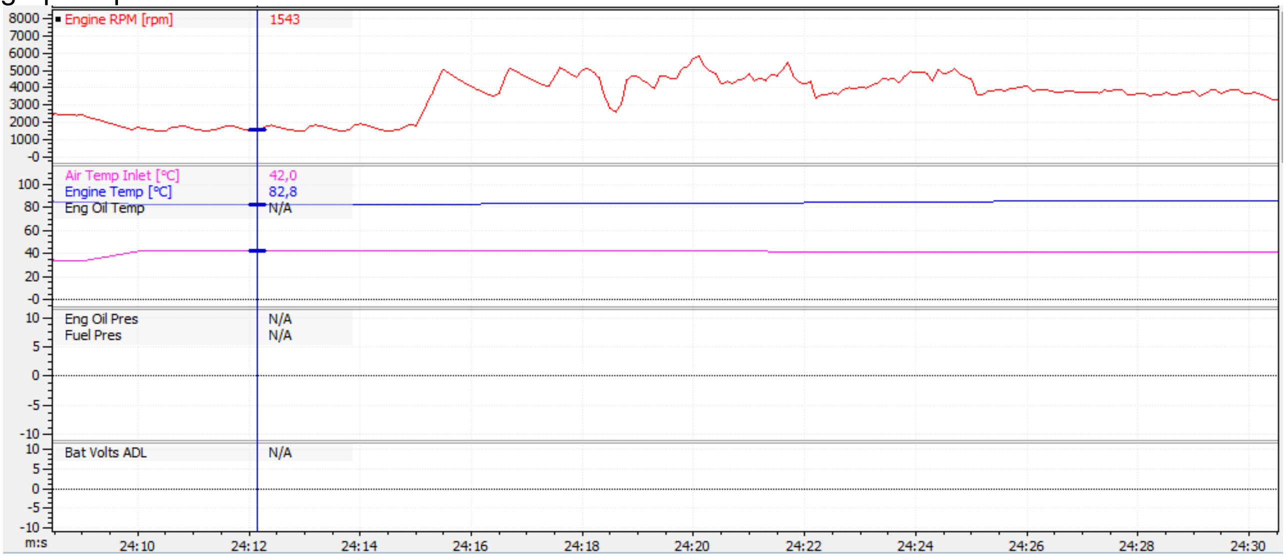

Fig. 3. Display capture in ECM with engine (crankshaft) speed variation and engine's fluid temperatures

Engine scanning and data processing are aimed also toward the investigation of air intake manifold pressure, throttle position, fuel injection duty and ignition advance angle versus time.

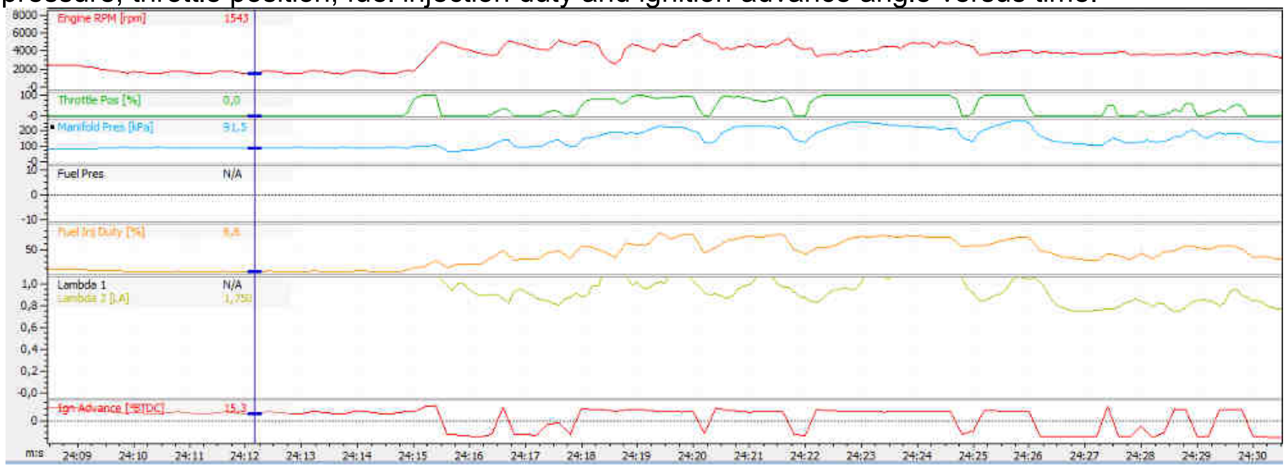

Fig. 4. Data capture with ECM regarding air intake manifold pressure and ignition advance angle before top dead center (BTDC)

2.2 The study of mathematical models

The main important aspect that is studied and outlined for a comprehensive approach is the model determination of injection duty related to engine's speed, as a percent from total mass of sprayed fuel when vehicle is fully charged and develops maximum speed, as it is expressed by relation (1):

$$F_{id} = 7 * 10^{6} * n^{2} - 0.0128x + 8.5398 \text{ , [\%]} \tag{1}$$

The other significant aspect, which must be analyzed in this paper regarding the hydraulic control in motor-sport powertrain, consists in the ignition advance vs. engine speed (n), as it follows:

$$F_{ia} = 0.0101n - 0.167 \text{, [°BTDC].} \tag{2}$$

3. Research results

The evaluated powertrain is started up and made ready to use when beginning the practical determinations in experimental testing (figure 5). Ignition advance and fuel injection duty are some of the first acquired values.

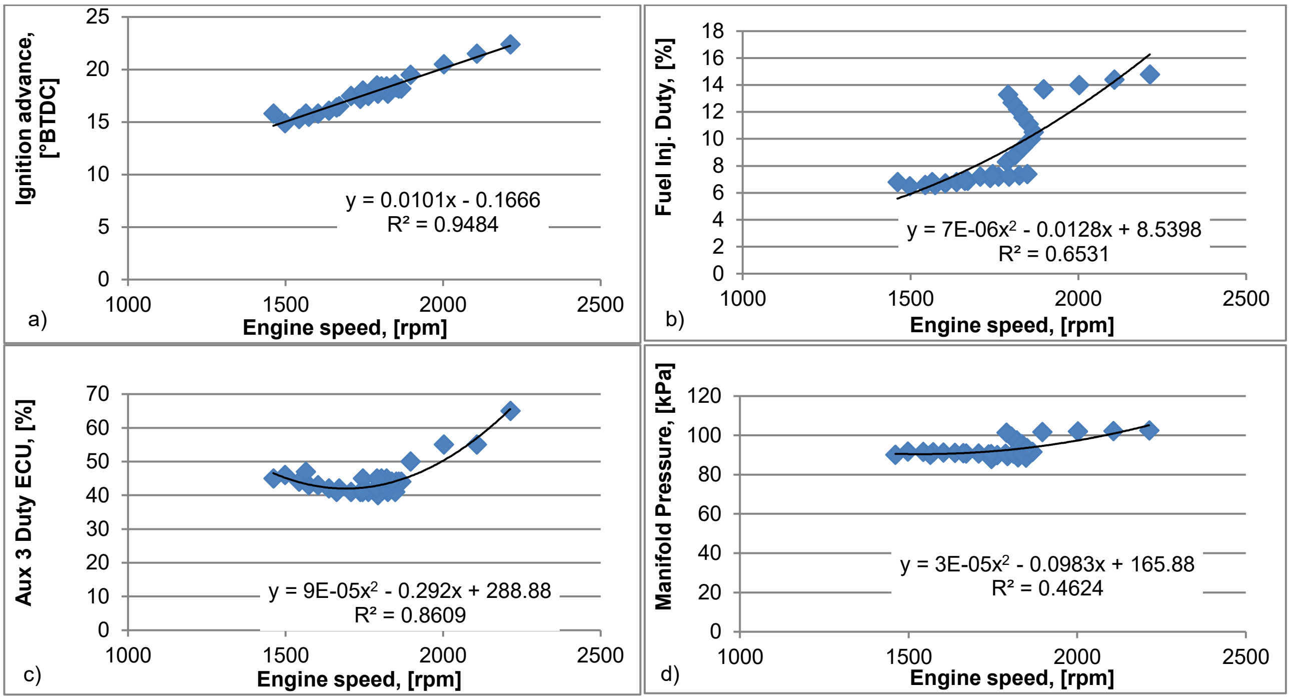

Fig. 5. Ignition advance (a), fuel injection duty (b), manifold pressure (c) and aux 3 duty ECU (d) vs. engine speed

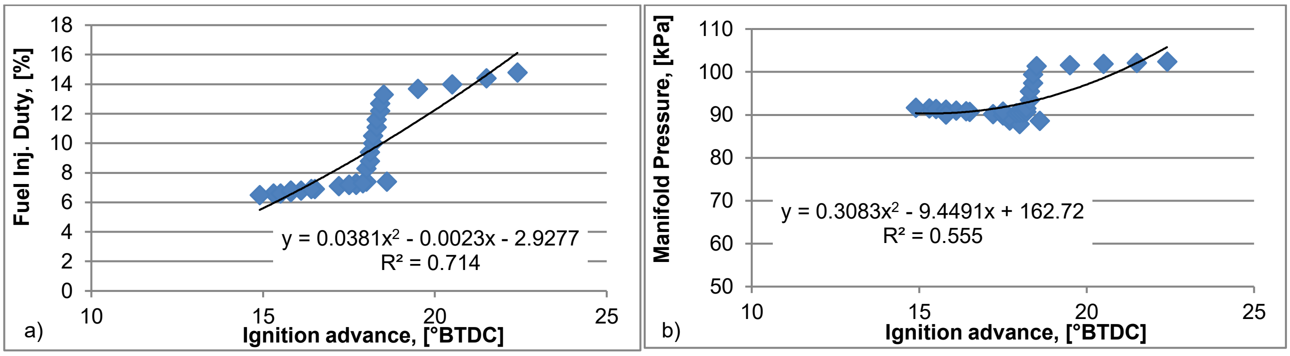

Fig. 6. Results of fuel injection duty (a), air pressure in the intake manifold (b) versus ignition advance

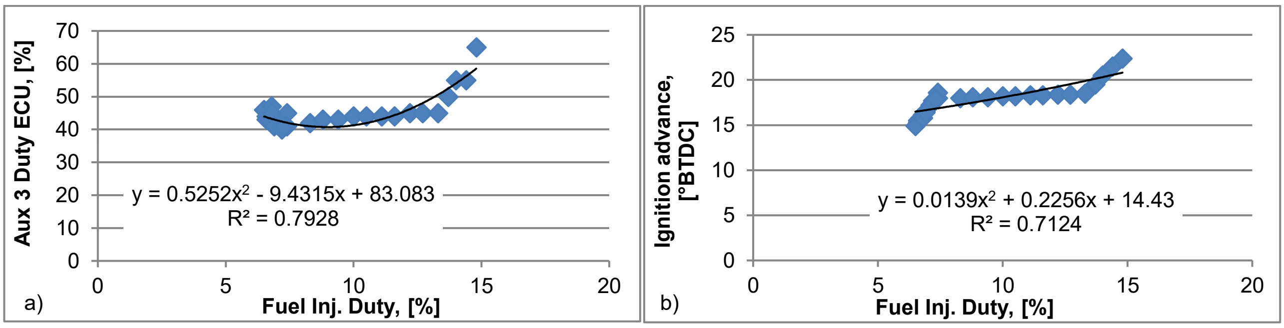

Fig. 7. Aux 3 Duty ECU (a) and ignition advance (b) versus fuel injection duty

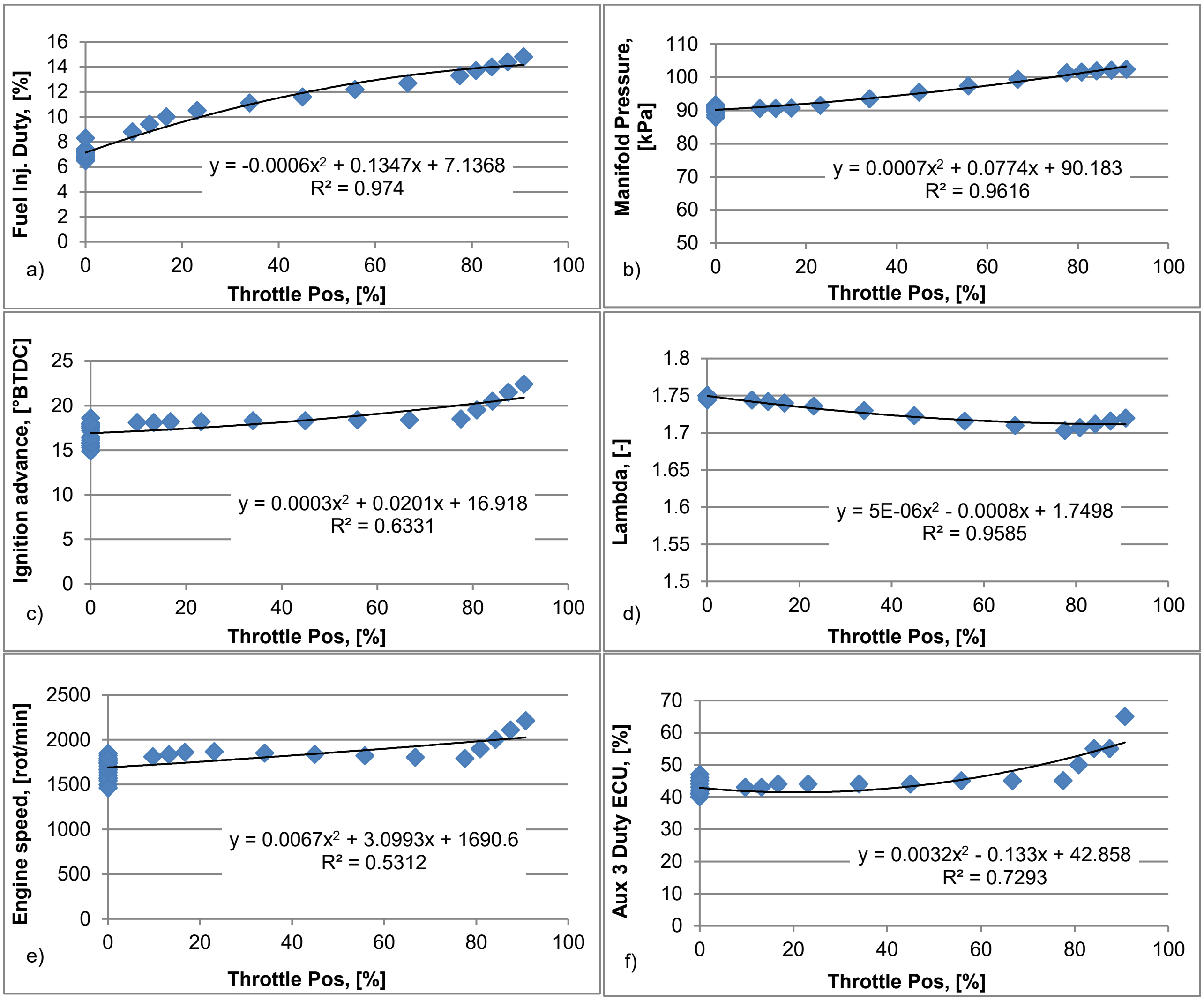

Fig. 8. Fuel injection duty (a), manifold pressure (b), ignition advance (c), lambda (d), engine speed (e) and aux 3 duty ECU (f) versus throttle position

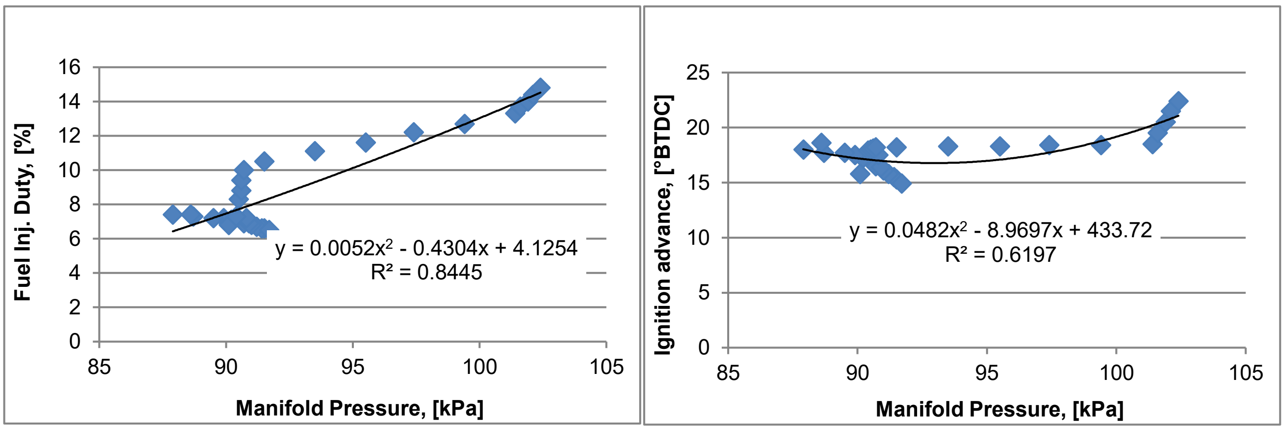

Fig. 9. Fuel injection duty as percentage (a) and ignition advance in rotational degrees before top dead center-BTDC (b) versus manifold pressure expressed in kPa

The applied testing was realized on a Mitsubishi Lancer with technical specs given in the table 1. By using the TeleMATriX engine's parameters are colected and

Table 1: Powertrain technical specs

Parameter	Actual Value	Unit of measurement
Vehicle Production Duration	March 2005 – January 2007 & 2008	year
Body Platform	CT9A	-
Powertrain – Spark Ignited Engine	2.0 L 4G63T I4 Turbo-supercharged	-
Manual Rally Transmission	6-speed mechanic	Gear ratios
Wheelbase distance (front-rear)	2625	mm
Total Length	4490	mm
Total Width	1770	mm
Total Height	1450	mm
Total authorized Weight	1350	kg

By inspecting the values and trend-lines of the recorded parameters there are made some interpratations and conclusions.

4. Conclusions

In the present engineering research, were studied the actual values from numerous hydraulic or fluid channels, with electronic control. These values and all hydraulic measurements in fuel supply and combustion control versus the engine speed, injection duty, spark advance angle and intake manifold pressure are monitored and evaluated.

The highest ignition advance (at 22.5°BTDC) was recorded for the 2200 rpm engine speed recorded at crankshaft with 15% fuel injection duty, while the lowest spark ignition advance was 14.9°BTDC found for 1500 rpm.

The peak manifold pressure (at 102 kPa) was found for the 2200 rpm and 65% Aux 3 duty ECU, while the lowest intake air manifold pressure was found for the 1850 rpm.

The minimal fuel injection duty was recorded for the 15°BTDC ignition advance angle, while the maximum fuel injection duty 13.9% was stored at 19.5°BTDC ignition advance.
The minimal manifold pressure 88 kPa was recorded for the 18.5°BTDC ignition advance angle, while the maximum manifold pressure 102 kPa was stored at 19.5°BTDC ignition advance.
This research paper elaborated the tests and value recording methodology. Monitoring the fuel system and its specific parameters is realized with diagnostic equipment by continuous measurements. Computer power was used to calculate the probability and determine trend-line of fluid mechanics and ignition advance phenomenology.

An innovative protocol to optimize the gasoline fuel injection systems for competition high demanding regimes in Mitsubishi powertrains may be highlighted through the present research results. The application of TeleMATriX equipment as an electronic On Board Diagnostic solution for optimized correlation between ignition advance angle and manifold intake pressure and charge instead of the conventional measurements could bring some advances in remote repair control and maintenance. This creates a possibility for improving operation and combustion process, thus leading to a better level of performances and exploitation in specific scenarios.

The applied study and recorded results revealed that the optimal performance and admissible results in operational regime (located for this particular stage at 17-18°BTDC ignition advance angle) provides a lower fuel quantity sprayed in the engine and an average engine speed range (1700-1900 rpm). At 2200 rpm the ignition advance increases toward the 23°BTDC, and thus leads to higher fluid quantities introduced in the engine. Determining the optimal operational model with the lowest repetitions of applied tests and measurements throughout the investigation of mathematical relations, trend-lines and the corresponding values would also be implemented in engine electronic control unit by specific intervention as particular sequences in the future studies.

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Competition interests: The authors of this paper declare that the research staff has no important inherent financial, professional or individual profits, that could have influenced the results or trend-lines of the post-processing and graphical representations published in this paper.

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FARMING MOTOR PLATFORM FOR SPRAYING USED IN HORTICULTURE

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Abstract: *This article presents the partial results of a research developed by INOE2000 - IHP, as well as a functional model of a motorized agricultural platform used for spraying in horticulture. This is part of a complex crop monitoring system that, with the help of a quad-copter, generates a map that is used later for remote guiding of the agricultural platform, which is equipped with tracks system and a differential steering system allows it to turn in place or with a very small radius to track as accurately as possible the trajectory generated by the remote guidance system. The spraying equipment of this agricultural platform is designed to be used in a wide variety of horticultural crops with the ability to adjust both the direction and the spraying distance.*

Keywords*: Horticulture, remote spraying, motorized agricultural platform, hydraulic automation.*

1. Introduction

Considering that the world population is growing at an accelerated rate, agriculture must grow and have the best possible productivity to meet demand for food globally. Developing new spray technologies with herbicides and pesticides applied locally to limit environmental pollution is essential. [1] An example is shown in Figure 1.

Fig. 1. A new, environmentally-friendly, selective spraying solution [1]

In order to penetrate / market innovative high-quality products that ensure competitiveness and market continuity, together with the R & D service provider, the beneficiary SME proposes to set up a motorized agricultural platform used for spraying works, with remote guiding automation system. The necessity and usefulness of such equipment is due to the modernization of the equipment for the realization of the horticultural works, but especially the introduction of innovative technologies and equipment, ensuring both high productivity and the production of quality food, knowing that on the market, is an increasing demand for clean organic / ecological products to ensure healthy food for the population. One of the agricultural activities, which is quite frequent in the horticultural sectors, is the spraying of crops, both for outdoor purposes, but especially for crops growing in sheltered areas such as solariums, greenhouses, etc. The equipment / product proposed by this project relates to a plant spraying plant, including those grown in enclosed spaces where plants are grown which require their spraying all their height to provide access to the treatment solution against diseases and pests in their most hidden places. The usefulness of such equipment is supported by the high demand for healthy food, products obtained by applying the latest techniques. Knowing the market requirements very well, in order to be sure of a quality product, the beneficiary SME has proposed to the research-development services provider the collaboration within this CEC project, the provider having more than half a century of research experience. Nationally and internationally, there are a variety of spraying systems of different sizes, some worn / pushed by humans, another tractor, helicopter, airplane or self-propelled. In the world, there are many companies that produce and market, including in Romania [2], such as: ROYAL BRIKMAN, global specialist in horticulture, GREGSON-CLARK, focused on high-quality sprinkler equipment in green industry, EMPAS, in horticulture spraying equipment, HYDRO SYSTEMS EUROPE with irrigation and horticultural applications, MARTIN LISHMAN Ltd and others. In the Romanian market, apart from human ones, there are classical sprinkling systems, generally of large size, for irrigation and spraying with treatment solutions for large crops, with small productivity, not fully satisfying the market requirements, being necessary tools sized self-propelled dimensions that SMEs in horticulture need. Sprayed crops are sprayed using systems worn or towed by humans. In Romania there is no spraying technology and no specialized equipment. Recognizing this market failure, the beneficiary SME is requesting funding for this project, which will launch an innovative product based on new, productive and competitive technology, useful and necessary in horticulture in Romania.

2. General concept of the functional model

As a result of winning a research competition, the INOE 2000 - IHP Research Institute in Bucharest conceived, physically designed and tested a functional model of a remote guided agricultural platform used in horticulture spraying works. Equipment’s of this kind are also used outside the country. For the time being, there is no offer of such equipment in the country, which has led to its realization by its own forces. The motorized agricultural platform, which is the physical result of this project, is designed to be commanded by both ordinary manual commands and remote controls, which is an especially important innovation because by performing remotely spraying to combat pests and diseases, protects the operator against the harmful effect of chemical substances in the plant treatment solutions. The project idea belongs to the SME wishing a remote-controlled mobile machinery. In Figure 2, the concept of realization of the motorized agricultural platform, which consists mainly of a self-propelled platform (1), equipped with a thermal engine (2), which includes the fuel tank and the battery, is presented a mechanical transmission (3) for pulling a pump (4) which aspirates the liquid from a tank (5) through a suction line (6) and releases the pressurized liquid through the discharge pipe (7) into the injector (8) which injects the liquid of the spraying head (9) [3]. The remote control of the platform is carried out by means of hydraulic distributors (11), whose levers can also be actuated by means of cables, which allow interfacing with the remote control / guidance system (12), which respond to the orders given by remote operator via a command / programming console.

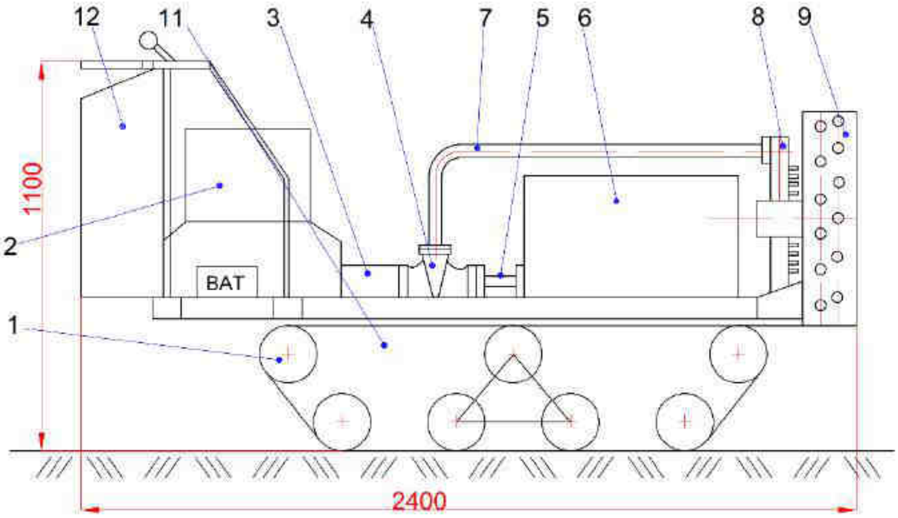

Fig. 2. General concept of the functional model

3. Physical realization of the agricultural platform and technical characteristics

Figure 3 presents the agricultural platform at the current stage of development by the end of the year, it will be equipped with three electro-valves that will allow it to selectively spray the plants.

Fig. 3. Physical realization of the agricultural platform

Technical characteristics:

Travel speed: 0 - 7 km / h;

Engine power: 5.2 kW at 1800 rpm;

Spraying tank volume: 100 l;

Spraying pressure: 20 bar;

Spraying rate: 20 l / min;

Spraying distance: 1 - 3 m.

4. Conclusions

In this form, the platform was also presented at the national fair of agricultural products INDAGRA 2018. The stand at the fair is shown in Figure 4. Where the main technical features of the platform have been demonstrated.

Fig. 4. The stand at INDAGRA 2018 at which the agricultural platform was presented

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OPERATING ELEMENTS OF A PISTON PUMP DRIVEN WITH ELECTRIC AXIS

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Abstract: *The paper presents a piston pump driven by electric axis with stepper motor and ball screw which through the electronic control system allows adjustment of pump flow by varying amplitude, frequency or duty factor in dynamic mode. The pump piston is driven by an electric axis consisting of a stepper electric motor and a ball screw which ensures the linear movement of the axis.*

Keywords*: Piston pumps, electric axis, hydraulic drive, stepper motor*

1. Introduction

Piston pumps are hydraulic machines known for a long time, in which the working fluid is set in motion by reciprocating rectilinear movement of a piston inside the pump body. The direction of the piston movement changes periodically, so that at stroke ends (in dead spots) speed becomes null; the movement of the fluid is therefore a pulsating one.
The piston pump operation is based on the cyclical change in the working volume. One operating cycle consists of two phases: the first one, in which, by moving the piston in the direction of increasing the working volume, a depression occurs in the working cavity, which causes suction through the suction valve; the second one, in which by moving the piston in the direction in which the working volume decreases, the pressure increases and the fluid is discharged through the discharge valve.

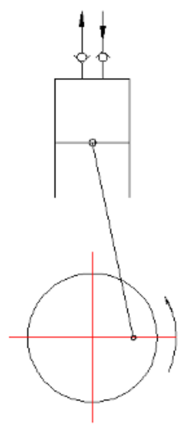

Fig. 1. Kinematic schematic diagram of the piston pump mechanically driven

Actuation of piston pumps is routinely made by mechanical drive, by using a hydraulic cylinder or a pneumatic cylinder.
The piston pump shown in Figure 2 is used in pumping processes involving products with particles in their structure. It is important to emphasize that the pumping system has a low shear rate because it is intended to protect the integrity of the product. This is especially important when processing vegetables, cut fruit, etc. Piston drive can be hydraulically or pneumatically done.

Fig. 2. Hydraulic / pneumatic drive piston pump

The gauge and weights of piston pumps are, however, high compared to other pumps, and as a result, since they cannot be driven at high speeds, they are provided with a reducer between the drive motor and the crank axis. Driving the crank axis at high peripheral speeds results in high piston accelerations at stroke ends, which causes the fluid to detach from the piston as a result of the pressure drop, thus the occurrence of cavitation. That is why drive speeds are often limited to values between 40 and 180 rpm. Using reducers along the pump drive chain has direct consequences not only on the gauge and weight of the machine, but also on the cost price.

2. The piston pump driven with electric axis

The piston pump driven by use of an electric axis with stepper motor and ball screw is actuated through the electronic control block and it allows adjustment of pump flow by varying amplitude, frequency or duty factor in dynamic mode.
Schematic diagram of the piston pump actuated with linear electric axis, with stepper motor (figure 3) functioning as a pulsating pump or flow metering pump, powered by a piston chamber, developed at INOE 2000-IHP (figure 4), comprises electronic control and adjustment block (1), stepper motor (2), ball screw (3), frame (4), coupling (5), piston (6) and two check valves (7).

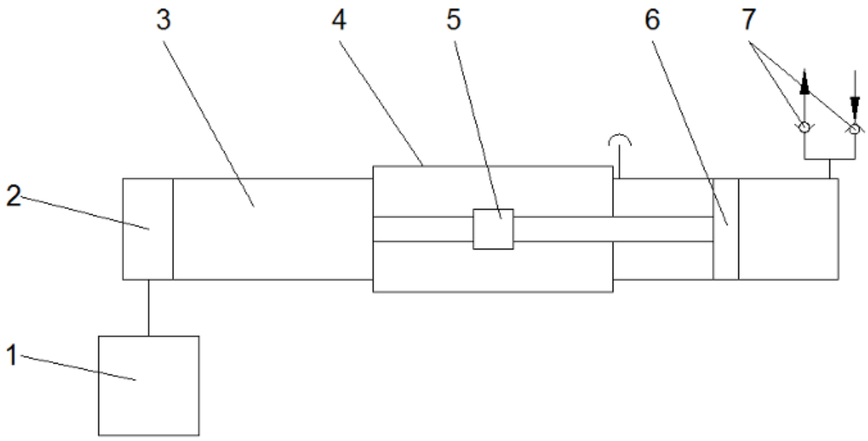

Fig. 3. Schematic diagram of a piston pump driven with linear electric axis

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The two components, the electric axis - stepper motor (2) and ball screw (3) – and the piston (6) have the rods coupled by a coupling (5) and they make up a pump controlled with an electronic module (1); the pump flow rate is adjustable by varying the stroke, acceleration or frequency for any area of the piston stroke.

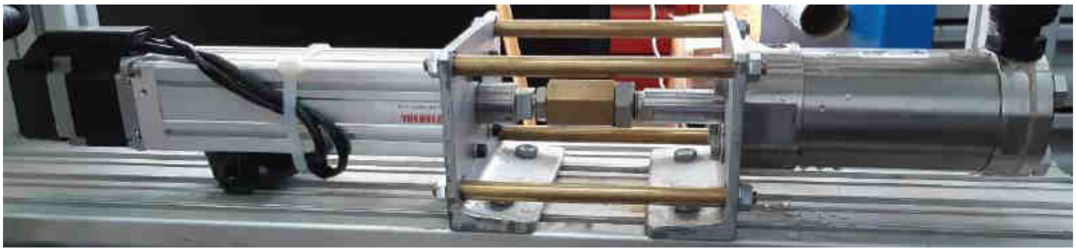

Fig. 4. Piston pump driven with the electric axis developed at INOE 2000-IHP

3. Determination of horizontal axis forces and motion equations

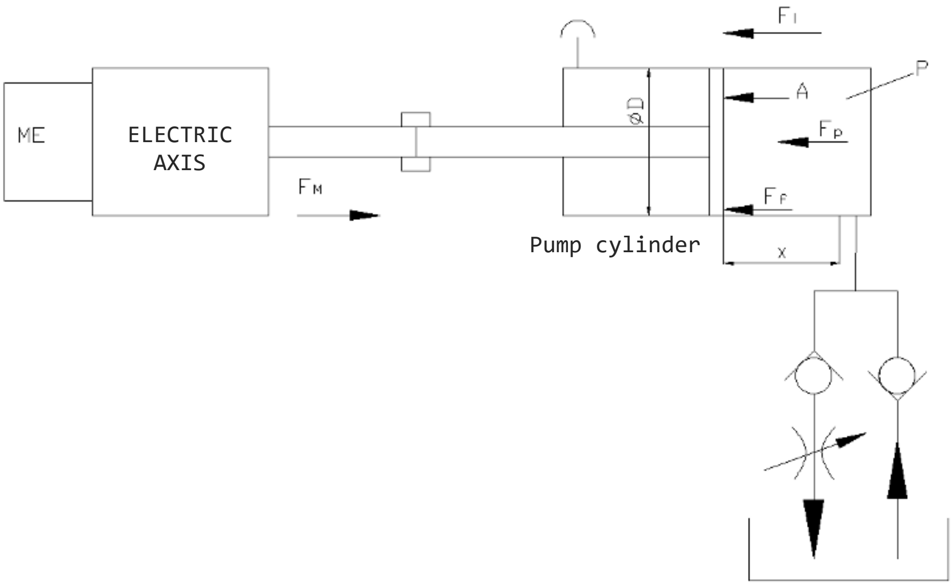

Fig. 5. Determination of horizontal axis forces

Equation of forces on the working axis of the pump is as follows:

$$F_M = F_p + F_f + F_i + \sum F_a \quad (1)$$

F_M – drive force = the force that the electric axis must provide

F_p – pressure force = useful force = pumping force

$$F_p = p \cdot \frac{\pi D^2}{4} \quad (2)$$

F_f – friction force

$$F_f = K_f \cdot \frac{dx}{dt} \quad (3)$$

Where

$$K_f = \frac{\pi D \cdot l \cdot \eta}{j} \tag{4}$$

F_i – inertia force. It is manifested especially when changing the direction.

$$F_i = M \cdot \frac{d^2x}{dt^2} \tag{5}$$

Where M – mass of the rods + mass of the piston + mass of the working fluid

There are also:

- F_ϑ – viscous friction force due to the piston displacement speed
- F_{hs} – hydrodynamic force (in stationary mode)
- F_{ht} – hydrodynamic transient force

$$\sum F_a = F_\vartheta + F_{hs} + F_{ht} \tag{6}$$

The sum of these forces is generally less than the force of inertia and therefore in the preliminary calculations it was neglected.

After entering the physical data of the pump model developed

$$\begin{pmatrix} D = 30\, mm \\ X = stroke = 30\, mm \end{pmatrix}$$

we obtained:

F_p=25 daN

F_f= 18 daN

F_i=5 daN

Total max. 48 daN

This value is below the catalogue value of the electric axis $-F_M \simeq 60\ daN$

4. Control system of the pump drive electric axis

4.1 Schematic diagram of the axis

In the schematic diagram shown in figure 6 one can notice the features of the electric axis manufactured by the company from which it was purchased by INOE 2000-IHP.

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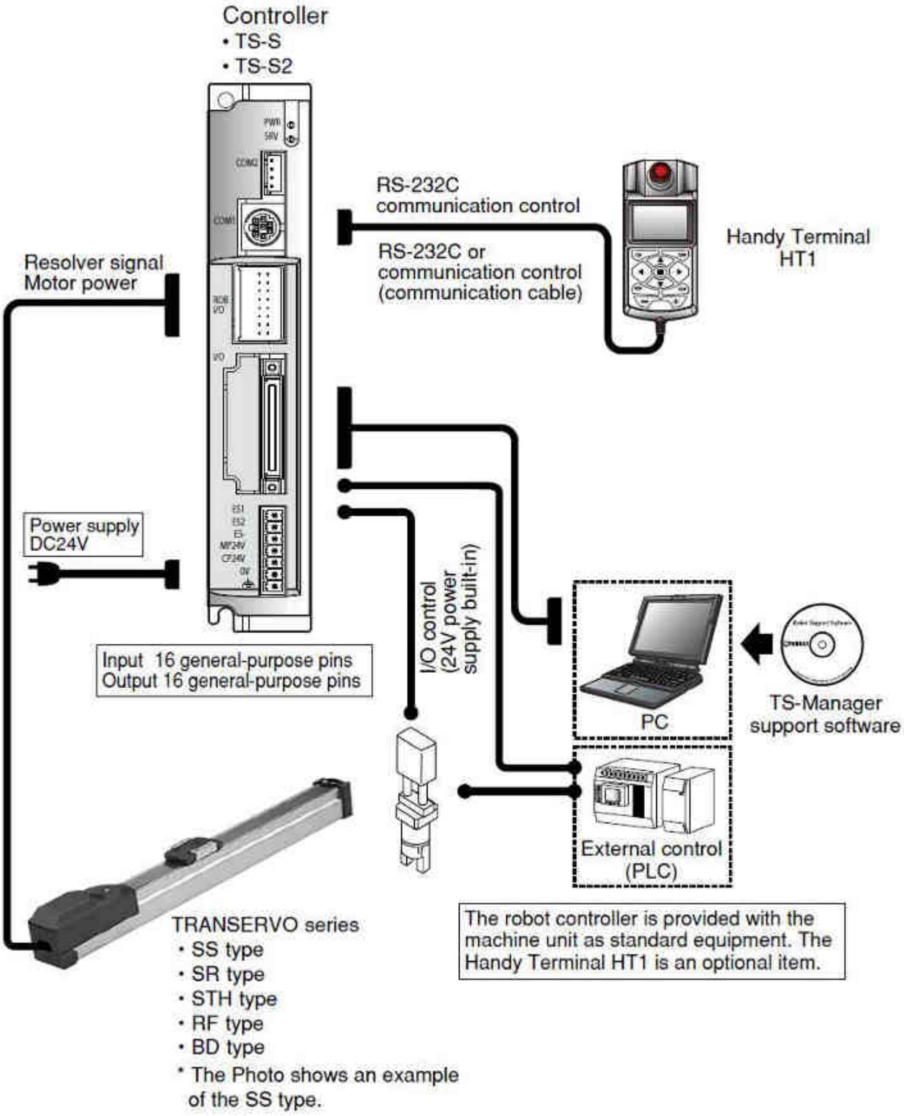

Fig. 6. Schematic diagram of TRANSERVO – YAMAHA electric axis

4.2 Types of control for the electric axis

Pump drive with the electric axis can be achieved by using several forms of control. Figure 7.1 shows the trapezoidal control which, in the case of a working frequency of 2-3 Hz, for a 30 mm stroke, was found to introduce some shocks (alias jerk, Figure 8) which most often create problems. Therefore, as the axis allows it, we turned to using an S-Curve type control, as shown in figure 7.2.

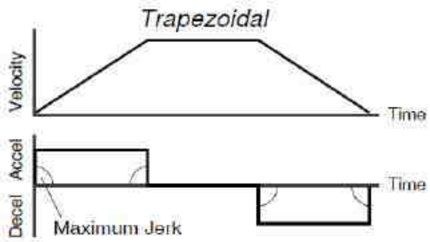

Fig. 7.1. Trapezoidal control

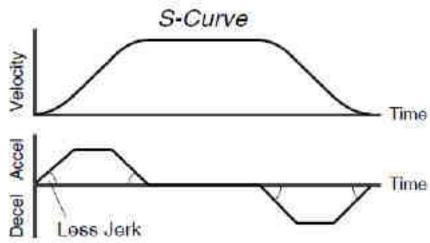

Fig. 7.2. S-Curve control

4.3 Calculating Jerk

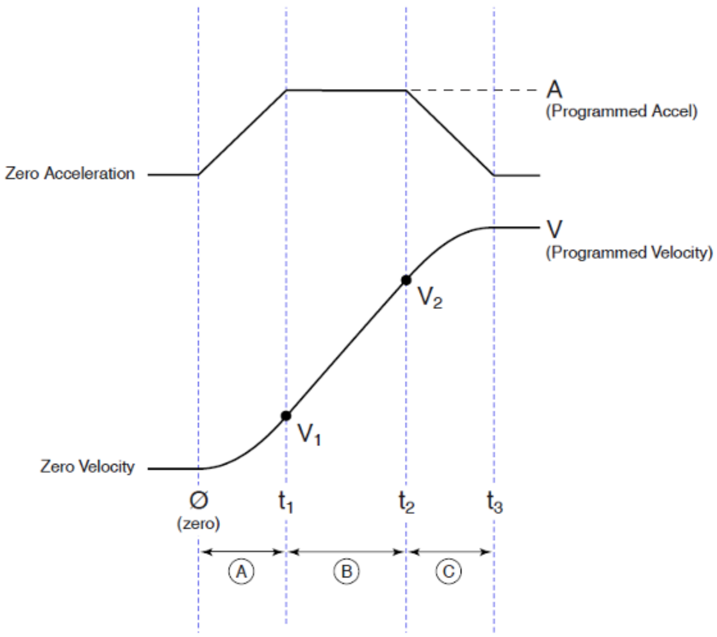

Fig. 8.

Rules of Motion:

$$\text{Jerk} = \frac{da}{dt}$$

$$a = \frac{dv}{dt}$$

$$v = \frac{dx}{dt} \quad (x = \text{distance})$$

Assuming the accel profile starts when the load is at zero velocity and the ramp to the programmed velocity is not compromised:

$$\textbf{Jerk} = J_A = \frac{A^2 * AA}{V\,(A - AA)}$$

A = programmed acceleration (A, AD, HOMAD, etc.)
AA = average acceleration (AA, ADA, HOMAA, etc.)
V = programmed velocity (V, HOMV, etc.)

$$t_1 = \frac{A}{J_A}$$

$$t_2 = \frac{V}{AA} - \frac{A}{J_A}$$

$$t_3 = \frac{V}{AA}$$

NOTE: $t_3 - t_2 = t_1$

$$V_1 = \frac{J_A * t_1^2}{2} = \frac{A^2}{2 * J_A}$$

$$V_2 = V - \frac{A^2}{2 * J_A}$$

a (t) = acceleration at time t
v (t) = velocity at time t
d (t) = distance at time t

Ⓐ $t_1 \geq t \geq Ø$

$$a(t) = J_A * t$$

$$v(t) = \frac{J_A * t^2}{2}$$

$$d(t) = \frac{J_A * t^3}{6}$$

Ⓑ $t_2 \geq t > t_1$

$$a(t) = A$$

$$v(t) = \frac{A^2}{2J_A} + A * (t - t_1)$$

$$d(t) = \frac{J_A * t_1^3}{6} + \left(\frac{A * (t - t_1)^2}{2}\right) + \left(V_1 * (t - t_1)\right)$$

Ⓒ $t_3 \geq t > t_2$

$$a(t) = A - (J_A * (t - t_2))$$

$$v(t) = V - \left(\frac{J_A * (t_3 - t)^2}{2}\right)$$

$$d(t) = \frac{V^2}{2AA} + \left(\frac{J_A\,(t_3 - t)^3}{6}\right) - \left(V * (t_3 - t)\right)$$

5. Experimental results

Adjusting the pump flow by adjusting the frequency, amplitude or duty factor

The software for generation of trapezoidal motion profile for the electric axis, screenshots (Figures 9, 10, 11):

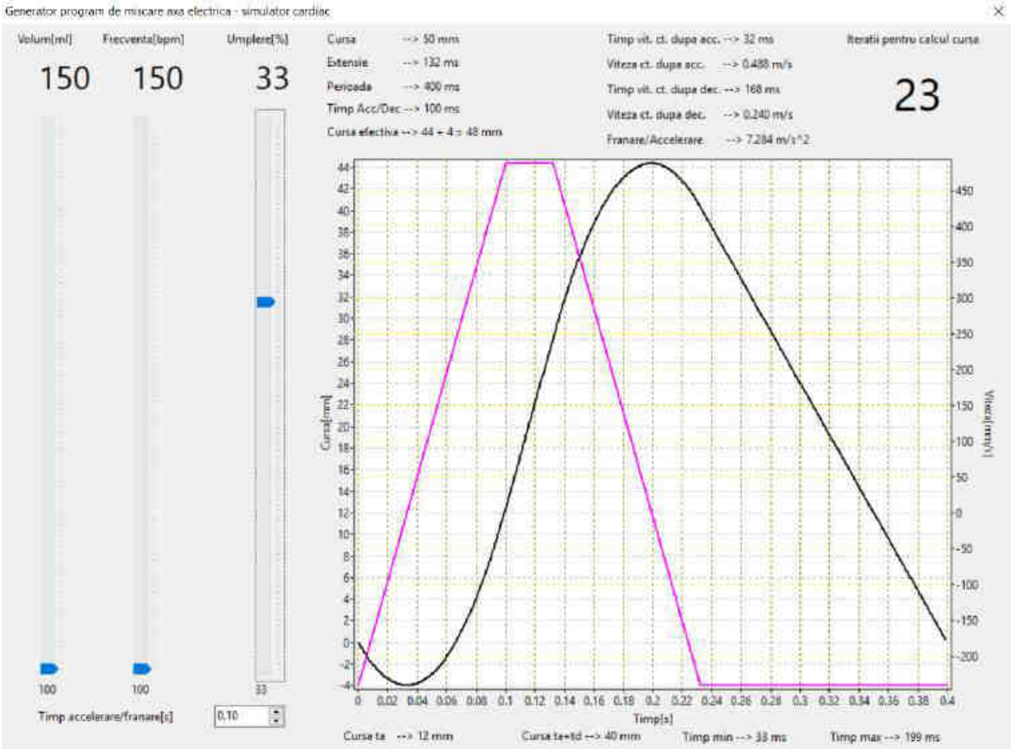

Fig. 9. Graph for: volume = 150ml, frequency = 2.5 Hz, duty factor = 33%

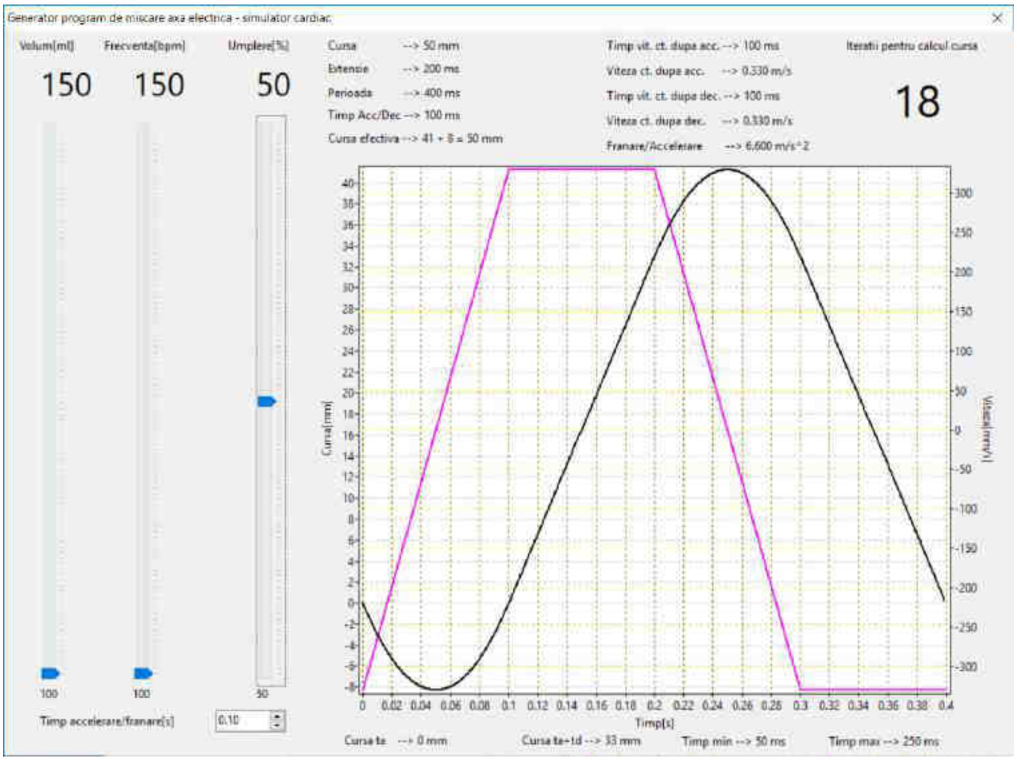

Fig. 10. Graph for: volume = 150ml, frequency = 2.5 Hz, duty factor = 50%

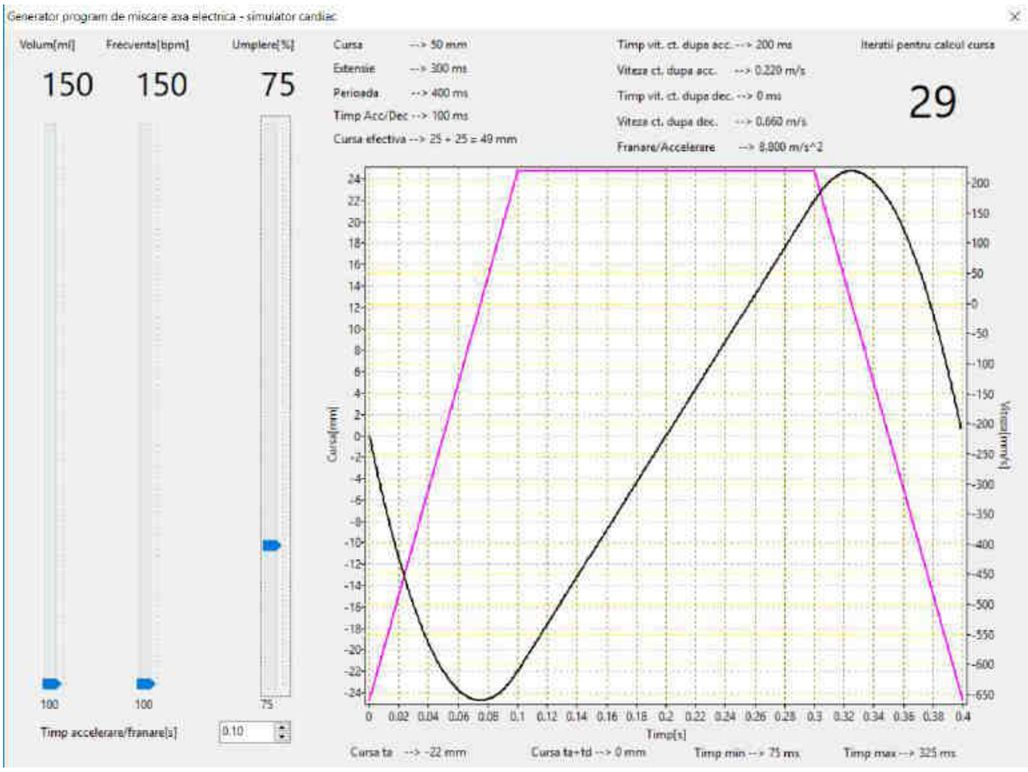

Fig. 11. Graph for: volume = 150ml, frequency = 2.5 Hz, duty factor = 75%

6. Conclusions

Out of a simple piston pump, by controlling it with an electric axis, it is possible to obtain a variable output flow, with easy to control characteristics of fluid volume, flow rate, duty factor.
In the laboratory tests a large volume of fluid was used at the pump output, which resulted in a high value of the inertia force.
The pump developed in the laboratory of INOE 2000-IHP works well at pressures up to 3 bar and frequencies up to 4 Hz, if the stroke is maintained in the 25-30 mm range.
The pump can be controlled with appropriate software to ensure operation without shocks and noise.
A patent application has been filed on this pump by its authors.

Acknowledgment

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BIONICWORKPLACE: HUMAN-ROBOT COLLABORATION WITH ARTIFICIAL INTELLIGENCE

Flexible production down to batch size 1 for the factory of the future

BionicWorkplace: A human works together with a bionic robotic arm, along with numerous assistance systems and peripheral devices that are connected and communicate with each other.

Short product life cycles and a high diversity of variants are requirements brought about by industrial change. At the same time, it is becoming increasingly important to ensure that employees can rapidly and intuitively adapt to new tasks. This calls for new forms of collaboration between people, machinery and software. A key role is played here by self-learning systems with artificial intelligence and by robot-based automation solutions that can work hand in hand with the human operator and can form networks with each other. All these requirements are fulfilled by the BionicWorkplace – a ground-breaking working environment being presented by Festo at the Hanover Messe 2018 trade fair.

The future of production is flexible – in terms of the products manufactured, but also of the workplace and the design of the working environment. Artificial intelligence and machine learning are transforming workplaces into learning systems that constantly develop and optimally adapt themselves to the requirements at hand. Festo is impressively demonstrating this with the BionicWorkplace, in which a human works together with a bionic robotic arm, along with numerous assistance systems and peripheral devices that are connected and communicate with each other. The operator is supported in these tasks by technology that relieves him or her of tiring or hazardous activities.

Keywords*: artificial intelligence, industry, machine learning, connectivity, BionicWorkplace, Hannover Messe 2018*

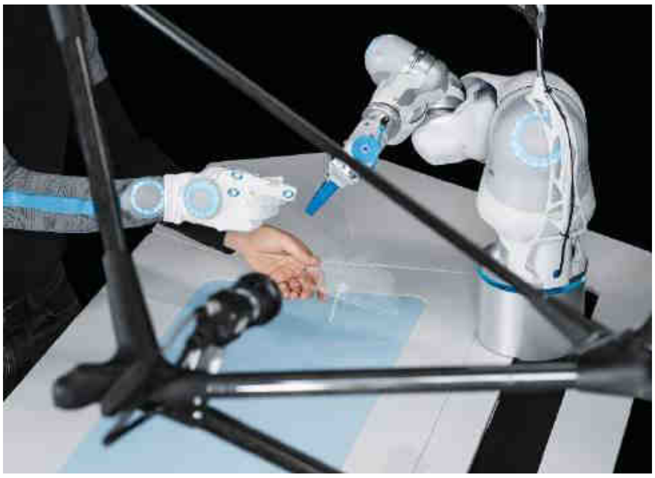
A learning system based on sensors and artificial intelligence

The entire workplace is ergonomically designed and can be individually adapted to people, right down to the lighting. Sensors and camera systems register the positions of the operator, components and tools, so that humans can intuitively control the BionicCobot by means of gestures, touch or speech. At the same time, a software system processes all the camera images and input from the various peripheral devices. It uses this information to derive the optimal program sequence. The system learns from each action initiated and thus constantly optimises itself. Controlled, programmed and set sequences therefore gradually make way for a much freer method of working.

Sharing knowledge and making it globally available

Once learnt and optimised, the processes and skills of the BionicWorkplace can be very easily transferred to other systems of the same type in real time and made available worldwide. It will be possible in future, for example, to integrate workplaces into a global network in which knowledge modules can be shared; the communication would be effected in the various national languages.
Production will then become not only more flexible, but also more decentralised: the operators could call up production orders via Internet platforms, for instance, and carry them out autonomously in cooperation with the machinery – in keeping with individual customer desires and requirements. Remote manipulation of the workplace is also conceivable.

Humans can intuitively control the BionicCobot by means of gestures, touch or speech.

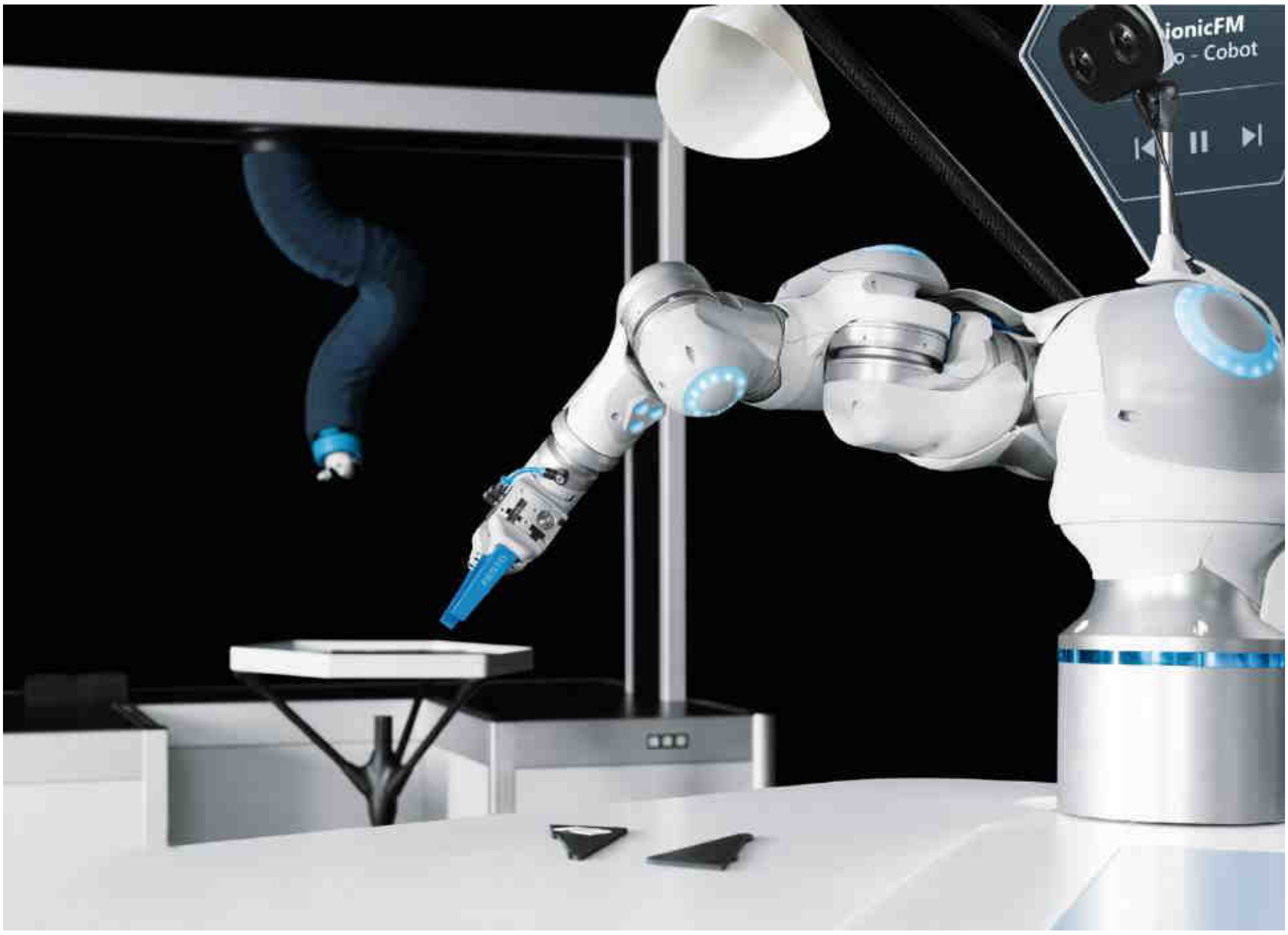

Sensors and camera systems register the positions of the operator, components and tools.

The BionicCobot as a central element

A key component of the working environment is the pneumatic lightweight “BionicCobot”. This robot is modelled on the human arm. Its movements are generated by compressed air, which makes it flexible; it can therefore directly and safely interact with people. This is made possible by digitalised pneumatics: the Festo Motion Terminal used together with the BionicCobot opens up entirely new solution spaces for safe human-robot collaboration and enables the BionicCobot to carry out either rapid and powerful, or soft and delicate movements.

Scenario for individual production

At the Hannover Messe, a scenario is being demonstrated for the manufacture of an individual product at the BionicWorkplace. To produce an individual model of a head, for example, a laser cutter first slices sections of acrylic glass: a software program converts the stored facial features of a person scanned using a smartphone into a CAD model, which it then breaks down into separate slices. The laser cutter then cuts the elements out of acrylic glass on the basis of this 3D template. The BionicCobot takes the slices directly from the cutter and gives them to the operator in the right sequence, who then assembles them to make a unique model.



The constant automatic feed of material in this scenario is ensured by a Robotino®, which autonomously travels back and forth between the stations and safely finds its way by means of a laser scanner. It is loaded by a refined version of the BionicMotionRobot, a soft robotic structure with pneumatic compartments and a 3D woven textile covering. This configuration thus combines all key elements of robot technology.

For further information: www.festo.com/bionics

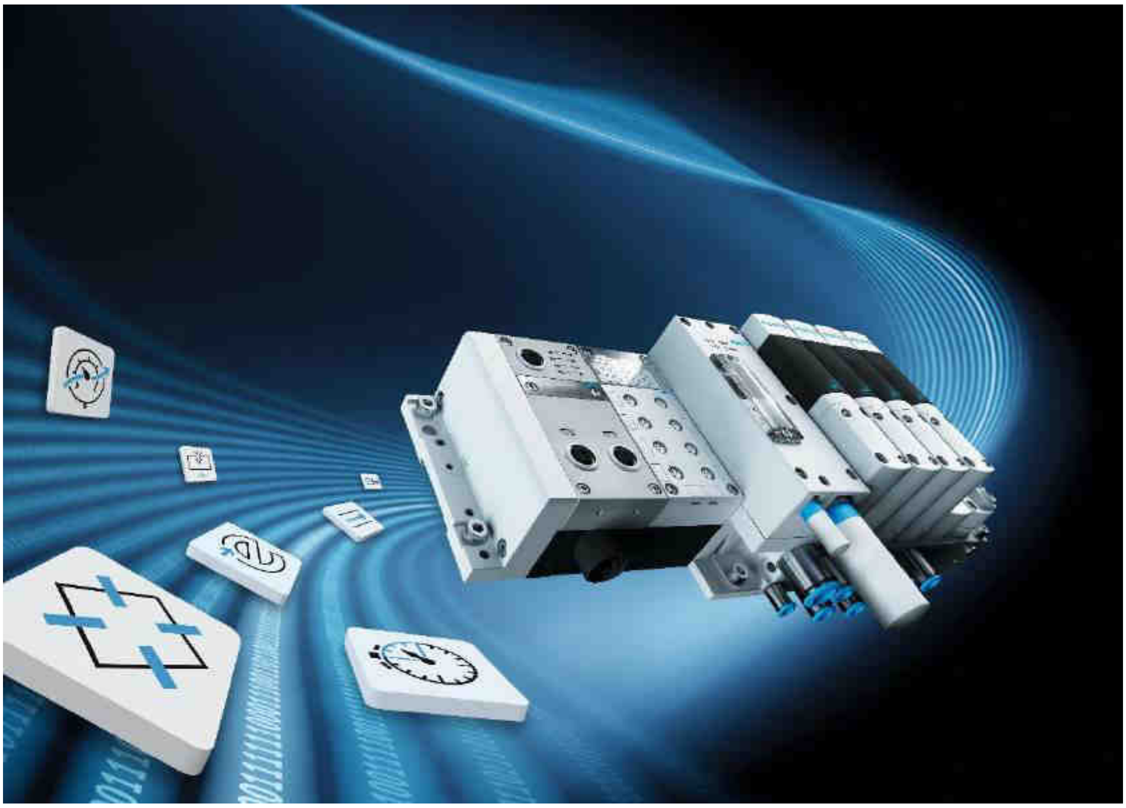
About Festo:
Festo AG is a global player and an independent family-owned company with headquarters in Esslingen am Neckar, Germany. The company supplies pneumatic and electrical automation technology to 300,000 customers of factory and process automation in over 40 industries. The products and services are available in 176 countries. With about 20,100 employees in over 250 branch offices in 61 countries worldwide, Festo achieved a turnover of around €3.1 billion in 2017. Each year around 8 % of this turnover is invested in research and development. In this learning company, 1.5 % of turnover is invested in basic and further training. Yet training services are not only provided for Festo's own staff – Festo Didactic SE also supplies basic and further training programmes in the field of automation technology for customers, students and trainees.

REVOLUTION IN AUTOMATION TECHNOLOGY

Saving time and money in tyre manufacturing

The Festo Motion Terminal VTEM, one of the first products of the Industry 4.0 era, combines digitalisation and pneumatics. Quickly activated software apps are revolutionising pneumatics by increasing flexibility and energy efficiency, and accelerating production processes. This also benefits tyre manufacturing, as demonstrated by the use of the automation platform VTEM in tyre moulding presses.

The Festo Motion Terminal VTEM catapults pneumatics into the age of Industry 4.0 – with apps that can replace over 50 individual components. Just as the smartphone turned the mobile communication market on its head a decade ago, so too is the Festo Motion Terminal set to revolutionise automation technology. The new type of function integration – combined with software apps – simplifies the entire value chain, since only one piece of hardware is now required. And thus the experts view the Festo Motion Terminal VTEM as a revolution in automation technology.



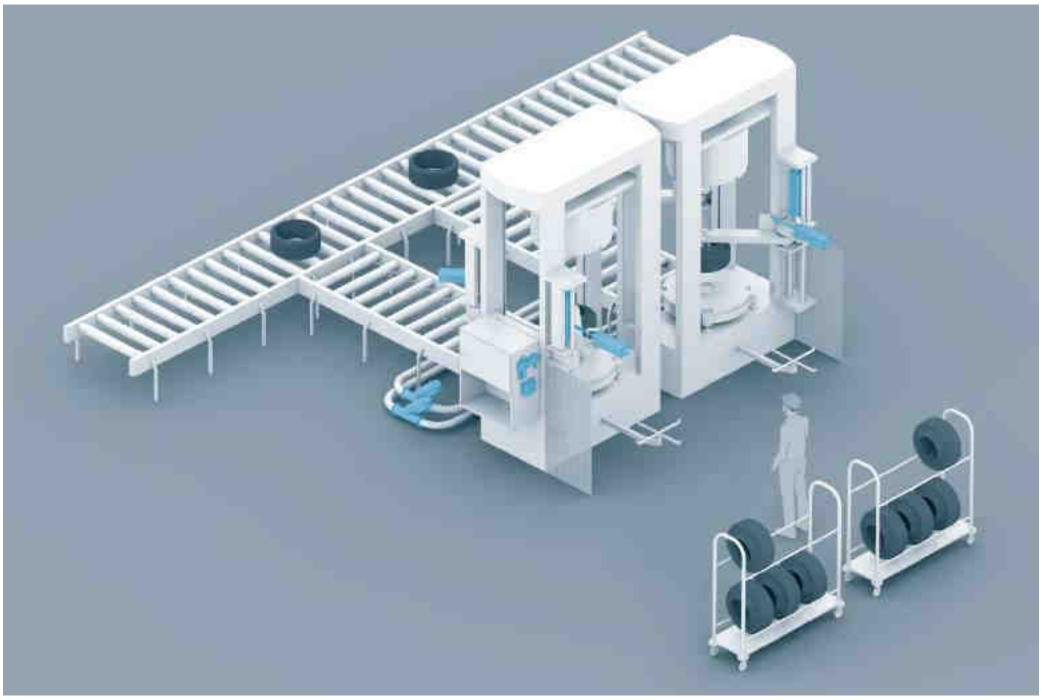
Revolution in automation with the Festo Motion Terminal: thanks to fast activation of new functions via apps, machine developers can create a basic machine type and then, depending on which apps are selected, equip it with different functions and features as per the customer's requirements. (Photo: Festo AG & Co. KG)

***Keywords**: digital, pneumatics, automation, revolution, flexibility, efficiency*

Full flexibility

Thanks to the fast activation of new functions via apps, machine developers can create a basic machine type and then, depending on which apps are selected, equip it with different functions and features as per the customer's requirements. Assigning functions via software has the added benefit of preventing tampering and protecting know-how, since it's not possible to tell from the outside which functions the valves are executing. Maintenance is also simplified, as long lists of spare and wearing parts will be a thing of the past.

In tyre manufacturing, this results in potential savings for loading and unloading operations at the moulding presses, as the “selectable pressure level” app included with the Festo Motion Terminals ensures gentle loading of the raw tyre without profile. The profile is added to the tyre in this press. The smaller the fluctuations of the handling system during loading and unloading, the more the feeding-in speed can be increased. The process for each tyre is thus accelerated by several seconds. This doesn’t sound like much at first, but with roughly 1.5 billion car tyres produced each year, this can result in considerable sums for each tyre manufacturer.



Potential savings for loading and unloading operations in tyre moulding presses can now be achieved with the Festo Motion Terminal VTEM. (Photo: Festo AG & Co. KG)

Less pressure = less energy

In practice, it is not just that the loading and unloading operations are accelerated, they also require less energy because pressure can be reduced and so compressed air consumption is also decreased. Calculations even reveal compressed air savings of nearly 33% when comparing the movement of the horizontally installed pneumatic cylinder DSBC with standard pneumatics, and of nearly 75% when the same cylinder is installed vertically. Just for controlling the vertical and horizontal cylinders, energy savings of roughly 60% are achieved for these loading and unloading operations.

Predictive maintenance

The “leakage management” app enables predictive maintenance by pinpointing leaks throughout the entire pneumatic control chain including valves, tubing, connectors and drives. The goal is to detect defective components at an early stage before they bring production to a standstill or damage the machine.

Furthermore, the Festo Motion Terminal can seal off the faulty air duct, thus preventing the supply of more and more compressed air in the case of a leak. The innovative automation platform thus prevents unnecessary air consumption.

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ON THE DISSOLVED WATER AMOUNT IN THE OIL FILM ON A PISTON ROD

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Abstract: *Rod seals in hydraulic cylinders play a very important role, besides they are very cheap compared to other components. Without those, pressure build-up in the rod chamber of the cylinder wouldn´t be possible. The cylinder could only perform extension and would need an additional device (such as a spring) for retraction. If a rod does not operate properly, oil can exit the system and hence causing hazards to human beings and the environment. As they are usually made of rubber, they are highly vulnerable to wear. So, a lubricating oil film is needed to separate rod and sealing element to avoid excessive wear. The seal is designed to ensure that the film is retracted back into the system. During extension, humidity from the air can be dissolved in the film which is also tracked into the system and which can cause multiple damages. In this work, the amount of dissolved water in correspondence with humidity is investigated.*

Keywords*: Rod, seal, water, oil, saturation*

1. Introduction

In hydraulic systems, contamination of the fluid with water is one of the most common causes of damages [1].

In the fluid, water is partly dissolved, partly emulsified and partly undissolved and can lead to various damage mechanisms, see *figure* 1.

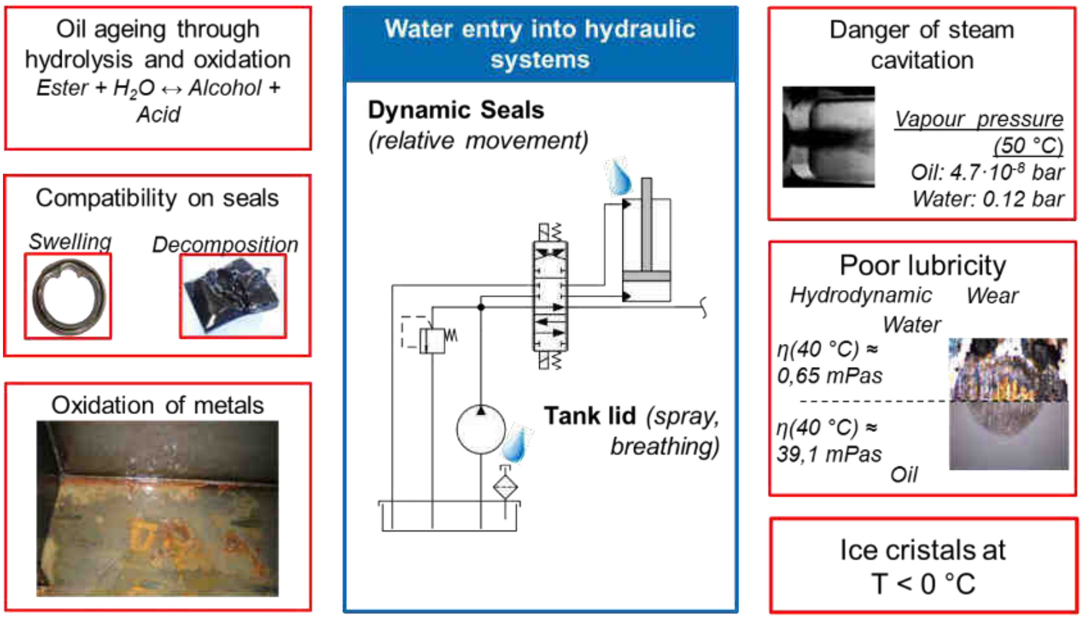

Fig. 1. Various damages due to water

Water accelerates the aging of the oil by hydrolysis or oxidation. Bio-oils are particularly susceptible to hydrolysis because they contain a large proportion of ester compounds, which split into an alcohol and an acid in the presence of water. On the other hand, Mineral oils are subject to oxidation. High water content in the oil has an accelerating effect for oxidation. [2, 3]

In addition, materials used in hydraulic systems are also directly influenced by water. Due to an increasing proportion of polar water molecules in the fluid, the overall fluid polarity changes. The swelling behaviour of elastomer seals is significantly determined by the polarity of the surrounding fluid. Hence a change in the swelling behaviour of seals can also be expected. For polyurethane (PU) seals, which are widely used in hydraulics, decomposition by hydrolysis at high water contents in the fluid must also be taken into account [4] in addition to the swelling behaviour due to water.

There is also the risk of corrosive attack of metallic surfaces by water in the oil [4]. Especially in the case of bio-oils, the splitting of the esters in the presence of water can cause damage to both metallic surfaces and seals due to the resulting acid in addition to water-related corrosion.

The much higher vapour pressure of water compared to oil-based pressure media can lead to increased vapour cavitation in flow areas of low pressure. If these cavitation bubbles implode in areas of higher pressure near material surfaces, cavitation erosion can damage the material surface [5].

There is also the danger of ice crystal formation at temperatures below 0 °C. The crystals significantly change the flow properties of the medium and can, for example, lead to clogging of the filters in the system.

Water can enter a hydraulic system through two locations: through the tank opening and through dynamic sealing points, which form a gap to the environment during operation. In case of the rod seal, which seals translational movements, there is a high draw-in potential due to the othogonality of the sealing element and the direction of movement. In principle, two types of water entry can be distinguished here. On one hand, water can be drawn in freely as a separate phase, which has already been investigated in [6]. On the other hand, water can be dissolved in the lubricating film, which the rod seal allows to pass due to its working principle, during contact with a humid atmosphere. How much water is drawn in via this mechanism, however, is the subject of this work. First, a solubility model is theoretically derived and experimentally validated. This model is then applied to the lubricating film on the rod and the amount of water drawn in is calculated. Finally, the entered water quantities of the two entry types are compared with each other.

2. Solubility of water in oil

In [7] curves of water in hydraulic oil HLP 46 have been determined, see *figure* 2. The maximal soluble amount water over temperature is depicted. The saturation m_W^* is normalized based on the oil mass in which the water is desolved (all variables marked with * are oil mass based).
It can be seen that the saturation capacity increases exponentially with increasing temperature. Overall, the order of magnitude of saturation is in the range of several 100 mg water per kg oil.

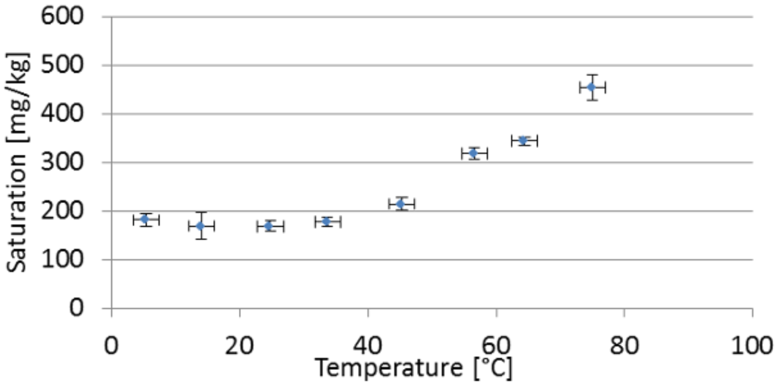

Fig. 2. Saturation curve for water in HLP-D

The relative saturation Rh can be measured with oil condition sensors. It is defined as the mass of dissolved water in the oil m_W related to the maximum soluble water mass $m^*_{W,max}$ which is the saturation point at the corresponding temperature. With known temperature and the measured relative saturation, the absolute water content per kg of oil can be calculated with the help of formula (1) using the saturation curve from *figure* 2.

$$m^*_W = Rh \cdot m^*_{W,max} = Rh \cdot \frac{m_{W,max}}{m_{Oil}} \tag{1}$$

In order to be able to calculate the relative substance amount of dissolved water, formula (1) is divided by the molar mass M_W of the water, see formula (2).

$$n^*_W = \frac{m^*_W}{M_W} = \frac{Rh \cdot m^*_{W,max}}{M_W} \tag{2}$$

The concentration of water in a fluid is defined as the amount of substance per volume, formula (3).

$$c_{l,w} = \frac{n_W}{V} \tag{3}$$

Since the water content is only very little, the volume is practically only taken up by oil. If the absolute amount of water in the oil is calculated with formula (2) by multiplication with the oil mass m_{Oil} which is substituted by the density of the oil ρ_{Oil} and the volume V, the following formula (4) for the concentration is derived.

$$c_{l,w} = \frac{Rh \cdot m^*_{W,max}}{M_W \cdot \rho_{Oil}} \tag{4}$$

To determine the solubility of water in oil, the law of Henry is used [8]. This law states that the partial pressure of a gas over a liquid is directly proportional to the concentration of the gas in the liquid. Since temperatures below the boiling point of water typically prevail in hydraulic applications, the applicability must be examined here, since a change of state can occur when the saturated vapor pressure falls below the saturation point. This is done by calculating the mean molecular distance of the water in the oil and the mean distance in the gas phase.

At 40 °C an air molecule takes up a volume of about $V = 4 \cdot 10^{-23}\ m^3$ which results in a uniform distance of $3.5 \cdot 10^{-8}\ m$. between the molecules.

At the same temperature, the saturation capacity of the considered oil is approx. 200 mg/kg. If a uniform distribution of the water molecules in the fluid is also assumed here, the distance between two water molecules is approx. $5.3 \cdot 10^{-9}\ m$. It can be seen, that the distance between two molecules in a gas and in the case of dissolved water in oil is of the same order of magnitude. Therefore, Henrys law can be applied to this phenomenon.

The Henry solubility constant H^{cp} is defined as the ratio of the concentration $c_{l,w}$ of the gas (here of water, index w) in the liquid to the partial pressure p_w above the liquid, formula (3).

$$H^{cp} = \frac{c_{l,w}}{p_w} \tag{5}$$

The relative humidity φ is defined as the ratio of the pressure of the water p_w in the air to the maximum pressure $p_{w,max}$ that the water can exert at the temperature, the so-called saturation pressure, formula (6).

$$\varphi = \frac{p_w}{p_{w,max}} \tag{6}$$

The saturation pressure $p_{w,max}$ of water for different temperatures is known and is tabulated [9].

If formula (6) is transformed to the partial pressure p_w and used together with formula (4) in formula (5), the following expression is obtained for the Henry constant H^{cp}, formula (7).

$$H^{cp} = \frac{\frac{Rh \cdot m^*_{W,max}}{M_W \cdot \rho_{Oil}}}{\varphi \cdot p_{w,max}} \tag{7}$$

With this formula, the Henry constant for the water / oil system can be determined experimentally by measuring the humidity φ, the temperature and the relative water content Rh in the oil.

3. Theoretical considerations

With the help of formula (7), theoretical considerations can be made regarding the dependence of the relative water content Rh in the oil and the humidity of the air φ. Assuming an isothermal state and thus a constant value for the saturation pressure $p_{w,max}$, a constant value for the density ρ_{Oil} of the oil and a constant Henry solubility number H^{cp}, both quantities are linearly linked. This means that the time derivatives are also linear, independent from the current values for φ and Rh. There is no discontinuity possible.

If the oil is exposed to a very dry air atmosphere (i.e. φ =0), the water dissolved in the oil will diffuse out until there is no water molecule left. This means that Rh will also assume the value 0.

If the air humidity φ is at 100 %, however, it contains much more water than the oil can absorb (about factor 1000 more). This means that Rh is also 100% in this case.

Due to these considerations, two pairs of values for φ and Rh are known. In addition, these points are connected linearly, since the relation of the derivatives is also linear.

It follows that $\varphi = Rh$ and therefore the following relation applies (formula (3)) for Henry constant H^{cp}.

$$H^{cp} = \frac{\frac{m^*_{W,max}}{M_W \cdot \rho_{Oil}}}{p_{w,max}} \tag{8}$$

In the following, the experimental investigations for the validation of the presented theory are explained.

4. Experimental validation

To investigate the correlation between air humidity φ and relative water content Rh in the oil, the test setup which was already used to determine the saturation curves of water in oil, is used [7]. It consists of a vessel in which an oil condition sensor, which measures the relative water content of the oil Rh, is installed. The vessel is placed on a stirring plate to homogenize the filled oil during the tests. The vessel and the stirring plate are placed in a climatic chamber, which controls the air humidity and the air temperature. The conditioned air of the climatic chamber is blown directly onto the oils surface via a funnel using a commercially available PC fan. The complete test setup is shown in *figure* 3.

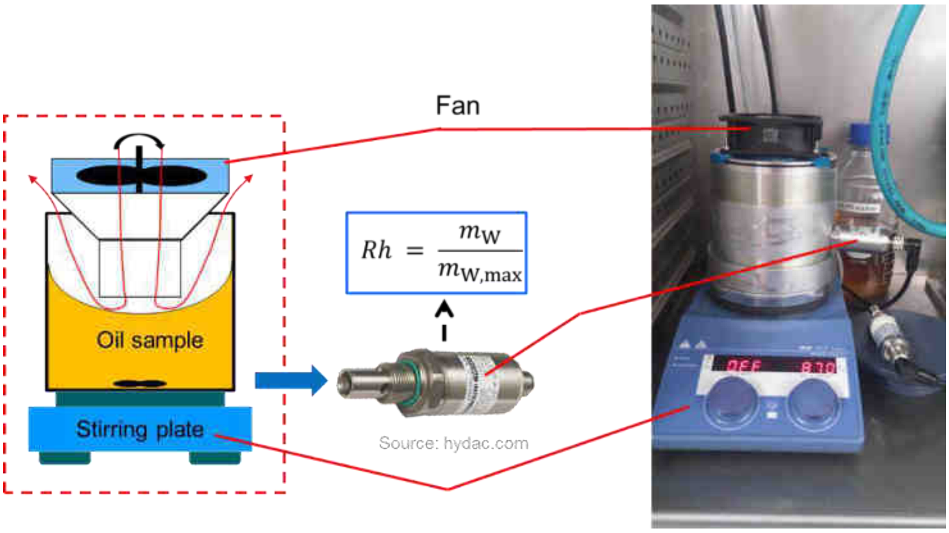

Fig. 3. Test set-up, left scheme, right in climatic chamber

The oil was filled into the previously intensively cleaned vessel and is brought into the air-conditioning chamber. The stirrer ensures constant thermal and mixture homogenization of the oil. The fan is inserted into the vessel and switched on. Then the climatic chamber is closed and the temperature and air humidity are set. After a long period of 9 hours in which a balance between air humidity φ and water content Rh is reached, the measured values are recorded. The next operating point was then approached entirely automatic.

The solubility of water was measured for a hydraulic fluid based on mineral oil of viscosity class VG 46 (HLP D 46). F*igure* 4 shows the relative water content Rh of the oil over the set air humidity φ at different temperatures.

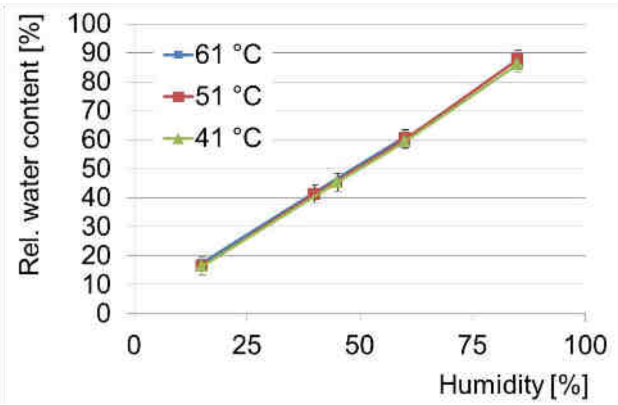

Fig. 4. Experimental results for HLP D 46

The relative water content at any temperature is equal to the humidity previously set. Therefore, the above theoretical considerations are confirmed.

5. Entrainment of dissolved water

In this section the order of magnitude of the water masses which is entrained dissolved in the oil film on the rod is estimated and compared with the entrainment of free water. The parameters and assumptions given in table 1 are used for this purpose.

Table 1: Parameters and assumptions

Rod diameter d	**Stroke H**	**Oil**	**Temperature**	**Humidity air**	**Lubrication film height h**
50 mm	1000 mm	HLP-D 46	40 °C	100 %	1 µm

At 40 °C the saturation capacity of HLP D 46 is approx. 200 mg/kg. The mass of the oil in contact with the air in the extended state is calculated using the formula (9). Note, that the oil mass is based on the performed stroke of the cylinder. It should also be noted that the assumed lubricating film height h is very large in comparison to measured lubricating film heights and that the result is therefore an estimate upwards.

$$\frac{m_{Oil}}{H} = h \cdot d \cdot \pi \cdot \rho_{Oil} = 0.135\ g/m \tag{9}$$

Due to the findings above 200 mg water per kg oil are solved at 40 °C under the assumptions made. If this value is multiplied by the oil film mass, the absorbed water mass is derived. Therefore, the order of magnitude of the dissolved water mass is in the range of 30 µg/m.

In [6] the entry of free water has been investigated. It was shown that the order of magnitude is in the range of some 10 µl/m, which corresponds to about 10 mg/m. Therefore, the water entry dissolved in the lubricating film plays only a minor role.

6. Conclusions

In this work, the entrainment of water dissolved in the oil film on a cylinder rod is investigated. First, a theoretical model, which is based on Henry´s law, for the relation of a humid environment and the oil water content, is derived. Discussing the derived equation let to the assumption, that both values, relative water content of the oil and humidity of the air, must be the same. This assumption was confirmed in an experimental approach. Finally, the entrained amount of water was discussed and compared with former findings for the entrainment of free water through that particular rod / seal contact.

The entrainment of dissolved water in the lubrication film on the rod is of magnitude of approx. 30 µg/m. Compared to the entrainment of free water, it only contributes minor to the overall entrainment of water. Unknown in this context is the role of wipers. It is thinkable, that the wipers can stop the free water during retraction. In that case, water would only be dissolved entrained. Further work to investigate these assumptions has to be carried out.

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CALCULATION OF RESISTANCE FORCE AT INCOMPRESSIBLE VISCOUS FLUIDS LAMINAR MOTION

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Abstract: *Starting from Newton's viscous friction law for unidirectional movement, this paper presents the calculation of the resistance force to the laminar motion of the viscous and incompressible fluids. Mentioned description can be applied to the demonstration of the Navier-Stokes equations.*

Keywords*: Resistance force, laminar motion, viscous fluids, incompressible fluids*

A problem of both theoretical and practical interest through applications in numerous technical fields and implications in scientific research is the calculation of the resistance force to the movement of viscous incompressible fluids. This calculation was initiated by the French mathematician Claude-Louis-Marie-Henri Navier in 1822, based on a reasoning based not on the action of molecular forces but on arbitrary assumptions [1]. Although he was the first to complete Euler's equations in ideal fluid dynamics with a term that takes into account the internal friction phenomenon, Navier did not recognize the physical significance of viscosity, attributing to his dynamic viscosity coefficient the properties of an intermolecular function. However, we should not be too exacting for Navier's mathematical work, since the inclusion of the friction phenomenon in Euler's equations was a difficult problem from the very beginning, because these equations describe the macroscopic flow velocity of the fluid in while energy dissipation occurs at microscopic level.

In the nearly two hundred years of research in the field of viscous fluid dynamics, various methods of calculating viscosity have been proposed. Most of them are based on tensor calculus and only in singular cases relations based on the principles of general physics have been obtained, using the first impulse theorem – the quantity of motion theorem [2]. The development of a simple method of calculating the strength of laminar motion resistance of incompressible fluids can therefore be regarded as one of the priority problems of modern hydrodynamics.

For the calculation of the strength of the laminar motion resistance of the incompressible viscous fluids, we apply Newton's viscous law to a fluid particle of the shape of an elementary parallelepiped of dimensions dx, dy, dz. For the beginning, examine the unidirectional motion along the *OX* axis (fig. 1). Considering tangential tension τ_{zx} linear with the length, the frictional force exerted between two neighbouring layers, spaced apart from each other, is

$$F_{\mu,zx} = \left(\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz\right) dx\,dy - \tau_{zx} dx\,dy = \frac{\partial \tau_{zx}}{\partial z} dxdydz. \qquad (1)$$

According to Newton's viscous friction law, the tangential frictional tension between two neighboring layers of the unidirectional viscous fluid is directly proportional to the linear variation of the velocity in the transverse direction to the general direction of motion, meaning $\tau_{zx} = \mu \partial v_x / \partial z$. In the hypothesis of the constant of the coefficient of dynamic viscosity for the resistance force that is exerted in the *XOZ* plane it is obtained

$$F_{\mu,zx} = \frac{\partial}{\partial z}\left(\mu \frac{\partial v_x}{\partial z}\right) dxdydz = \mu \frac{\partial^2 v_x}{\partial z^2} dxdydz \qquad (2)$$

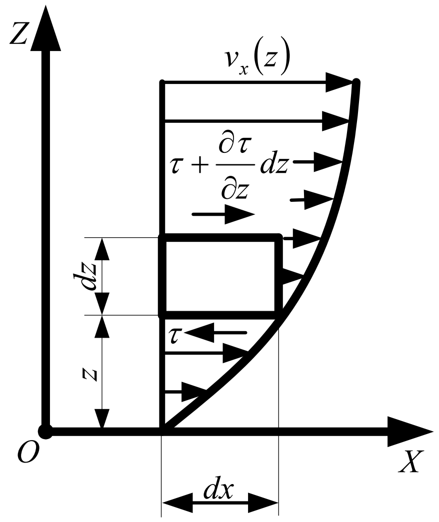

Fig. 1. Resistance strength calculation scheme.

Similar are the expressions of the resistance forces caused by the variation in the amount of motion in the other two planes:

$$F_{\mu,yx} = \mu \frac{\partial^2 v_x}{\partial y^2} dxdydz, \tag{3}$$

$$F_{\mu,xx} = \mu \frac{\partial^2 v_x}{\partial x^2} dxdydz. \tag{4}$$

The resistance force exerted on the *OX* direction is therefore

$$F_{\mu,x} = \mu \left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2} \right) dxdydz, \tag{5}$$

while a mass unit has a resistance force expressed by the mathematical relationship

$$f_{\mu,x} = \frac{F_{\mu,x}}{\rho dxdydz} = \upsilon \left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2} \right), \tag{6}$$

where υ is the kinematic viscosity coefficient.

Similar relationships can be written for the other two speed projections:

$$f_{\mu,y} = \upsilon \left(\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2} \right); \tag{7}$$

$$f_{\mu,z} = \upsilon \left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2} \right). \tag{8}$$

Consequently, the strength of resistance relative to a mass unit becomes

$$\begin{gathered}\vec{f}_\mu = f_{\mu,x}\vec{i} + f_{\mu,y}\vec{j} + f_{\mu,z}\vec{k} = \\ = \upsilon\left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right)\vec{i} + \upsilon\left(\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right)\vec{j} + \\ + \upsilon\left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right)\vec{k} = \upsilon\Delta v_x\vec{i} + \upsilon\Delta v_y\vec{j} + \upsilon\Delta v_z\vec{k} = \upsilon\Delta\vec{v},\end{gathered} \tag{9}$$

where $\vec{i}, \vec{j}, \vec{k}$ are the versors of the coordinate axes, $\Delta\vec{v}$ – the Laplace operator in three dimensions, applied to the vector function $\vec{v}(v_x, v_y, v_z)$, and $\Delta v_x, \Delta v_y, \Delta v_z$ – Laplace scalar operators.

Obtained expression is found in the Navier-Stokes equation for the laminar movement of incompressible viscous fluids [3, 4]. Therefore, the proposed reasoning can be applied to the deduction of this equation.

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EXPERIMENTAL SETUP TO STUDY BIPHASIC MIXTURES

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Abstract: *In this paper is presented an experimental setup for the study of biphasic mixtures, adapted for measurements with PIV technique, suitable for the rotor induced flow study in a cylindrical tank used in industrial processes. The design of the setup considers specific aspects of laboratory experimental activities, allowing the visualization of hydrodynamic phenomena from within and being suitable for measurements with modern PIV techniques. Also, the setup is able to replicate as many types of flow. Finally, are presented streamlines and velocity fields induced by the rotor in the mixing tank.*

Keywords: *Mixing tank, PIV, biphasic mixture*

1.Introduction

Over the centuries, researchers have studied the flow of fluids in different ways, this being still an important research field. Flow Visualization is a branch of experimental hydrodynamics that provides important information about flow phenomena. Visualization methods were the first experimental techniques used to understand the phenomena of fluid dynamics. By visualizing the flows, the qualitative aspects of the phenomena are highlighted, with quantitative conclusions being obtained only after some experiments performed with very high accuracy. Experimental viewing techniques are applied for many purposes: to get a first image of the flow of a fluid around a scalar model of a real object, without any calculations, as a source of inspiration for the development of new fluid flow theories, or to verify a new theory or a new model.
However, the flow characterization involves the use of intrusive probes or captors that cause instability in the flow, so that reproduction of phenomena does not remain faithful. Thus, in many situations the fluid flow is disturbed by the experimental technique.
In the most situations encountered in practice in the engineering field, the flows are turbulent. In these conditions, the characteristic parameters are strongly influenced by the presence of vortexes, and solving motion equations for them remains an open problem even with the use of the latest generation solvers. The Particle Image Velocimetry (PIV) measurement technique for turbulent flow characterization provides a reliable solution for validation of CFD data.
The of laser technology in the second half of the 20th century has resulted in increased use of non-intrusive measurement methods. With the introduction of gas lasers, Laser Doppler Velocimetry (LDV), developed by American researchers [1], is one of the most important advances in determining characteristic parameters of the flows. Regarding the LDV technique, significant progress has been made in signal processing techniques and in the optical components used. Also, the LDV method has been expanded to become Doppler Phase Technique, a technique that, in addition of velocity, measures particle or bubble size.
If two decades ago, the main instruments for measuring fluid velocity in a fluid were the Pitot tube and the hot wire anemometer, the main option today is the optical instrumentation. Particle Image Velocimetry (PIV) or Laser Doppler Velocimetry (LDV), are being used on a wider scale. Due to the development of the CCD and CMOS captors and the diminishing of their size, the measuring techniques (Particle Image Velocimetry, Tomography, Particle Tracking Velocimetry, Holography, etc.) have become very common in the field of Fluid Mechanics. PIV measurement techniques a suitable for a broad spectrum of velocity fields, in two and three dimensions, with maximum acquisition frequencies being suited to solving phenomena encountered in practical applications on an increasingly large scale. With these techniques velocity fields, concentration, temperature,

turbulence, particle size can be determined, because by using the data processing software other statistical quantities derived from these measurable quantities can be determined.
PIV is often used in areas where thousands of vectors have to be measured simultaneously over the entire area or volume of the flow. Being a non-intrusive method, together with Laser Doppler Velocimetry LDV technique are used when fluid flow does not have to be influenced by external factors: aeronautics, biomedical, combustion, natural sciences, etc. These methods are also often used to validate CFD models.

2. Generalities on two-phase flow study

Certain industrial applications require knowledge of the simultaneity of the flow characteristic phases. For the complete characterization of these flows, it is necessary to determine the instantaneous velocity fields of the two phases and to process the experimental data obtained using specific processing and post processing software.
Flow induced by rotor in mixing/homogenization tanks is one of the areas where the study of multiphase flow is made by optical methods. Mixing represents hydrodynamic operation which aimed homogenization (reduction of concentration or temperature gradients) within the volume to be mixed until a uniform distribution of constituent materials or temperature uniformity. Physical or chemical processes are all the more complete, as the substances involved are in a homogeneous mixture. Mixing processes are used to accelerate chemical reactions, homogenization of multiphase fluids, dissolving, acceleration of some physical processes, improving thermal transfer, etc. To achieve efficient mixing, it is necessary to obtain high velocity gradients at all points of the fluid, which results

- producing velocity with different sizes and directions, in the mixer vicinity (local mixing); if possible, creating local turbulence diffusion
- relatively slow moving of the entire volume of material, so that, periodically, all the quantity of mixture from mixing tank passes through regions where the turbulence is more intense.

Mixing efficiency is influenced by the turbulence degree and movement velocity, estimated by required time to pass for the entire quantity of material to pass through a given area (for example, the area described by the blades of the mixer). Mixing can be seen as:

- main process operation: for the homogenization of multiphase fluids to obtain solutions, suspensions, emulsions;
- auxiliary operation: to increase the heat transfer and/or substance transfer, or accelerating chemical or biochemical reactions.

As regards the experimental study of mixing processes, this is difficult due to problems encountered to making experimental models which must approximate as accurately as possible industrial installations. Another issue is represented by lack of adequate measurement methods for non-transparent multiphase mixtures. Initially the research focused on the study of mixing processes from a chemical point of view. However, these techniques provide no information about flow pattern, phase distribution and turbulence parameters (kinetic energy, effort, etc.
Up to now, punctual measurements were mainly limited to the axial particle concentration profile at relatively low concentrations using electrical methods (intrusive conductivity, impedance of the analysed samples) or electromagnetic (X-ray tomography or nuclear magnetic resonance). However, these methods, provide limited information cannot be used to characterize concentrated suspensions or measuring three-dimensional distributions [2].
Mixing is a complex process whose efficiency depends mainly by the flow pattern generated by the rotor. Mixing requirements vary according to the problem to be solved. Therefore, selecting a suitable rotor for a specific type of mixture is determined primarily by the flow patterns and the velocity profiles that it is able to generate [3].
Issues related to the study of blending processes are approached both within the university centres, as well as in the research and design centres of the equipment manufacturers. Regarding the constructive optimization of mixers, the dynamics of research and design activity, boosted by the advancement of information technology has led to development of new mixer configurations,

according to the requirements of a growing market. At international level there are prestigious firms, specialized in mixing equipment: STELZER Rührtechnik International and EKATO Group from Germany, Dynamix Inc. from Canada, CHEMINEER and SPX FLOW from SUA, etc.

3. PIV application in mixing tanks

Recent advances in optical measurement techniques, such as PIV technology, offer great advantages in measuring flow parameters, such as high precision, non-intrusiveness, high spatial resolution, etc. PIV measurement can be used for:

- validation of CFD predictions [4]
- optimizing mixing tank design by selecting the tank geometry but also selecting the type, size, placement location and rotation speed of the rotors
- optimal positioning of the tank inlet in batch or continuous regime.

The investigations carried out [5] on the flow from the mixing tanks, both experimental and numerical, highlighted the following aspects:

- high complexity and three-dimensional nature of viscous flows in mixing tanks
- the need to define global measurement techniques to investigate and validate CFD code predictions of these flows
- for similar flows, most of the techniques previously used in the experimental investigation were either intrusive (Pitot tubes, thermal probes), or punctual (LDA) or qualitative (flow visualization techniques) and cannot provide the data required to fully characterize the mixing phenomenon

3.1 Characterization of flow in mixing tanks - case study

Further is an example of flow characterization in mixing tanks [6]. The tank used is transparent, cylindrical and contains three Rushton rotors, each with six rectangular radial blades, placed equidistant along the height of the vessel. The mixing tank is shown in Figure 1, and the testing was done under the following conditions:

- mixing was performed at two speed, 175 rpm and 575 rpm, corresponding to Reynolds numbers 38 and 124
- the signal from an encoder integrated in the mixing system shaft was used to synchronize the PIV acquisition phase
- a programmable delay time generator integrated into the processor synchronization module gave the ability to change relative acquisition time within one blade passage cycle
- within this cycle, for each speed two stages were investigated $\theta = 0°$, respectively $\theta = 30°$, where $\theta = 0°$ corresponds to the case when the blade is parallel to the laser plane.

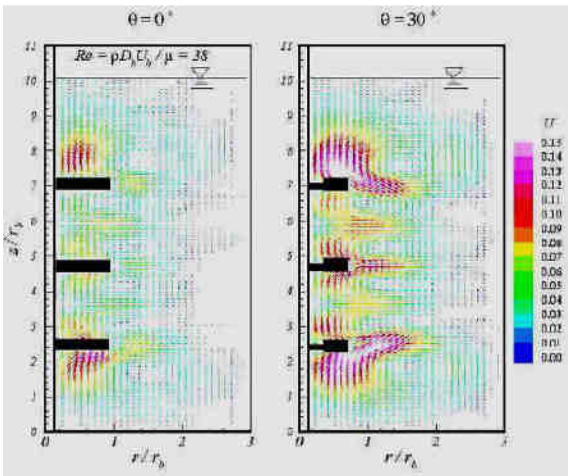

Fig. 1. Flow characterization in mixing tanks [6];

Data processing was done by cross correlation of the double frame images and then validation of raw vector maps using peak and moving average. The resulting velocity vector maps are averaged to obtained a single vector map that corresponds to one measurement.

4 Design and building of the experimental setup

An experimental setup to study the flow induced by rotors in cylindrical tanks such as those used in the chemical, food, pharmaceutical, energy, was designed and developed. The system designed has taken into account constructive aspects specific to conducting experimental laboratory activities. Thus, to allow a good view of hydrodynamic phenomena from the inside, tank is made of transparent Plexiglas. Also, to reproduce as many types of flow typical of the industrial processes, setup allow changing the rotor mounting height or operating parameters (height and diameter of the liquid column, rotor speed, blade shape and pitch angle etc.).
The experimental setup consists of cylindrical tank with diameter ∅ 300 mm, height H = 500 mm, wall thickness = 5 mm, provided with square covers and outflow valve Figure 2. A mixing system, consisting of a 10mm diameter shaft on which they can be mounted rotors of different types and sizes, ensures liquid flow into the setup. The mixing system is driven by a variable speed DC electric motor in the range 15 ÷ 2000 rpm, provided with a digital speed and torque indicator and fixed on tank cover.
In order to minimize optical distortions caused by curvature of cylindrical tanks, the cylindrical tank was introduced in a transparent Plexiglas rectangular tank (wall thickness 15 mm) (Figure 3). The material has been chosen so that the optical distortion is minor and can be corrected in the post image processing stage. Figure 3 shows the experimental setup for study dynamics in mixing tanks.

Fig. 2. Cylindrical tank

Fig. 3. Experimental setup

5. PIV arrangement and Calibration process

5.1 The custom target

PIV image calibration is done using a custom target with very precise features that allows computation of the transfer function between image output of the camera and reference system of the measurement area. The laser sheet and the camera are focused on the target plane, which will become measurement plane (the target is removed during measurements) (Figure 4b). The target is placed in the symmetry axis of the mixing tank. The calibration target was dimensioned to fit in the diametral section of the tank (Figure 4a).

Fig. 4 a. The custom target in the mixing tank.

Fig. 4 b. PIV setup

The distance between target marks was chosen so the conditions (1) and (2) to be respected.

$$\sqrt{\frac{A}{N_{max}}} \le d \le \sqrt{\frac{A}{N_{min}}}, \tag{1}$$

where A is the measurement area, N_{max} = 1600 and N_{min} = 100 represent the maximum and minimum recommended number of marks [7].
The superior limit of 1600 assure a good separation of the marks on the output image. For example, for a 1600 marks target and CCD sensor with a resolution of 1.3k × 1.3k pixels, the smallest mark is about 27 pixels in diameter.
Another condition [7] is to have at least 5 marks on each direction of the target, which can is described by:

$$d \le \frac{W}{5};\ d \le \frac{H}{5}, \tag{2}$$

where W is width and H height of the target.
To have a Zero mark in the target centre, the computations usually aim towards an odd number of marks per direction. Once the distance between marks is chosen, the mark diameters are chose using the following rules [7-9]:

Zero mark: $$\phi_{Zero} \le d/2; \tag{3}$$

Axis marks: $$\phi_{Axis} \le d/4; \tag{4}$$

Main marks: $$\phi_{main} \le d/3\,. \tag{5}$$

The resulting target has *d* = 10 mm, ϕ_{Zero} = 4 mm, ϕ_{Axis} = 2 mm, ϕ_{main} =3 mm, N = 1053 markers, covering an area of 400×280 mm.

5.2 PIV measurements

The experimental setup, designed for PIV measurements, is composed by a parallelepipedal tank filled with water, in which the cylindrical mixing tank is inserted (Figure. 4). The material used for the tank construction is Plexiglas® 0A000 XT. It has a refractive index of 1.49 for a wavelength of 527 nm, close to the water refraction index of 1.33 at same wavelength. The transmittance (transmissibility index) of the material is 92%. In this way, the optical distortion is mitigated before acquisition. Further correction is done in post-processing, using the transfer function determined on image calibration.

The light source consist on a DualPower TR 15-1000 laser, which is a pulsed Nd:YAG laser of 30 mJ with the wavelength of 527 nm and pulse duration of ~150 ns.

The camera, placed perpendicular to the measurement plane respectively to the laser sheet (Figure 4b), is a FlowSenseEO_4M-32, a monochrome CCD camera with resolution of 2072×2072 pixels. The camera is used in double frame mode with exposure time for frame 1 at 15 μs.

As tracers, S-HGS particles - silver coated hollow glass spheres of 10 μm in diameter and density of 1.4 g/cm3, are used. The particles are chosen to respect the flow but also to assure a good SNR (signal to noise ratio) of the image, a clear peak in cross-correlation map and a uniform distribution of the tracers. DynamicStudio software from Dantec Dynamics was used for configuration, data acquisition, and post-processing.

Measurements were run for two rotating speeds, of 60 rpm and 120 rpm, with an acquisition rate of 4 and, respectively, 8 (double) frames per second.

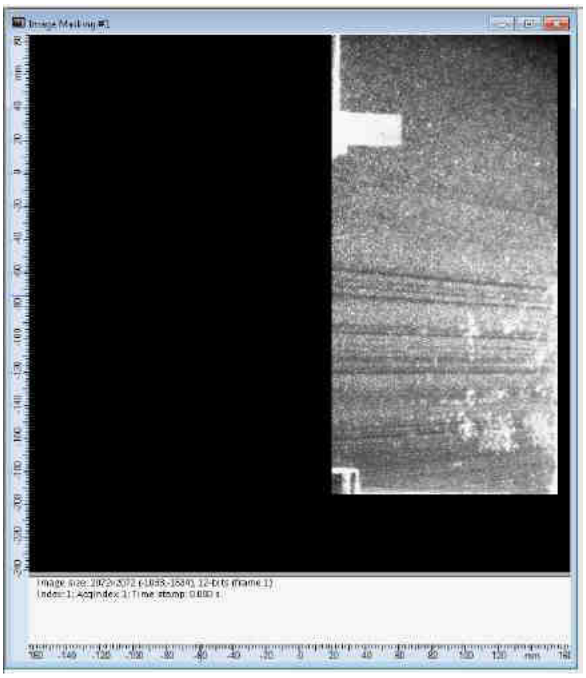

Fig. 5. The processed image for Adaptive PIV

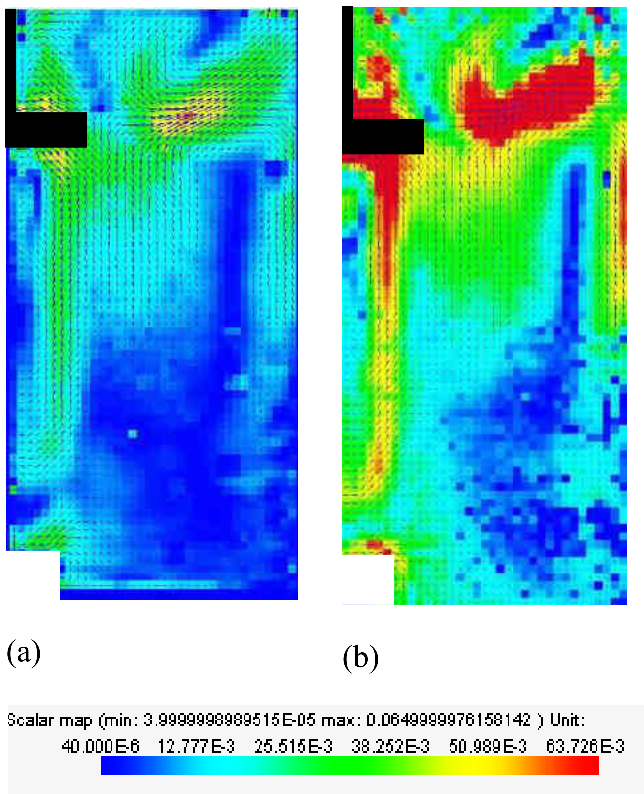

Fig. 6. Mean velocity fields corresponding to rotating speeds of 60 rpm (a) and 120 rpm (b)

Captured raw images were pre-processed to remove the areas outside of the study area and then Adaptive PIV analysis module was applied to transform the double frame images in a set of velocity vector fields. A local validation of the velocity vectors is done by DynamicStudio, considering an axial symmetric flow (Figure 5). Vector Statistics module was used to calculate the mean velocity vector from the data set, at each point from the right side vector field (Figure 6). A streamline representation of the vector field is shown in Figure 7.

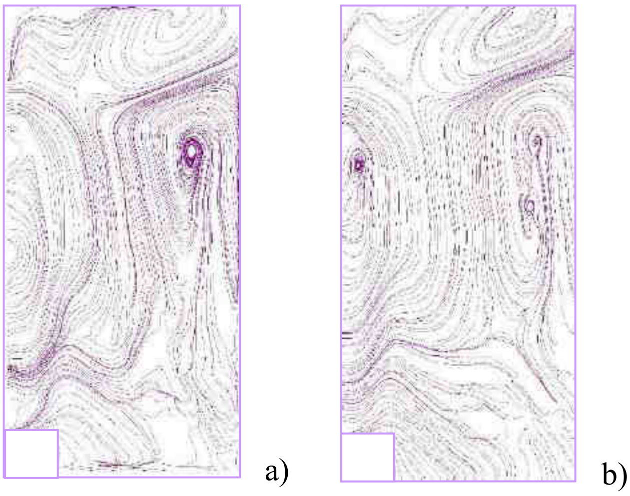

Fig. 7. Streamlines corresponding to rotating speed of 60 rpm (a) and 120 rpm (b)

The database obtained can be utilized to solve problems specific to mixing phenomena: simultaneity and phase interaction [6], shape coefficient of the phases, the degree of homogenization etc.

6. Conclusions

An experimental setup was design and build for the study of the induced flows in cylindrical mixing tanks. In order to be able to reproduce many types of industrial processes, the setup allows adjustment of the rotor height, rotating speed and liquid column.
Using the PIV technique, mean velocity fields and associated streamlines were determined for two mixing rotating speeds. The flow in the mixing tank can be observed as well near the rotor blade, as also in the all study area of the tank. The experiment can be used for identification of still zones in the mixing process and for the optimization of the mixing parameters (tank shape, rotor speed and mounting height, blade shape and pitch angle etc.). Future works will be performed to study these parameters.

Acknowledgments

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RELIABILITY MODELLING OF HYDROSTATIC EQUIPMENTS AND SYSTEMS DRIVES

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Abstract: *In industrial practice it is important to develop systems with a high degree of reliability. Even from the design phase of a technical system project, it is possible to ensure both system reliability (functional reliability) and the technological reliability of the system manufacturing process by using the probabilistic design concept. The numerical evaluation of a system's reliability can be achieved by various numerical simulation methods based on statistical mathematical models. This paper presents the way in which statistical models are applied in the study of the reliability of hydrostatic equipment and systems, mentioning the research currently underway at INOE 2000-IHP.*

Keywords: *Maintenance, distribution function, mathematical model, reliability, hydraulic drives*

1. Introduction

Reliability (or safety) in operation of a technical system or product is the probability that the system/product will function without failures on a specified period of time in given environmental and operating conditions [1, 2]. The prediction of reliability is considered statistically. Environmental and operating conditions includes constraints on the use of the system/product with the reliability of that we determine, as long as these conditions remain unchanged for all similar products.

The event that leads to stopping a product is called failure. Failures are discrete events over time which are depended on the process reached as the fault state. From this point of view, failures can be instantaneous or gradual.

The behavior of the technical system over time is characterized by parameters of the time-dependent system. Considering the uncertainties associated with these parameters, the assessment of the possibility of a malfunction can only be made in probability terms [2].

If the system parameters are time independent, we can no longer talk about a system reliability issue.

The analysis of a system's reliability, or the analysis of the probability of system's failure, starts from the system specific performance criterion ($\tilde{Z}$), the essential parameters (X_i with $i = 1, \dots, n$), *t* time and the appropriate relationship:

$$\widetilde{Z} = g\left(X_1, X_2, \dots, X_n\right). \tag{1}$$

The numerical evaluation of a system/product's reliability can be achieved using a simulation method that generates different possible system states based on system reliability functions and evaluating all times the performance of the system.

The ratio between the number of situations in which the system does not fail and the total number of simulations for a given possible status is an estimate of the system's reliability. The accuracy of the estimation depends on the number of simulations made.

A simulation algorithm for estimating the reliability of a system/product includes: the generation of a random number in the range of [0.1]; the initialization of algorithms to generate the reliability functions of the system (or component); the finding of the performance function of the system; the

generation of the individual reliability of system components; and finally find the reliability of the entire system.
The reliability calculation is characterized by a certain degree of confidence, due to the limited nature of statistical information about the system. Statistical system information relates to the behavior of the system over time, specifying operating times, malfunctions, operating and failure conditions, fault components in the system and causes of their failure.
The statistical information requires the existence of a database.
The advantage of the numerical simulation is to be able to make experiments on a mathematical model of the system with the determination of the reliability indicators.

2. Reliability indicators

Reliability indicators are: the reliability function $R(t)$, the function of the fault density $f(t)$, the hazard function or the instantaneous fault rate $h(t)$, the average operating time t_m, dispersion of operating time σ_t^2, the average square deviation of the operating time σ_t, [2].
The reliability aim is the performance analysis of a system or product without defects. If we assume that we have a population of *N* products and that after *t* years N_d products are out of order and N_s products are functional $N=N_s+N_d$ then the N_s/N ratio is that the product will work after *t* years, and this is the product reliability in the *t* time. If *T* is the failure time, *T* being a random variable, then the probability that this time will exceed any specific time *t*, that is $P(T > t)$ the expression of the product's reliability at time *t*, and the function is denoted $R(t)$, the product reliability:

$$R(t) = P(T > t) = N_s(t)/N. \tag{2}$$

The probability of failure before time *t* is expressed as:

$$F(t) = P(T < t) = N_d(t)/N. \tag{3}$$

Reliability and failure are complementary functions,

$$R(t) + F(t) = 1. \tag{4}$$

The failure rate of a product is the frequency with which similar products of the *N* product family are defective, respectively:

$$f(t) = \frac{dF(t)}{dt} = \lim_{N\to\infty} \lim_{\Delta t\to 0} \left(\frac{1}{N} \frac{\Delta N_d}{\Delta t} \right). \tag{5}$$

The failure rate over time is represented by the failure density function.
The instantaneous fault rate or the hazard function has the expression:

$$h(t) = \lim_{N_s\to\infty} \lim_{\Delta t\to 0} \left(\frac{1}{N_s(t)} \frac{\Delta N_d}{\Delta t} \right) \tag{6}$$

or

$$h(t) = \frac{f(t)}{R(t)}. \tag{7}$$

The average failure time of a system/product is equivalent to the probability of its distribution and is estimated by mediating the defect density function,

$$T_{mf} = \int_0^\infty R(\tau) d\tau. \tag{8}$$

For a discrete data set, the integration operation is replaced by a summary operation and the average failure time becomes, $T_{mf} = \sum_{i=1}^{N} R_i(t_i)\Delta t_i$.

An example of the reliability and hazard function as well as the mean failure time for a group of 100 identical hydraulic directional valves for which failure times were recorded over 150 days intervals ($\Delta t_i = 150$). The problem data and results are presented in Table 1.

Tabel 1: Reliability indicators

Days of working	Number of failure valves $N_d(t_i)$	Number of working valves $N_s(t_i)$	Reliability $R(t_i)$	$f(t_i)$	$h(t_i)$t
0-150	1	99	0.99	0.03	0.030303
150-300	3	96	0.96	0.05	0.052083
300-450	5	91	0.91	0.15	0.164835
450-600	15	76	0.76	0.24	0.315789
600-750	24	52	0.52	0.3	0.576923
750-900	30	22	0.22	0.15	0.681818
900-1050	15	7	0.07	0.07	1
1050-1200	7	0	0	0	

The average failure time calculated as the sum of the time interval Δt_i and the reliability $R(t_i)$ is:

$$T_{mf} = 148.5 + 144 + 136.5 + 114 + 78 + 33 + 10.5 = 664.5 \text{ days}$$

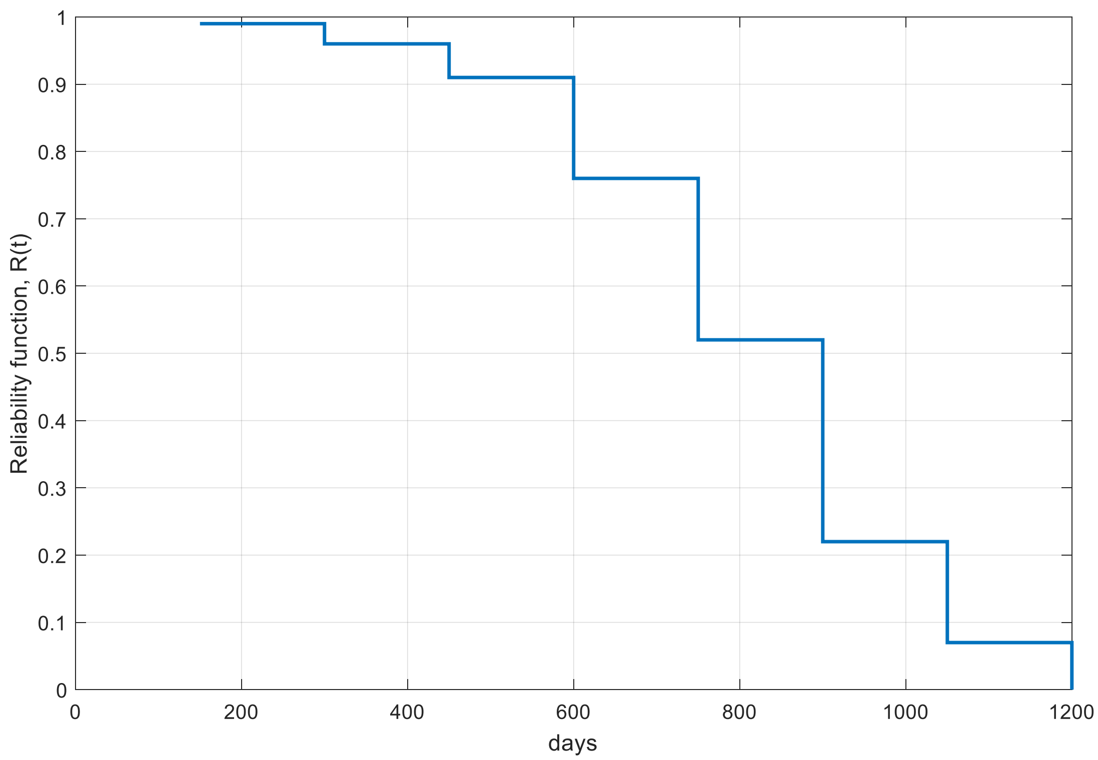

Fig. 1. The reliability function

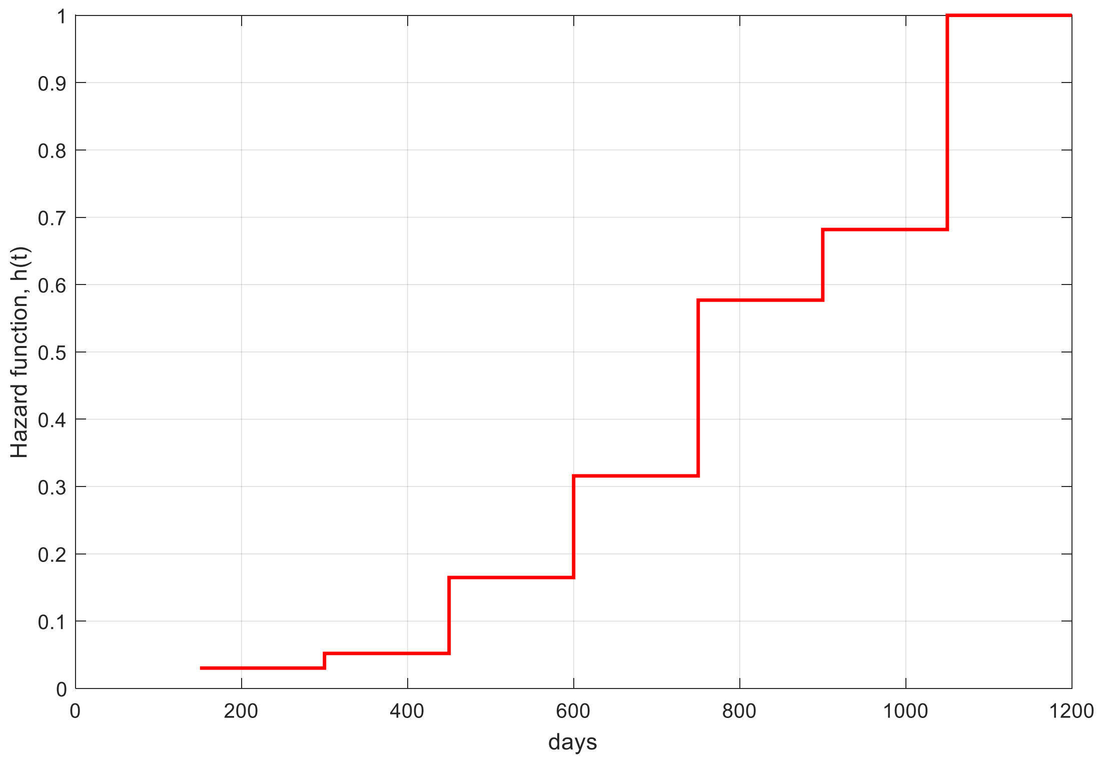

Fig. 2. The hazard function

It can be seen in the graphical representation of the reliability function (Fig.1) that between 900 and 1050 days of operation the reliability decreases suddenly and the hazard function (Fig.2) rises to high values. This information is useful for planning preventive repairs and supplying spare parts.

3. Mathematical models of failure rate

The reliability calculation is characterized by a certain degree of confidence due to the limited nature of the statistical information characterizing the system/product. Statistical information is based on laboratory experiments, manufacturer's real endurance testing, and product data baseline databases for different beneficiaries.

The mathematical modeling of complex system/product operation has the advantage of reducing the time and costs of laboratory experiments that can be replaced by numerical simulations. There are some models that can describe several experimental data series. The most common distribution models are the exponential distribution, Weibull distribution and normal distribution [2].

In the literature it is specified that for electrical equipment the fault function is usually modeled with exponential distributions functions,

$$f(t) = \frac{1}{\lambda} e^{\left(-\frac{t}{\lambda}\right)},\ t \leq 0,\ \lambda > 0, \tag{9}$$

where λ is a distribution parameter representing the average failure time in percent. The reliability function for the exponential distribution of the fault function is:

$$R(t) = e^{\left(-\frac{t}{\lambda}\right)}. \tag{10}$$

Under these conditions the average failure time is $T_{md} = \lambda$ [2].

In Table 2 are given the functions of failure rate, reliability and hazard function for Weibull and normal exponential distributions [2, 4].

Tabel 2: Models of failure rates

	Exponential distribution	Weibull distribution, biparametric case	Normal (Gaussian) distribution
Failure function	$f(t)=\frac{1}{\lambda}e^{\left(-\frac{t}{\lambda}\right)}$	$f(t)=\lambda(t)e^{\left(-\left(\frac{t-\delta}{\theta-\delta}\right)^{\beta}\right)}$ with $\lambda(t)=\frac{\beta}{\theta-\delta}\cdot\left(\frac{t-\delta}{\theta-\delta}\right)^{\beta-1}$	$f(t)=\frac{1}{\sigma\sqrt{2\pi}}e^{\left(-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^{2}\right)}$
Reliability function	$R(t)=e^{\left(-\frac{t}{\lambda}\right)}$	$R(t)=e^{\left(-\left(\frac{t-\delta}{\theta-\delta}\right)^{\beta}\right)}$	$R(t_a)=1-\Phi(t_a)$ with $t_a=\frac{t-\mu}{\sigma}$ and $\Phi(t_a)$ Laplace integral function with tabular values in [3].
Hazard function	$h(t)=\frac{f(t)}{R(t)}=\frac{1}{\lambda}$	$h(t)=\frac{\beta}{\theta-\delta}\cdot\left(\frac{t-\delta}{\theta-\delta}\right)^{\beta-1}$	$h(t)=\frac{f(t)}{R(t)}$
Recommendation [1,2,3]	Electrical equipments	Mechanical and hydraulic equipments	

The significance of the Weibull distribution parameters is:

- *δ* local constant, expressed in time units and defining the starting point or origin of the distribution. If the tracking of the system coincides with the start of the operating period (even after repairs) $\delta = 0$, if not $\delta > 0$. If *δ* cannot be determined, then it is considered that experimental data cannot be represented by the Weibull distribution [2].
- *β* the form coefficient that controls the form of distribution. Weibull distribution approximates any of the three operating times of a system/product: $\beta < 1$ for early failures, $\beta = 1$ for random failures and $\beta > 1$ for wear-related defects [2].
- *θ* is the scale constant.

When $t-\delta=\theta-\delta$ the reliability is constant and $R(1)=e^{-1}=0.368$, this means that 68.2% of the products may fail if $t=\theta$.

In the case of normal distribution (or Gauss), *μ* is the mean of *t* time values and *σ* is the mean square value.

In general, the wear-related defects are modeled using Weibull or Gauss distributions and are characteristic of mechanical and hydraulic systems.

For the hydrostatic test rig in the INOE 2000 Hydraulics Laboratory, a theoretical reliability estimation study was conducted for one of the volumetric pumps in the test rig, Figure 3.a. The rig is equipped with five volumetric pumps capable of running in parallel in different work formations adapted to different working conditions.

It was considered the exponential distribution of the reliability function for one of the five pumps (Figure 3.b), and Weibull distribution, Table 2, to compare them. The parameter of each distribution was modified: *λ* for the exponential distribution, *β*, *δ* and *θ* for the bi-parametric normal distribution. The Figures 4, 5 and 6 plots the evolution of the reliability function for each distribution case.

Although the exponential distribution is characteristic for the electrical systems [1], this type of distribution has been adopted for a hydro-mechanical equipment in which the wear phenomenon is characteristic. The parameter *λ* has changed from very low values, which corresponds to a small average failure time (T_{md}=0.00003 ore) at a failure time of 0.003 hours. From the graphical representation of reliability (Figure 4) it can be observed that the pump reliability reaches below 75% after 10,000 hours of working if λ = 0.00003 and drops sharply to less than 10% after less than 1,000 hours if λ = 0.003.

a) b)

Fig. 3. Hydrostatic test rig at the INOE 2000 Hydraulic Laboratory,
a) test rig; b) piston hydraulic pump with fixed cylinder, PVV4-1X / 122RA15UMC, produced by Rexroth (photo by A.D. Marinescu)

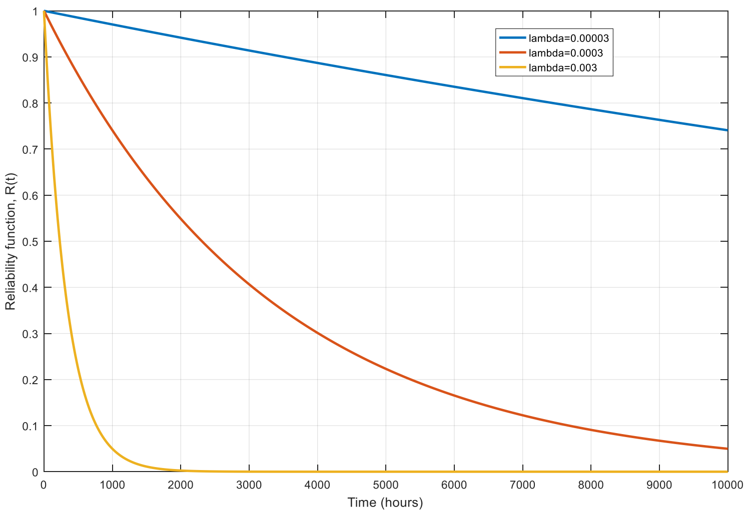

Fig. 4. Behavior of the volumetric pump at reliability exponential distribution and various λ.parameters

The Weibull distribution function is recommended for modeling the reliability of mechanical systems, and this category includes hydraulic equipments. Two working situations were considered:

- when tracking the product's running time coincides with the commissioning period, and then δ = 0 [2, 3], Figure 5;
- when monitoring period of the operation pump begins later and the local constant δ > 0, respectively δ = 2, Figure 6.

It is observed that the allure of the two graphical representations is similar between them but very different (regarding the rate of the function decrease) towards the representation of reliability through the exponential distribution function. Modifying the β form constant, controls the form of distribution. Figure 6 shows that for values of β = 0.6 and β = 1, the value of reliability at the beginning of the observation period (t = 0), given for δ = 2, is well above 100%, which is physically impossible. This means that the experimental data for estimating the Weibull distribution parameters were not correctly determined.

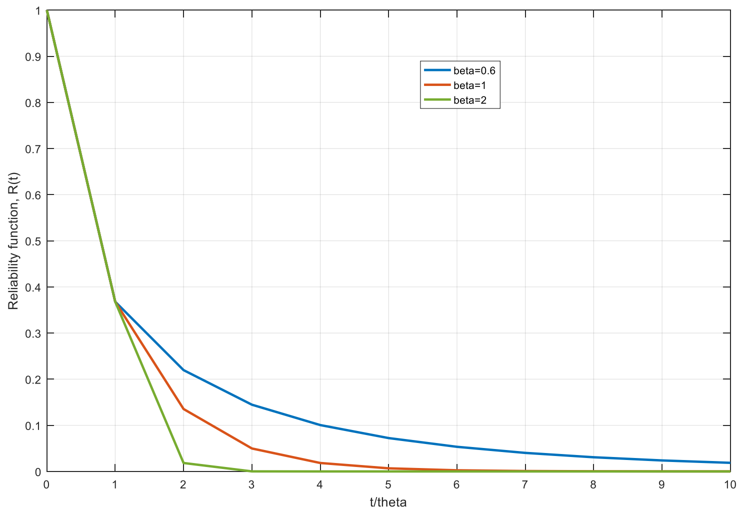

Fig. 5. The reliability behavior of the volumetric pump,
for Weibull distribution for the local constant δ = 0 and different parameters of form β.

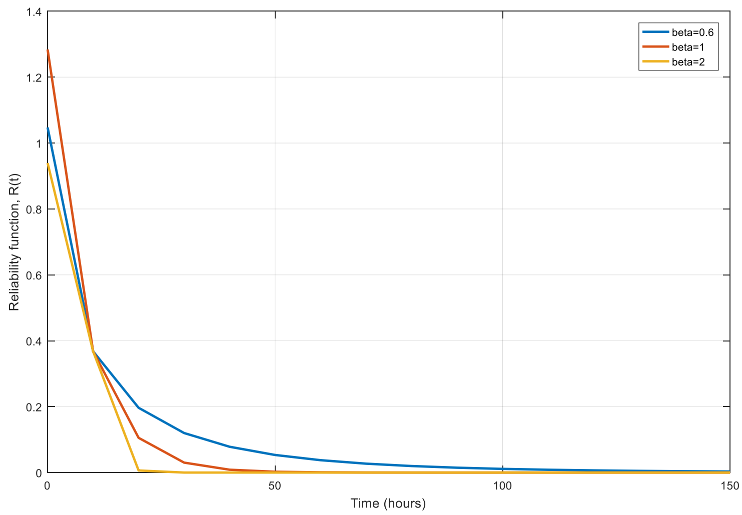

Fig. 6. The reliability behavior of the volumetric pump,
through Weibull distribution for the local constant δ = 2 and different parameters of form β.

Generating a Weibull distribution function is based on experimental, laboratory or in-situ measurements regarding the product performance. For example, for the same pump type, the failures times are record and the Weibull distribution is plotted for δ = 0. The Weibull reliability function is plotted in logarithmic coordinates, Table 2, considering that:

$$\ln\ln[R(t)]^{-1} = \beta[\ln(t-\delta) - \ln(\theta-\delta)]. \tag{11}$$

As the failure, $F(t)$, is the non-reliability due to the relation (4) it is obtained:

$$\ln\ln[1-F(t)]^{-1} = \beta[\ln(t-\delta) - \ln(\theta-\delta)], \tag{12}$$

relationship that becomes linear $y = \beta x + c$ using the notations:

$$y = \ln\ln[1-F(t)]^{-1},\ x = \ln(t-\delta) \text{ si } \quad c = -\beta\ln(\theta-\delta). \tag{13}$$

The representation of the reliability according to the failure time in the double logarithmic ordinate and the simple logarithmic abscissa is a straight line, Figure 7.

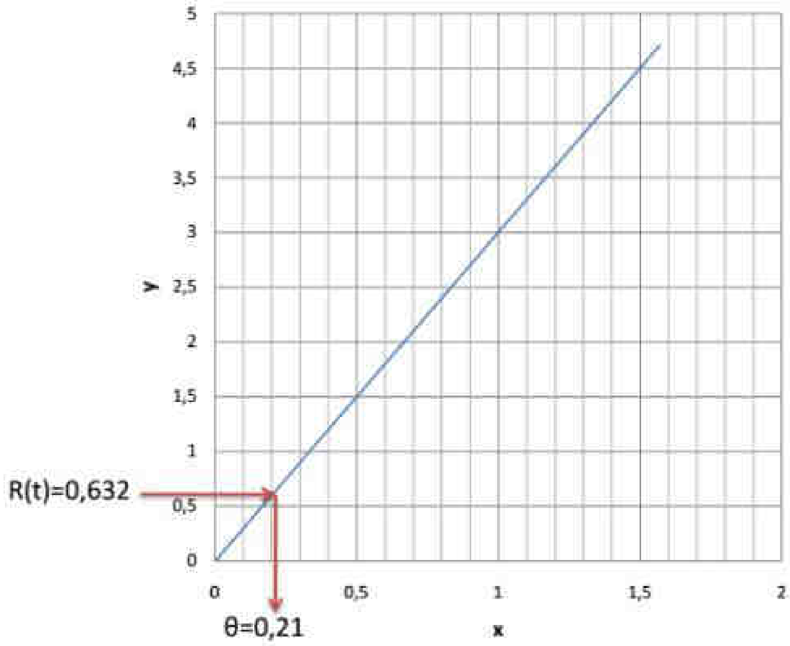

Fig. 7. Weibull distribution function in logarithmic coordinates

The slope of the straight line is β and θ is calculated knowing that $R(t=\theta)=0.368$ and $F(t=\theta)=0.632$. From the abscissa projection of the non-reliability point is found the value of θ, Figure 7.

4. Conclusions

Methods for estimating the reliability of hydrostatic drive systems are useful tools in the management maintenance of these systems.

This paper highlights the importance of determining the correct mathematical model to describe the distribution functions associated with the reliability of hydraulic drive systems. Also, the paper presents the working method for determining the reliability of a hydrostatic equipment having the information on the behavior of the system/product over a time period by using discrete variables.

The second example of the mathematical modeling of the hydrostatic equipment reliability highlights the importance of a correct parameters evaluation which characterizes the associated mathematical model. Determining the mathematical models is an important step in the reliability process simulation of a system, whatever the simulation method is used: Monte Carlo, Go, FTA (Fault Tree Analysis).

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APPLICATION OF KINETIC AND THERMODYNAMIC MODELS FOR AMMONIUM ION REMOVAL USING A NATURAL ZEOLITE

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Abstract: *The present study focuses on the removal of ammonium ion (NH_4^+) from aqueous solutions using a natural zeolite. The adsorption process was studied to establish the optimum zeolite quantity, using various initial NH_4^+ concentrations and different temperatures in order to identify the best uptake conditions. The adsorption kinetics showed that the ammonium removal can be describe by the pseudo-second order kinetic model. Furthermore, the thermodynamic analysis suggested that the adsorption process was exothermic at temperatures between 283 and 303 K. The obtained results indicated that the natural zeolite has a great potential for ammonium removal.*

Keywords*: Zeolite, ammonium, removal, kinetics, thermodynamic*

1. Introduction

Wastewater management became a priority during the last decades. There is a main interest for the use of new, alternative technologies and materials for the removal of hazardous waste. The use of natural zeolites can offer new environmental-friendly remediation possibilities [1]. Natural zeolites are classified as microporous materials and have several unique properties such as high ion-exchange capacity, thermal stability, non-toxicity, high surface areas, adsorption and molecular sieve capabilities for several water contaminants due to their structural characteristics [2-4]. Zeolites are aluminosilicate minerals containing exchangeable alkali and alkali-earth metal cations in their three-dimensional framework structure [5]. Moreover, their ion selectivity is effective even in aqueous solutions containing more than one competing ions [6]. Zeolites can be used effectively as ion-exchangers, catalysts, adsorbents in several fields such as oil refining, chemical and petrochemical industry, agriculture, water and wastewater treatment [7].
Ammonia is widely used as cleaning and bleaching agent in many industries. Ammonia pollution has a negative effect on the environment, water quality of water bodies, can cause surface –water eutrophication and has toxic effects on human health [8].
Wastewater treatments based on ion-exchange methods are considered to be more effective for the removal of ammonium than air-stripping or any biological methods. Thus, ion-exchange is an attractive method due to the operation as well as application simplicity, technical feasibility and economic viability by using low-cost materials [9].
Several studies have focused on the application and evaluation of zeolites as potential adsorbents for the removal of heavy metals and ammonium from wastewaters [10-14]. Natural zeolites capacity and performance cannot be predicted only by determining the zeolites chemical-physical parameters, full-scale laboratory studies are needed to evaluate their performance for any practical applications. Natural zeolites cation exchange capacity depends on the nature of the cation, contact time, initial concentration, pH and temperature [15].
In the present study a natural zeolite from the region of Chilioara, Salaj County, Romania was examined for the adsorption of ammonium from aqueous solutions under various conditions (effect of zeolite quantity, initial NH_4^+ concentration and effect of temperature). Laboratory-scale investigations were conducted in order to determine the kinetic and thermodynamic characteristics of ammonium exchange using natural zeolite as adsorbent.

2. Materials and methods

2.1. Materials and solutions

The natural zeolite was obtained from Chilioara, Salaj County, Romania. The zeolite was washed with distilled water several times and was sieved in order to obtain a fixed granulation size 0.5 - 1.25 mm prior to its use.

2.2. Solutions

The stock solution, 1 g/L ammonium solution (purchased from Merck, Germany) was prepared by dissolving NH_4Cl salt in distilled water. A series of solutions (20 - 190 mg/L) were prepared by diluting the stock solution of 1 g/L NH_4Cl.

2.2. Apparatus and analytical procedure

Adsorption experiments were performed in batch mode for 300 min, contacting different quantities of zeolite (1 - 5 g) with 100 mL ammonium solutions of different initial concentrations (20 - 190 mg/L) at three temperatures. All the experiments were realized in triplicate and the average value was used.
Ammonium concentration has been determined by ultraviolet–visible spectrophotometer using Perkin Elmer Lambda 25 equipment.

The ammonium amount in the adsorbent phase, q_e (mg/g) was calculated using equation (1), while ammonium removal efficiency, E (%) was calculated using equation (2).

$$q_e=\frac{(C_0\text{-}C_e)}{m}\cdot\frac{V}{1000} \tag{1}$$

$$R(\%)=\frac{(C_0\text{-}C_e)}{C_0}\cdot 100 \tag{2}$$

where, q_e is the ammonium amount adsorbed per gram of adsorbent at equilibrium (mg/g), V is the volume of solution (mL), m is the weight of zeolit (g), C_e is the equilibrium ammonium concentration (mg/L) and C_0 is the initial ammonium concentration (mg/L) [16].

3. Theoretical

3.1 Kinetics models

3.1.1 Pseudo-first-order kinetic model

The pseudo-first-order kinetic model equation can be expressed as follows:

$$\ln\left(q_e - q_t\right) = \ln q_e - k_1 t \tag{3}$$

where q_t is the ammonium amount adsorbed at time t, k_1 first-order rate constant.

Pseudo-first-order parameters q_e and k_1 can be obtained from the slope and intercept of the plot ln (q_e - q_t) *vs.* t [17].

3.1.2 Pseudo-second-order kinetic model

The pseudo-second-order equation can be expressed as [18]:

$$\frac{t}{q_t}=\frac{1}{k_2\,q_e^{\,2}}+\frac{1}{q_e}t \tag{4}$$

where k_2 is the second order rate constant [19].

Pseudo-second-order parameters q_e and k_2 can be obtained from the slope and intercept of the plot of t/q_t vs. t.

3.2 Thermodynamic parameters

The thermodynamic parameters can be determined as follows:

$$\Delta G^0=-RT\ln K_d \tag{5}$$

$$\Delta G^0=\Delta H^0-T\Delta S^0 \tag{6}$$

$$\ln K_d=-\frac{\Delta H^0}{RT}+\frac{\Delta S^0}{R} \tag{7}$$

where, $\Delta G°$ is Gibbs free energy, $\Delta H°$ is the enthalpy (kJ/mol), $\Delta S°$ is the entropy (kJ/K·mol), K_d (q_e/C_e) is the distribution coefficient (L/g), R is the universal gas constant (8.314×10^{-3} kJ/K·mol), T is temperature (K) [20, 21] .

$\Delta H°$ and $\Delta S°$ can be calculated from the slope and intercept of the plot $\ln K_d$ vs. 1/T

4. Results and discussions

4.1 Effect of zeolite quantity

The experiments were performed by contacting different zeolite quantities (1 - 5 g) with 100 mL ammonium solutions (20 mg/L). The obtained results can be seen in Fig 1.

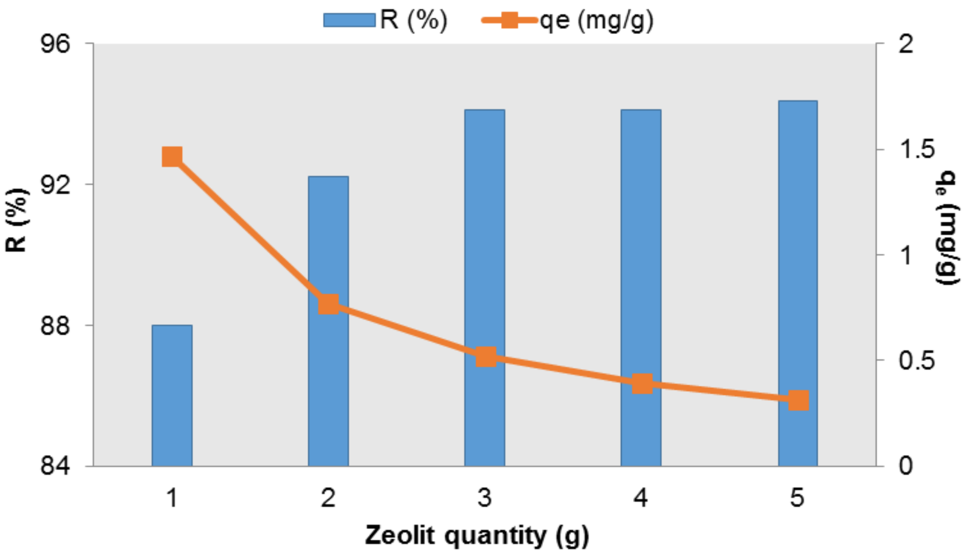

Fig. 1. The effect of zeolite quantity. C_0 = 20 mg/L; pH= 5.6; m = 1 - 5 g; particle size: 0.5 - 1.25 mm; V = 100 mL; 100 rpm; t = 20 °C ± 2 °C.

As the zeolite quantity increases the removal efficiency of ammonium increases due to the availability of a larger number of vacant absorbent sites (implicitly, a higher adsorption area is available). According to the obtained results, the removal efficiency increased rapidly (1 g of zeolite), after which a slight increase was observed at quantities greater than 2 g of zeolite used. Therefore, when ammonium ions are completely exchanged with the cations on the surface of the zeolite, at a certain amount, ammonium removal reaches equilibrium [9]. Based on the obtained results it was decided to perform the following tests using 3 g of natural zeolite.

4.2 Effect of initial concentration

The experiments were performed by contacting a fixed quantity of natural zeolite (3 g) with 100 mL ammonium concentration (20 - 190 mg/L). The obtained results are presented in Fig 2.
In the studied range of concentration, NH_4^+ removal was rapid in the first 15 minutes, after that the NH_4^+ removal slightly decreased until the equilibrium was reached. Under these conditions an amount in the adsorbent phase of 0.51 mg/g was obtained for 20 mg/L initial concentration (95.7%) and 4.33 mg/g (75.6%) for 190 mg/L initial concentration.

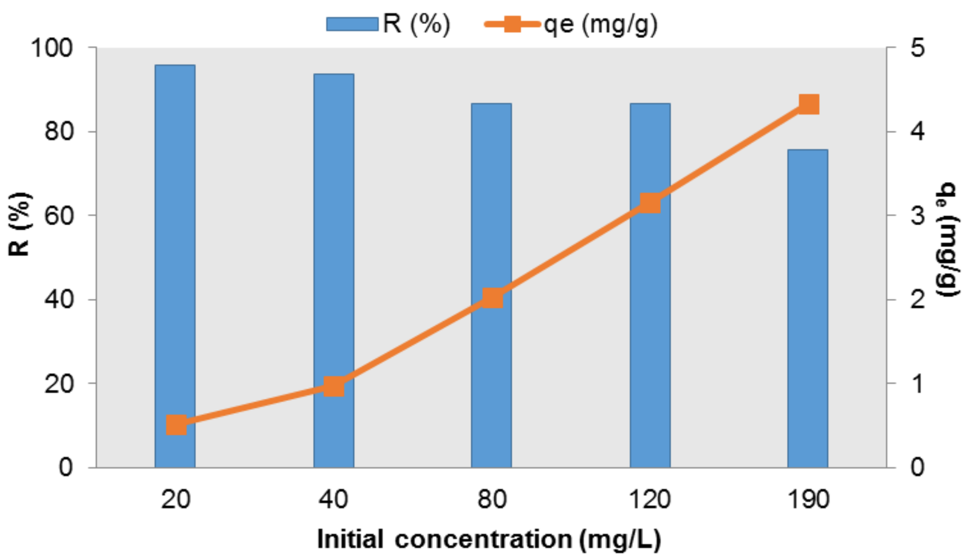

Fig. 2. The effect of initial concentration: C_0 = 20 - 190 mg/L; m = 3 g; particle size: 0.5 - 1.25 mm; V = 100 mL; 100 rpm;t = 20°C ± 2°C.

The capacity of the natural zeolite for ammonium removal increases with increasing initial concentration due to mass transfer. Thus, ammonium ions could migrate from the surface of the zeolite into its pores at a certain contact time (exchange between ammonium ions and zeolite cations could occur both on the zeolite surface and pores, respectively) [9].

4.3 Effect of temperature

In order to study the effect of temperature for ammonium removal on natural zeolite the experiments were performed by contacting 3 g natural zeolite with 100 mL ammonium solution (20 mg/L) for 300 min at 100 rpm at three different temperatures.

The results are presented in Fig 3.

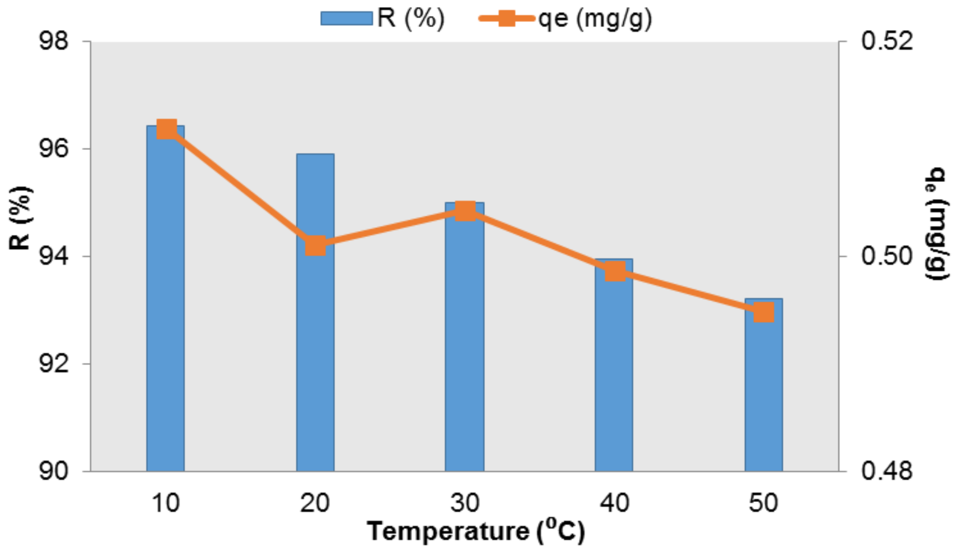

Fig. 3. The effect of temperature: t = 10 - 50 °C; C_0 = 20 mg/L; pH = 5.6; m = 3 g; particle size: 0.5 - 1.25 mm; V = 100 mL; 100 rpm.

The results showed that with increasing temperature the ammonium removal slowly decreases. A maximum removal efficiency of 96.4 % was obtained at a temperature of 10 °C and a minimum removal efficiency of 93.2 % was obtained at a temperature of 50 °C.

4.4 Kinetic models

Pseudo first parameters are presented in Table 1**.**

Table 1: Pseudo-first and pseudo-second order kinetic constants

Kinetic model	Parameters	U.M.	20 mg/L	40 mg/L	80 mg/L	120 mg/L	190 mg/L
Pseudo-first order	k_1	1/min	0.016	0.020	0.016	0.018	0.015
	$q_{e,calc}$	mg/g	4.05	1.93	1.88	3.13	3.55
	R^2		0.9031	0.8932	0.9619	0.9273	0.9919
Pseudo-second order	k_2	g/mg·min	0.124	0.078	0.009	0.008	0.004
	$q_{e,calc}$	mg/g	0.55	1.06	2.36	3.55	3.96
	R^2		0.9989	0.9991	0.9966	0.9993	0.9746
	$q_{e,exp}$	mg/g	0.52	1.01	2.03	3.16	4.33

As it can be seen in Table 1, the calculated q_e values are different from the experimental q_e values and R^2 obtained are low for ammonium removal.
Also, pseudo-second order parameters are listed in Table 1. As shown in Table 1, the calculated q_e values and the experimental q_e values are close and, the R^2 are higher than the values obtained from the pseudo-first order model. This suggests that the pseudo-second-order kinetic model is more adequate to describe the ammonium removal from water than pseudo-first order.

4.5 Thermodynamic parameters

The values of thermodynamic parameters are presented in Table 2.

Table 2: Thermodynamic parameters

$\Delta S°$	$\Delta H°$	$\Delta G°$		
kJ/K·mol	kJ/mol	kJ/mol		
		283 K	293 K	303 K
-0.13	-36.05	0.88	2.19	3.49

The value obtained for $\Delta H°$ (Table 2) in case of ammonium removal onto natural zeolite, suggests an exothermic interaction at temperatures between 283 and 303 K.

The negative value of $\Delta S°$ indicates that the adsorption is possible at low temperatures. The $\Delta G°$ value indicates that the adsorption process can be possible in certain condition (high or low temperature) [22].

5. Conclusions

The results showed that the investigated parameters had a relevant effect on ammonium removal. The results indicated that the maximum removal efficiency (94.1% removal efficiency) for ammonium removal was obtained using 3 g natural zeolite of 0.5 - 1.25 mm particle size. Raising the initial ammonium concentration from 20 to 190 mg/L, the amount adsorbed increased from 0.51 mg/g (95.7% removal efficiency) to 4.33 mg/g (75.6% removal efficiency). Pseudo-second order model indicated a chemical process involved in ammonium removal onto the investigated natural zeolite. The calculated thermodynamic parameters indicated that the adsorption process was exothermic at temperatures between 283 K and 303 K. Thus, the considered natural zeolite can be used as an effective adsorbent for domestic and wastewater treatment.

Acknowledgments

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CONTACT ANALYSIS OF HELICAL GEARS BY USING FINITE ELEMENT METHOD

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Abstract: *Contact analysis of helical gears by using finite element method helps to know the state of strength, strain and transmission stability for development of new mechanical structures without long analysis time, tests and validation.*

Keywords: *Contact, analysis, helical, gears, finite element method.*

1. Introduction

It is known that gears are generally used to transmit power and torque. For the external pumps the problems of the contact at involute helical external gear pump is proposed. J Zhang et al., G Yang et al.,[1,2] and others adopt helical gear instead of spur gear drive in order to improve the pressure fluctuations, large noise, the balance of radial forces et alt.
Gears are used to change the speed, magnitude, and direction of a power source. Gears are being most widely used as the mechanical elements of power transmission. When two gears with unequal numbers of teeth are combined, a productive output is realized with both the angular speeds and the torques of the two gears differing through a simple relationship. AGMA [3] and ISO [4] standards generally are being used as the strength standard for the design of spur, helical, and worm gears. The strength determined from the AGMA and ISO standards is valid under the assumption that the load is uniformly distributed along the line of contact. However, in actuality, the load per unit length varies with the point of contact [5].
The meshing characteristics, the information and simulation of contact in meshing gears aim to know better the state of strength and strain and transmission stability. In this way could increase the development of a new mechanical structure and decrease the time of analysis, test and validation. [6]

2. Geometric model

The basic 3D gears model for the helical gear analysis is represented in Figure 1. This model was obtained after dimensioning of two wheels in engagement and design them in Autodesk Inventor, by generating a volume based on 2D drawings with extrusion function along a line (built in a plane, tilted at 12° from the plane normal to the original sketch of the wheels) resulting in two cylindrical wheels with helical teeth. The parameters of the gears are shown in Table 1

Table 1: Parameters of the gears

Input data	Designation	Wheel 1	Wheel 1
Teeth number	Z1,2	15	46
Helix angle	β	12°	12°
Module	m_n	4	4

As a result, it is shown in Figure 1 the “master model” of the wheels involved in the next simulation of gear meshing.

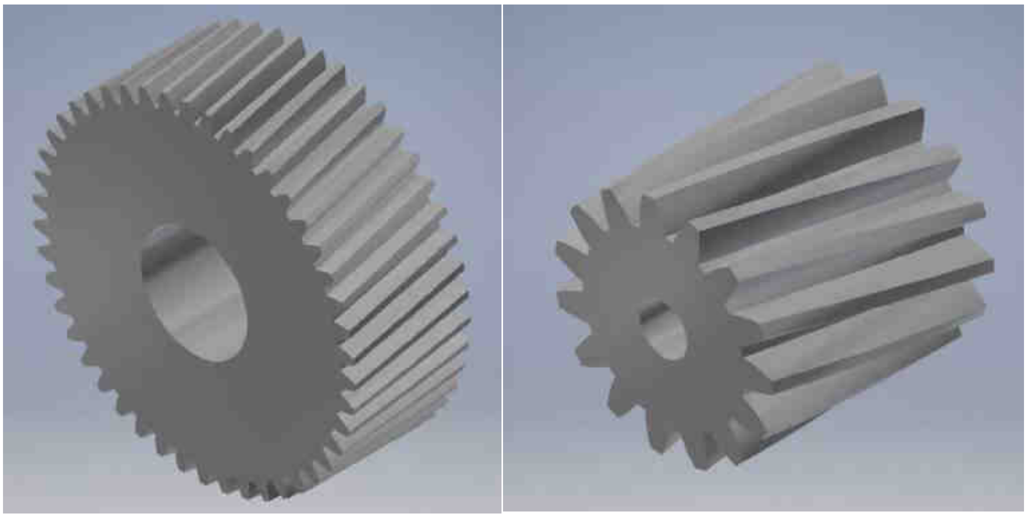

Fig. 1. The 3D model of the gears

3. Finite Element Model and Simulation

After the design of the two separated wheels we have imported the gears as 3D body in commercial code Ansys. In this step we must declare the contact between the flanks of the two wheels as shown in Figure 2. For each declared pairs of contact points, we can see o front plane of meshing.

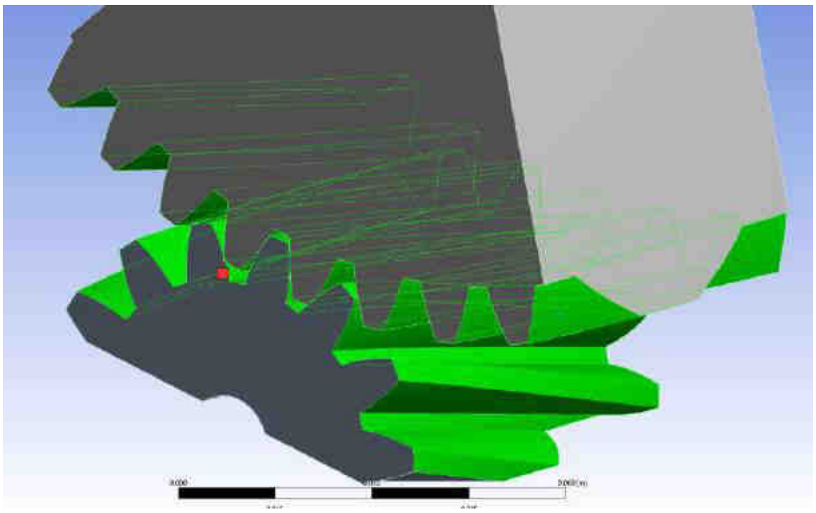

Fig. 2. The simulation of contact state in meshing as declared contacts

Example of the 2D contact between the tooth surfaces of the two wheels in engagement is shown in Figure 3. We must verify these contacts along the contact line in the next step.
Contact can be classified by several features as follows

- in terms of changing the contact surface when applying the load;
- in terms of material behavior;

• in terms of movement of the elements in contact

The contacts studied in this paper have the following characteristics, according to the features in the previous list

• free of friction;

• a penetration value is admitted as a lack of the finite element method, but which is to be evaluated from a physical point of view;

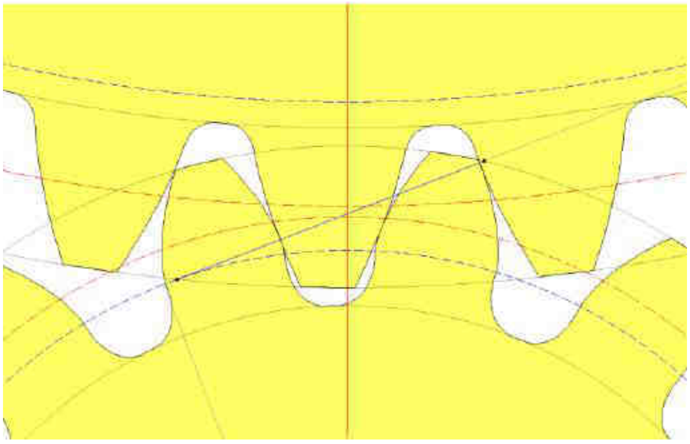

Fig. 3. Front plane of declared contacts

• the elastic behaviour of materials in contact is allowed;

• the movement of the elements in contact is considered possible, due to penetration, both at the beginning of the calculation and at the end. Applying the finite element method involves meshing the outer surfaces of the engaging wheels so that the accuracy of the results is smooth as possible in the area of direct contact. For this step we used a mesh method as shown in Figure 4.

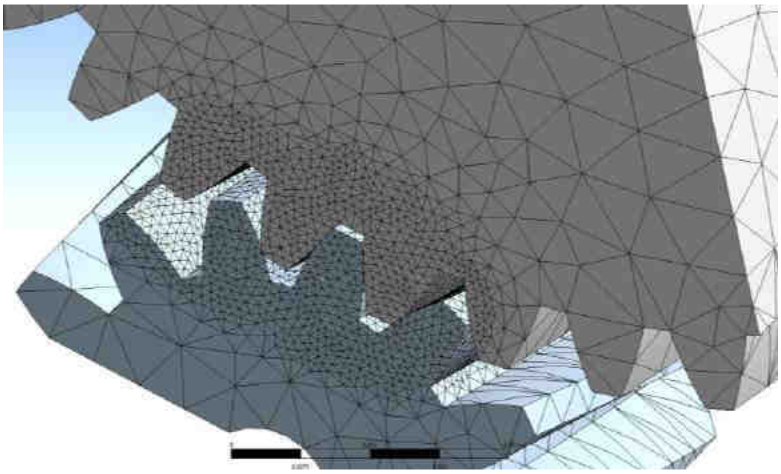

Fig. 4. Finite Element mesh

4. Results

The simulation of the gears functioning, in the state of static analysis of stress and strain was obtained for each contact line with imposed step of rotation. The result shown in Figure 5 indicate first of all the situation of contacts for declared contacts along meshing line (far, near, sticking)

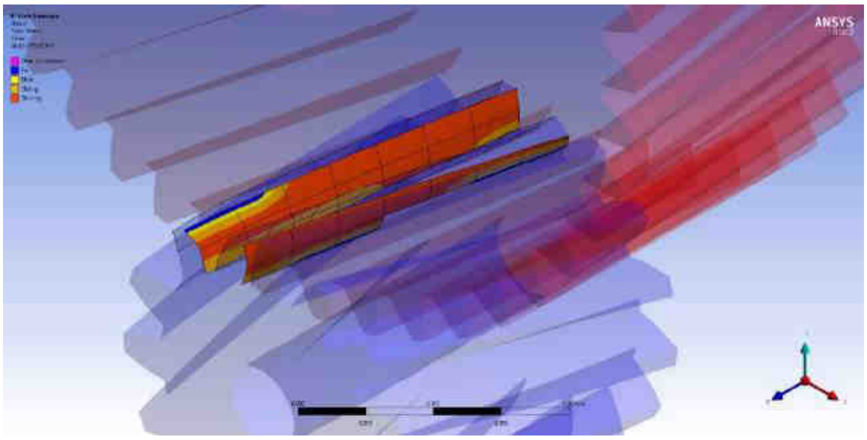

Fig. 5. Static analysis - state of contacts and gaps

The elastic deformation of teeth has maximum values on the main engagement line between the two wheels. The case studied refers to simultaneous engagement through two teeth (Figure 6)

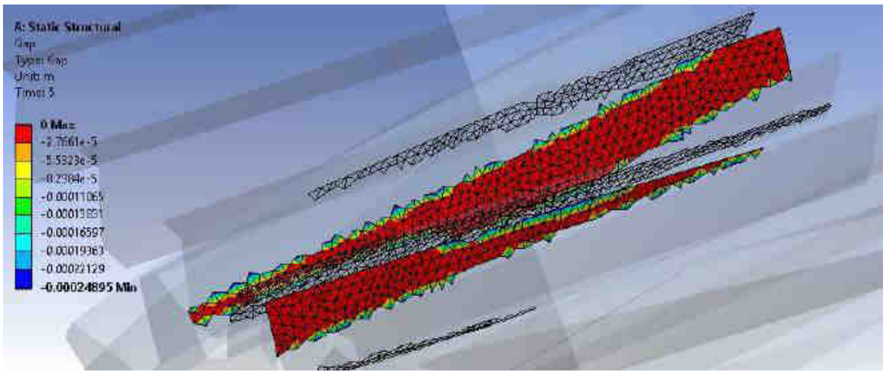

Fig. 6. Elastic deformation of teeth in static contact

Normal stress has maximum values on the tooth flank of the tooth that is going to engage, on the tooth that is also engaged and on the linear contact area between the two wheels.

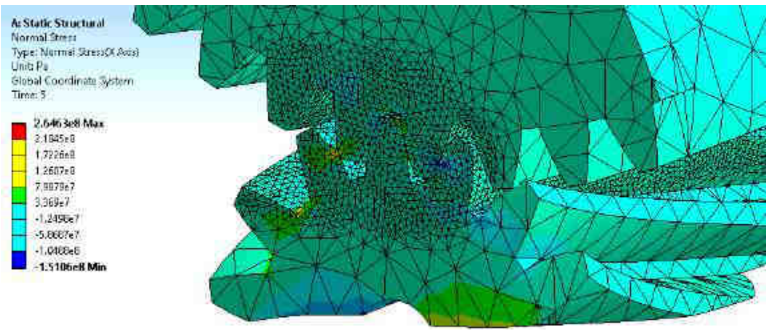

Fig. 7 Maxim values of normal stress

The equivalent von Mises stress is the result of the two wheels engagement, the rotation force received by the drive wheel and the actual engagement.

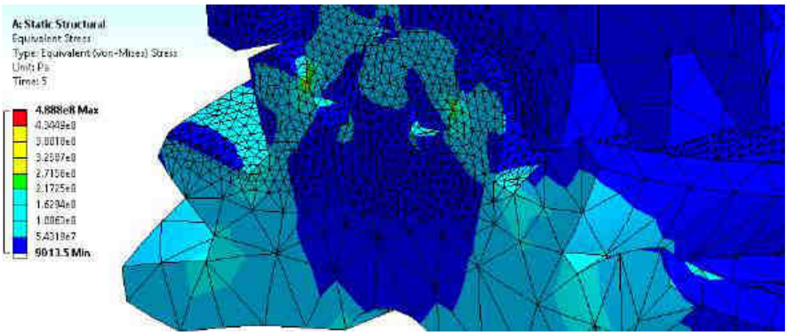

Fig. 8. Equivalent von Mises stress

5. Conclusions

Contact analysis of helical gears by using finite element method avoid development of a large variety of mechanical structures by modelling the gears and simulate the actions that appears in use.
One of the most important benefit is that this method allows changing some parameters in the stage of design and calculate all the possible effects presented for any reliable structure.

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FLUID FLOW ASPECTS WITHIN CIRCULAR DUCTS WITH SECTION CHANGE

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Abstract: *Aspects of the fluids flow within circular ducts have been presented along the time being established the main flow regimes represented by the laminar and the turbulent regime. It should be emphasized that the fluids movement in circular ducts is always accompanied by energy losses, due to both the pipe walls roughness and the change of the flow section, leaving aside the viscosity properties of the fluid. Summarized these energy losses are constituted as hydraulic resistances in the fluid flow path-lines. In this paper are presented the types of resistors that can influence the fluid flow through circular pipes when changing the flow section in the direction of widening or narrowing of the pipe flow section. Theoretical aspects of flow resistances as well as numerical analyzes on fluid flow on the virtual model are presented in order to highlight the flow parameters in the respective section.*

Keywords*: Fluid flow, circular duct, section change, three-dimensional model, numerical analysis*

1. Introduction

The liquids and mainly water flow has been studied over time, with experiments describing the main laminar and turbulent flow regimes. For the liquids flow inside the circular ducts, it can be argued that there are efforts acting in order to slow the fluid flow, called hydraulic resistors, which are actually fluid friction forces with the pipe walls, stresses due to the viscosity forces inside the fluid, forces due to terrestrial gravity, hydrostatic pressure forces, forces due to turbulent flow, but also compressibility forces. All these summed forces determine the hydraulic resistance when advancing the respective fluid through the circular duct, being taken into account when writing the fluid flow motion equations.

If we only refer to the pipe properties, it is mainly considered the roughness of the pipe walls that can oppose to the fluid motion through the circular pipe as well as the sudden changes in the flow section.

The main types of changes in the flow section of the circular pipeline are presented, showing both theoretical calculation and numerical flow analyzes performed on the virtual model of the pipeline in order to highlight the main flow parameters involved as well as their value modifications as result of pipe flow section change. [1][4]

2. Hydraulic resistances to fluid flow in circular ducts

In order to study aspects regarding hydraulic resistances in the fluids flow, we must refer to the flow regimes inside circular pipes represented by the laminar and turbulent regime.

The laminar regime is characterized by a steady flow, the fluid layers are arranged in parallel layers and the regime is considered to be as moderate energy consumer during the flow.

The turbulent regime is characterized by a very high energy consumption compared to the laminar regime due to the fluid swirls that are born during the transport of the fluid particles inside the pipe. [3][5]

Hydraulic resistors are considered both locally within the pipeline and linear along the whole length, being summed up with the following relationship: [2]

$$H_r = \sum H_d + \sum H_l \tag{1}$$

where:

H_r - total hydraulic resistances;

H_d - hydraulic resistances linearly distributed along the length of the fluid flow;

H_l - hydraulic resistances at the local level due to changes in the fluid flow geometry.

Hydraulic resistances as well as velocity distribution in the fluid flow section can vary depending on the flow pattern (laminar or turbulent).

The formula Darcy-Weissbach establishes the linearly distributed hydraulic resistances along the length of the fluid flow for the laminar and turbulent modes: [2]

$$H_d = \lambda \frac{l}{d} \frac{v_{med}^2}{2g} \tag{2}$$

where:

λ - flow resistance coefficient for distributed loads;

l, d - length and diameter of the pipeline;

v_{med} - average flow velocity;

g - gravitational acceleration.

$$\lambda = \frac{64}{\mathrm{Re}} \tag{3}$$

The distribution of the velocity values in the pipe section for the turbulent flow regime is described by the following relation: [2]

$$\frac{1}{u_{\max}} u = 1 - 2\lg \frac{\frac{r_0}{y}}{\frac{0.975}{\sqrt{\lambda}} + 1.35} \tag{4}$$

where:

u - the average value recorded for the local velocity at the distance y from the pipe wall;

$u_{\max}$ - the velocity value at the pipe axis;

r_0 - radius of the flow pipe;

Between the average flow velocity through the circular duct $\left(v_{med}\right)$ and the maximum velocity values at the pipe axis $\left(u_{\max}\right)$ there is Prandtl's relationship: [2]

$$\frac{u_{\max}}{v_{med}} = 1 + D\sqrt{\frac{\lambda}{8}} \tag{5}$$

where:

D - velocity deficit;

While A. D Altschul's relationship defines the ratio of the two velocity values as being: [2]

$$\frac{u_{\max}}{v_{med}} = 1 + 1.35\sqrt{\lambda} \tag{6}$$

For circular pipelines in which the flow regime is turbulent, we can define the Coriolis coefficient described with relation: [2]

$$\alpha = 1 + 2.65\lambda \tag{7}$$

For the laminar flow regime inside a circular pipeline it can be considered that the velocity is of the parabolic type according to the Stokes formula: [2]

$$u = \frac{\gamma J}{4\mu}\left(r_0^2 - r^2\right) = \frac{\gamma H_d}{4\mu l}\left(r_0^2 - r^2\right) \tag{8}$$

where:
u - the local velocity recorded at the distance *r* from the pipe axis;
r_0 - pipe radius;
J - hydraulic slope;
γ - fluid specific gravity weight;
μ - dynamic viscosity coefficient.

Changing the flow section in the case of circular pipes leads to the formation of local resistances in the flow path-lines so that the fluid velocity values are changed, which implies additional load losses in the fluid flow.
Two cases are presented, namely the case of pipe diameter increase (sudden passage at a larger diameter), as well as the case of a decrease in the diameter value for the pipeline (abrupt pipe narrowing).

2.1 The case of sudden drop in pipe diameter

In the event of a sharp drop in the diameter value of the flow pipe, a contraction of the fluid stream flow occurs.
The value of the local flow resistance coefficients is influenced by the flow path geometry as well as by the Reynolds number of the fluid flow and can be calculated with the relationship: [2]

$$\xi_l = \left(\frac{1}{\zeta} - 1\right)^2 \tag{9}$$

$$\zeta = \frac{A_c}{A_2} \tag{10}$$

where:
ζ - contraction coefficient of the fluid stream;
A_c - the fluid flow area due to the changing diameter of the contracted flow;
A_2 - the area of the reduced diameter pipe.
The area ratio or change in diameter determines the value of the contraction coefficient whose value depends on the input and output area.

$$n = \frac{A_2}{A_1} \tag{11}$$

Figure 1 shows a diagram for a sudden narrowing of the pipe section.

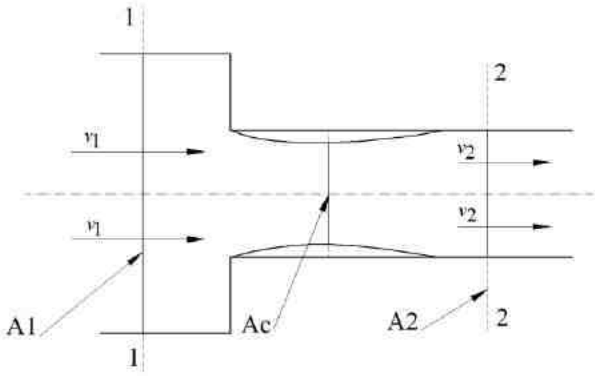


Fig. 1. The case of sudden drop in the pipe flow diameter

For the values of the ratio of the input and output areas in the interval (0; 1), the values of the contraction coefficient of the fluid flow are within the interval (0,6; 1); and the values of the local resistance to fluid flow are within the range of values (0.4; 0.1). [2]

2.2 The case of a sudden rise in the pipe diameter

In case of a sudden increase in the pipe diameter and the flow section, a load loss is recorded due to the flowing regime that becomes strongly turbulent in respective fluid region.

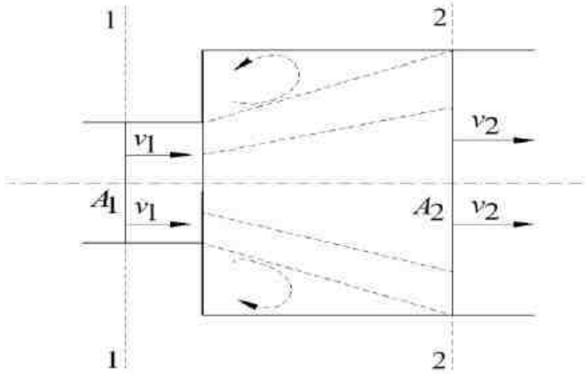


Fig. 2. The case of the sudden increase in the pipe flow diameter

For the calculation of the load loss at the sudden increase in the pipe diameter, Borda's relationship is used: [2]

$$H_l = \frac{(v_1 - v_2)^2}{2g} = \xi_l \frac{v_2^2}{2g} \tag{12}$$

The coefficients of the local resistance to fluid flow are within the range of values (80; 0) for the values of the section area ratios comprised in the range (10; 1). [2]

3. Numerical flow analysis on virtual model

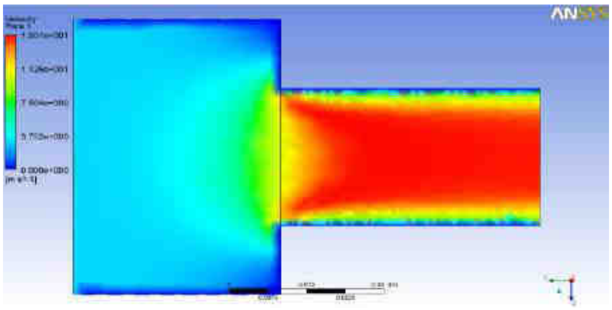
The flow analysis is performed on the virtual model for the two considered cases as the sudden narrowing of the flow section as well as for the sudden increase of the pipe diameter and consequently the increase of the flow section.

On the virtual model of the circular pipe is defined the fluid region with the reference pressure of 1 atm, having the input velocity value declared at 3 m/s.

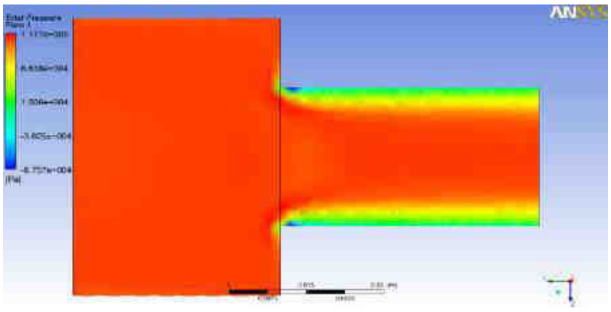
The obtained results for the two analyzed cases, referring to the narrowing of the flow section and the sudden enlargement of the section, are presented below.

3.1 Fluid flow analysis for the sudden drop in pipe diameter

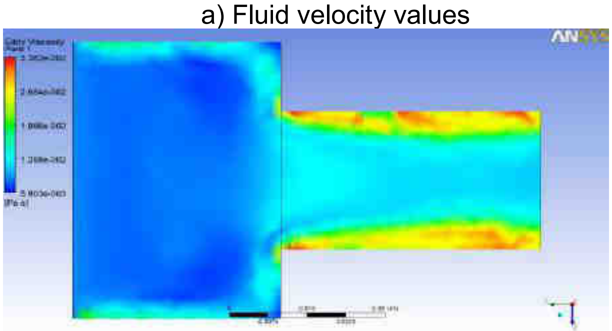
It is considered the case where occurs a sudden narrowing of the flow section as a result of a lower passage diameter through the pipe. The inlet is declared for the large pipe diameter (60 mm) and the fluid velocity value of 3 m/s. The outlet diameter is of 30 mm. The working fluid is represented by water at 25 °C, the turbulence model being of medium intensity k-Epsilon type.
The meshing network is made with tetrahedral shaped elements having a number of 9033 nodes and 45106 elements.
The result values are shown in Figure 3, where the values for the given working total pressure and for the fluid velocity can be seen on the cutting plane YZ.
Also, are presented values for turbulence due to fluid viscosity and kinetic energy.



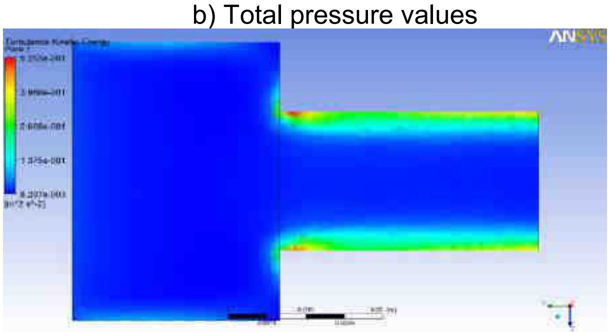
a) Fluid velocity values



b) Total pressure values



c) Eddy viscosity values



d) Turbulence kinetic energy

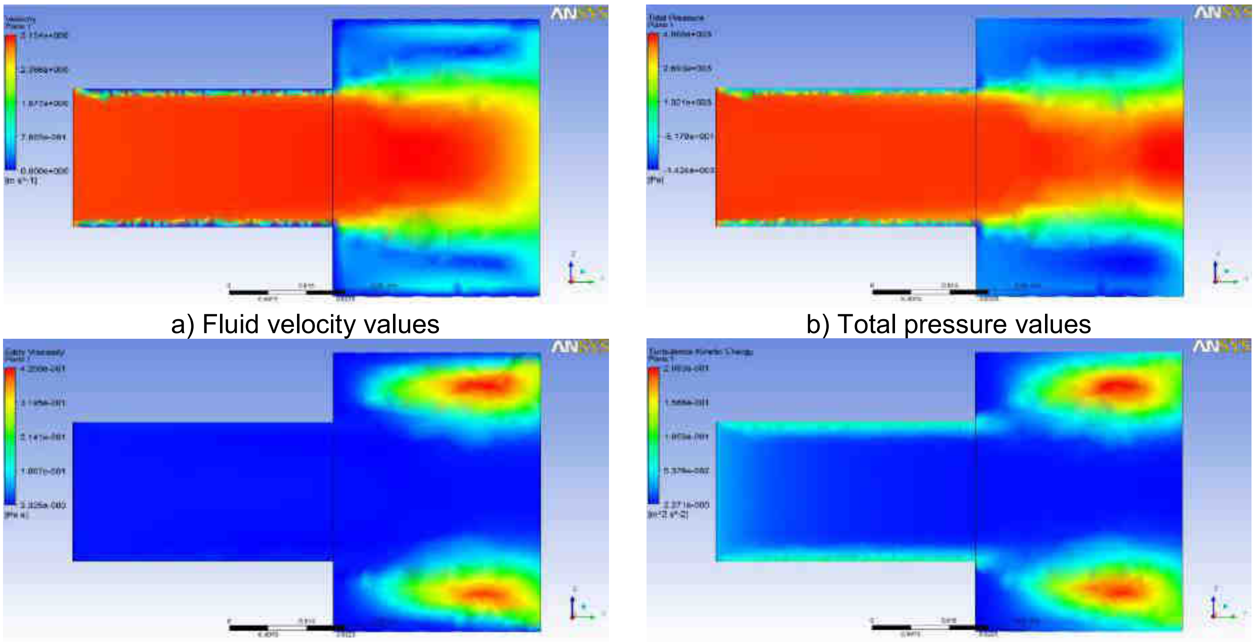
Fig. 3. Values obtained from the numerical analysis for the sudden decrease of the pipe diameter

By analyzing the fluid circulation velocity values in the range 3.7 - 15 m/s, it can be stated that there is an exponential increase in velocity values at the passage area from the large diameter region to the fluid region of reduced diameter where maximum values are recorded for pipeline axis and smaller near the pipeline wall due to friction dissipation in this area.
The total pressure values are larger on the inlet area, with a jump at the entrance to the reduced diameter pipe, where the fluid flow is strongly contracted.
Maximum turbulence values due to fluid viscosity are present within the shrinkage area of the fluid stream, near the pipeline walls.

3.2 Fluid flow analysis for the sudden increase of pipe diameter

For the second analysed case where the flow pipe has a connection with a larger diameter pipe, the numerical analysis being made on a virtual model whose inlet opening has a diameter of 30 mm and the outlet diameter is 60 mm. The working fluid is water at 25 ° C, the turbulence model is established as medium intensity k-Epsilon type.

The same value of 3 m/s is declared for the fluid velocity at the inlet, being expected a uniform fluid circulation around the reduced diameter pipe region and for the larger pipe diameter region a relaxation in the fluid flow stream mainly due to the larger space available for the fluid.
The obtained results for this case are shown in Figure 4 for the YZ coordinate section plane.
The velocity values recorded at the fluid region level within the range of (0.8-3.15 m/s) are higher on the reduced diameter pipe area, the path-lines being continued in the large diameter region only for the central pipe axis region, up to the outlet region where flow energy dissipation is accomplished.
The velocity values for the larger diameter pipe region near the walls are reduced.
For total pressure values, it can be noted that there is an increase in the small diameter pipe area, while at the passage into the larger diameter pipe there is an initial relaxation followed by higher values at the outlet region near the pipe axis.
The pressure values for larger diameter pipe region close to the wall are reduced.
The turbulence values due to the internal friction of the working fluid and the kinetic energy are higher in the region near the large diameter pipe wall.



a) Fluid velocity values
b) Total pressure values
c) Eddy viscosity values
d) Turbulence kinetic energy values

Fig. 4. Values obtained from the numerical analysis for the sudden increase of the pipe diameter

4. Conclusions

Aspects about flow through circular pipes with sudden change in diameter have been presented in this paper.
Specific resistances of fluid flow occurring in the situations described by the reduction and sudden increase of the flow section are shown.
Also, the numerical flow analysis on the virtual model of the pipeline was performed in order to highlight the specific values at the analyzed fluid region level relative to the flow velocity, total pressure and turbulence obtained.
There have been considered two specific cases: first case in which the diameter of the pipe has a sudden drop and in the second case there is a sudden increase in pipe diameter, altering in this way the fluid stream section.

The obtained results for both analysed cases highlight the turbulent fluid flow model with large values near the axis of the pipeline for the flow velocity and total pressure and along and in the vicinity of the walls for the turbulence values.
The numerical flow analysis on the virtual model of the pipeline was performed for water at 25 °C but can be performed for different types of fluids at different values related to the circulation velocity, pressure or working temperature, corresponding to the hydrostatic drive systems that work with high ranges of velocity and pressure values.

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FROM ANCIENT ATOMISM TO FIRST KINETIC THEORIES OF GASES

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Abstract: *Starting from ancient atomism and traditional scientific atomism, there is an analytical study of the development of kinetic gas theory in the 18th century. In particular, it is described the development of two main ideas, which underpinned the first formulations of this theory: the hypotheses regarding the internal structure of the matter and the speculations about the material nature of the heat and the first theories formulated by Jakob Hermann and Leonhard Euler. It is shown that the first quantitative formulation of this theory was given by Daniel Bernoulli, who explicitly determined the kinetic origin of pressure and temperature. In the eighteenth century, Bernoulli's kinetic theory was not taken seriously, but neither the theories developed by Lomonosov and Boscovich were successful. In this way, the causes that led to the stagnation of the kinetic theory of gases in the second half of the 18th century were highlighted.*

Keywords*: Atomism, gas theories, kinetic theories*

1. Introduction

Being one of the most solid bases of the modern science, the kinetic-molecular theory of gases is defined nowadays as a branch of molecular physics, that has as object of study gases' macroscopic behavior depending on the characteristics of the constituent molecules movement. Due to the knowledge of this relationship, many physical phenomena from gaseous, liquid and even solid media can find a simple and convincing explanation in the kinetic theory. It is known, for example, that the pressure exerted by a gas on the vessel's walls it comes into contact with is the result of multiple collisions of moving molecules, resulting in transmission of its quantity of motion. Its variation in the time unit leads, according to impulse's first theorem – the theorem of quantity of motion – to the appearance of an external force, that being divided on the unit of area of the wall's surface is indeed the pressure. The pressure thus defined is called kinetic pressure. The kinetic energy of the particles, averaged on a very big number, determines exactly what we call the temperature of the substance.

2. Problem formulation

Numerous studies have been sanctioned to the development of the kinetic molecular theory of gases in the early period, that have contributed to the correct understanding of the concepts and ideas formulated by the creators of this theory throughout history. However, up till now not a unitary approach of treating the historical process of scientific bases formation of the kinetic theory of gases has been imposed, and some aspects of the subject continue even nowadays to bother our scientific communities. Almost nothing is known about first theories formulated by Hermann, Euler, Bernoulli, Lomonosov and Boscovich. The same thing can be said about both the ancient atomism as well as the scientific atomism from the 17th century.
Considering the mentioned above, an analytical study of the kinetic theory of gases development in 18th century is performed in the following work, preceded by a short analysis of atomistic theory in the ancient philosophy and scientific atomism from the 17th century. In particular, it aims to develop two main ideas that underpinned the first wording of this theory, namely the hypotheses regarding the internal structure of the substance and the speculations about material heat.

3. The atomistic theory in ancient philosophy

The origins of the kinetic theory of gases are found in the ancient atomism, a theory that would have exerted an overwhelming influence on later science and technics. Right from the beginning the atomistic theory has been asserted as a philosophical stream, based on the idea that the substance has a discrete structure, the constituent particles, the atoms, being indivisible and eternal [1]. It seems that this theory has been created by the Phoenician philosopher *Mochus from Sidon* before the Trojan wars [2], that is in 14th century before Christ. The father of modern chemistry, Robert Boyle, advocates that in the past scientists were attributing the elaboration of the atomic hypothesis to a certain Mochus from Sidon. Isaac Newton was on similar positions. Indian philosophers *Uluka* (7th century B.C.) and *Acharya Kanad* (6th century B.C.) have talked about atoms and molecules, who were considering the objects as made of atoms bonded between them to form the molecules [1].

In the Western philosophy the ancient atomism is associated with the name of the Greek pre-Socratic philosopher *Leucippus from Miletus* (approx. 500-450 B.C.), that created his theory around the year 475 B.C. [1-3]. Based on Leucippus, the Universe is composed of an empty space and an infinitely large number of small and indivisible particles, called atoms. In Leucippus atomistic theory, the formation of the world and its different things was based on the join property of immortal atoms but not on the existence of a natural superpower. It was undoubtedly the first step made by a scientist on the path of materialistic understanding of the world.

But would there had been at that moment any relationship between Indian and Greek atomism? The only country where the Greeks could take over from the ideas of atomism in the 5th century B.C. was undoubtedly India. But this isn't exactly known to the modern science.

The atomistic theory has been furt her developed and founded by *Democritus from Abdera* (approx. 460-370 B.C.), the most important materialist philosopher of the ancient world [1-3]. A general image regarding Democritus' atomistic theory can be made out of the next quote very frequently used [3]: ,,*It doesn't exist anything else rather than atoms and empty space, everything else is opinion. Only in the general opinion the color exists, in opinion the sweet, in opinion the bitter…, but in reality exist only atoms and void*". The atoms were imagined by the great thinker as some solid, indivisible and of different sizes particles, that are in a continuous motion and eternal, from time perspective. According to Democritus, the atoms weren't deformable. Besides these physical properties, the atoms were having different geometrical shapes, that's the explanation of their possibility of combining each other to form the reality and all the physical bodies from the Universe. Democritus is reasoning on this idea [3]: ,,*The atoms are infinite and infinitely variable in shape. The variety of all the things depends on the variety of constituent atoms as number, dimension and state of motion*". By the ways of atoms joining and motion is explained the variety of phenomena from nature. So, moving initially in all the possible directions the atoms are colliding between them forming vortices, that give birth to countless worlds in the infinite void. The atoms' chaotic motion in all the directions lies at the heart of everything that is happening in the great world, whose phenomena don't resemble nevertheless the motion of the atoms in void.

Although Democritus theory has nothing in common with actual understanding of the nature, however, we shouldn't be too exigent toward the ancient atomism, because as the science historian George Sarton is warning us [4]: ,,*When judging the Greek atomic theory we have to protect ourselves against two temptations: first is the one of equalizing it with the modern theory invented by Dalton at the beginning of 19th century; second is the one of not including it in the history of science by virtue of its confusion. Certainly, there is a huge difference between the Greek and Dalton's idea: there's a big difference between a philosophical concept, that can't be checked, and a scientific hypothesis, that invites to a long series of experimental checks. On the other hand, there is no doubt that Democritus' theory, resurrected by Epicurus and popularized by Lucretius, has been an intellectual incentive for centuries. The Jewish and Christian professors have tried to sink it, but it has never died*". The atomistic theory has maintained itself ,,*through out the entire classical period, as a steadfast heresy*" [5], marking both the evolution of the materialistic philosophy about the world and life, as well as the development of natural sciences.

But, on the other hand, it would be an enormous error to consider the ancient atomism a scientific theory of physics. This idea results from the simple reason that no affirmation of the Greek atomistic philosophy could be proven experimentally. However, Democritus and Epicurus conceptions have served as a source of inspiration for a period of more than 2500 years, a reason why the atomism from ancient Greece is considered nowadays ,,*the direct and recognized ancestor of all the modern atomic theories*" [5].

4. The traditional scientific atomism

The technical and scientific progress from the first half of 17th century has substantially contributed to the revival of the atomistic theory of ancient Greeks. Among the animators of traditional atomism, we can find notorious names of worldwide science and philosophy, like Nicolaus Copernicus in Poland, Giordano Bruno and Galileo Galilei in Italy, Isaac Newton, Francis Bacon and Thomas Hobbes in England, but also less known names, like the ones of Daniel Sennert in Germany and Claude Guillermet de Bérigard in France, who have opted for the reconciliation of Aristotle's physics with Democritus' atomism. However, the great figures of the revival of atomism in this period were René Descartes, Pierre Gassendi and Robert Boyle.

The famous French mathematician, physicist and philosopher *René Descartes* (1596-1650) was not recognizing the atomistic conceptions of ancient and medieval philosophy [1, 6]. In contrast to then existing atomistic theory, he has developed his own corpuscular theory, known under the name of the doctrine of the full space. As it's known, Descartes has shown a special interest in Torricelli's void, although has vehemently denied its existence in nature. In the doctrine of the full space, elaborated in 1630, the emphasis has been placed on the simple expansion and the full and continuous filling of the Universe with subtle matter, powered through impulse transmitted from one place to another. In the 17th century, Descartes' theory didn't have a quantitative basis, even though was supported from a qualitative point of view by the widespread idea that the heat is closely related to the motion of the atoms, but the air pressure increases together with the temperature. Later, the Cartesian physics has been severely criticized by Isaac Newton.

Relying on the atomistic conceptions of Epicurus and Lucretius and also on the achievements of the physics of those times, the Provencal priest *Pierre Gassendi* (1592-1655), one of the greatest astronomers, mathematicians and philosophers of his time, in contrast to Descartes' reductionist view that only the purely mechanical explanations of the physics are true, created in 1649 a new corpuscular theory, where later the great Isaac Newton would have inspired from [1, 5, 6]. Unlike Democritus' atoms, Gassendi's atoms were particles, possessing mass and inertia, that could move in the void whose existence had been experimentally demonstrated by Torricelli and Pascal. The motion was considered as an indestructible property of atoms ,,*purified by associations of atheistic and subversive ideas*" [5].Gassendi has formulated the main theses of his theory with such a clarity and power of persuasion, that it has been recognized and accepted by all the naturalistic philosophers, who were in opposition to Descartes' full space doctrine.

The corpuscular theory was in an excellent conformity with the mechanistic tendencies from the naturalistic philosophy of that time. Having Galileo's tools of dynamics at hand, it was now easier to study the motion of some point particles rather than the motion of some heavenly stars. The Gassendi's corpuscular theory played an exceptional role in the further development of atomistic theory of physics and chemistry. In this regard we would mention that the definition of the atom given by Gassendi is found almost word in word in Newton's ,,Optics", launched in 1704, that from Gassendi's and not Newton's activity would actually inspire John Dalton after 150 years to reach ultimately the founding of chemistry's atomistic theory.

The interest shown by the famous British of Irish origins physicist and chemist *Robert Boyle* (1627-1691) in his youth for the atomistic theory has leaded him to the formulation of two alternative hypotheses for air pressure [7]. According to the first hypothesis, the air would have been composed from mutually rejecting particles, like small springs or laminated wool yarns. His second hypothesis was based on Descartes' theory of the vortex motion of material particles and was supposing that the air consists of particles in motion mutually rejecting when colliding with each other. Just like his predecessors, Boyle accepts the existence in nature of the absolutely empty space, where material particles of certain shape and same dimensions are found. He was considering that the atoms of the liquids are in a continuous motion, when the atoms of solid bodies are motionless, the space between particles being filled with a very fine substance. The phenomenon of adhesion of solid bodies was incorrectly attributed to the air pressure, a widespread thesis at that time. Boyle's atomism was in essence a mixture of two French doctrines. He has come to this form of atomism after reconciliation of Aristotelian physics with his famous experiences from chemistry, due to which the Boyle's atomism has been accepted by the most of English scientists.

The first hypothesis enounced by Boyle was taken over and utilized by *Isaac Newton* (1643-1727) in 1687, in ,,*Philosophiae naturalis principia mathematica*" (,,*The mathematical principles of natural philosophy*") to prove mathematically that if an elastic fluid consists from motionless particles between whom exist rejection forces inversely proportional to the distance between them, then the density is directly proportional to the pressure [8]. But this fundamental work, that marked the further evolution of the entire physics, didn't contain the physical explanation of the relationship between the gas' (air's) elasticity and the corresponding variation of the density or volume. Shortly after explaining the laws of planetary motion by using the forces between particles under the form of points endowed with inertia, he would confess [9]: ,,*It seems very likely that God may had formed at the beginning the matter out of solid, massive, hard, impenetrable and mobile particles of such dimensions, forms, quantities and proportions, that make them suitable for the pursued purposes. These primitive particles, being solid, are heavier than any other porous body made up of them… No ordinary power can divide what God himself made unique in his first creation*". Newton has made a name in the atom's physics also through his corpuscular theory, according to which the atom ,,*consists from envelopes inside other envelopes, more and more tight from exterior to interior*" [9]. It was a direct hint to the today's structure of the atom, made up of nucleus and electrons, which would have been forgotten for nearly three hundred years. In the 17th century the chemistry was still in an embryonic phase of development, for which reason the corpuscular analysis couldn't be applied. To reach this objective new experimental data were necessary, that would have only been acquired in the next century.

In 17th-18th centuries the atomistic theory gets a prominent mechanistic character, just like all the sciences and theories developed in that period [1, 2, 6]. The mechanistic atomicity was represented especially by Robert Boyle and Mihail Vasilievich Lomonosov, who were underpinning the explanations of natural phenomena through the idea that the constituent atoms of the substance behave like some mechanical parts in an assembly. A prominent representative of mechanistic atomism was also the Croatian encyclopedist *Roger Joseph Boscovich* (1711-1787), who elaborated the first general mathematical theory of atomism in 1758, by using the principles of Newtonian mechanics and the new mathematics of Leibniz [1, 6]. In his mechanistic philosophy the atoms were considered as simple points, that possess mass and between whom rejection and attraction forces exist, depending on the distance between them. He was the first one who has declared that the nature of the atoms forming the solids and liquids is the same as the one of the atoms from gases. Although his intention of establishing a unified theory of physical phenomena, based on the natural philosophy of Immanuel Kant, has failed, however, his ideas would be felt in the research activity of Michael Faraday, James Maxwell, William Thomson and many other scientists.

The mechanistic atomism was a general theory that, unlike ancient atomism, has offered a real image of the material world made of atoms. But how often has happened in the history of physics, because of the mechanistic character of the atomistic theory an impasse has been reached inexplaining the nature of the heat and the thermal phenomena, for unleashing their secrets being necessary the introduction of some fictive, abstract and imaginary fluids, like the ,,phlogiston" and ,,caloric", whose existence hasn't been confirmed by experiences.

5. The first kinetic theories and their hystorical appreciation

The discovery of Boyle-Mariotte law in the 17th century raised new problems in the face of nature's philosophy especially the physics of gases. One of the acute problems of the physics of gases was the creation of scientific bases of gases kinetic theory, a theory that was called to explain the kinetic phenomena that accompany the motion of the molecules in gases.

In the first kinetic theories the accent has been placed on the application of the principles of mechanics to the motion of the corpuscles or material particles. Robert Boyle enunciated in 1660 a theory according to which the elasticity of the air, meaning the ability to withstand the weight of the mercury column in Torricelli's experiences, is due exclusively to its microscopic constitution [7]. He considers the air composed from a multitude of small bodies whose ability to withstand compression is what confers it elasticity. Although the Boylean elastic model has never constituted a real kinetic theory, it's important because through the presence of a large number of small bodies in gases the basic line of the modern atomic reasoning was already seen, according to which the macroscopic phenomena could be quantitatively explained based on microscopic bodies constitution.

Probably the first kinetic theory of gases was created in 1716 by the famous Swiss mathematician and mechanic *Jakob Hermann* (1678-1733) (fig. 1). In the sentence LXXXV of his treatise of dynamics ,,*Phoronomia, sive de viribus et motibus corporum solidorum et fluidorum libri duo*", meaning ,,*Phoronomia or with regard to the forces and the movements of solid and liquid bodies*" (under ,,phoronomia" the Swiss was understanding the science, named later the rational mechanics or theoretical mechanics), he establishes, it's true without any explanations, the relation between pressure, density and the square of the average speed of gas particles [10]. But Hermann was not destined to check his own ideas, which is why the theory formulated by him wasn't appreciated by the scientific community of that time. It seems that it didn't have any influence on the further development of the physics in general and of kinetic theory in particular. With all the gaps, errors and imperfections the Hermann's kinetic theory had an indisputable quality and namely he was the first scientist who tried to quantitatively estimate the physical and mechanical properties of the gases based on natural attributes of the matter and of its particles motion.

Fig. 1. Jakob Hermann (1678-1733).

Fig. 2. Leonhard Euler (1707-1783).

The first man that formulated a real kinetic theory of gases was the great mathematician and physicist of Swiss origin *Leonhard Euler* (1707-1783) (fig. 2), in 1729 [4] or 1727 [11]. He tried to explain different properties of the air based on Descartes theory of material particles' vortex motion. Therefore he was assuming that particles forming the air are spheres made of an ether core, around which exists a layer of real substance, meaning a layer of air surrounded in turn by a layer of water in rotation motion. While the pressure is a manifestation of centrifugal force, the Euler's humidity is determined by the ratio between the water from external layer and the real substance contained in the intermediary layer. He also assumed that all the molecules of gas are rotating with the same speed. By applying this hypothesis, he obtains the relation between speed, density, pressure and humidity, that in case of dry air is reducing to a dependency between pressure and density. Although Euler' kinetic theory has been highly appreciated by great historiographers of physics, like Clifford Truesdell, it doesn't seem that the Eulerian model of air's molecular constitution to have had any influence on the development of physics or kinetic theory of gases [4]. Probably, from this reason the theory formulated by Euler is nowadays omitted in many works dedicated to the early period of this theory's development.

6. The kinetic theory in Bernoulli's work

The kinetic molecular theory of gases has developed on the path indicated by the famous Swiss mathematician, physicist and mechanic *Daniel Bernoulli* (1700-1782) (fig. 3), who publishes in Strasbourg in 1738 the first scientific treatise on fluids mechanics, called ,,*Hydrodynamica, sive de viribus et motibus fluidorum commentarii*", meaning ,,*Hydrodynamics, or comments on the forces and fluids' motion*" [11]. The theory he has developed is exposed in chapter X ,,*De affection ibusatque motibus fluidorum elasticorum, praecepue autem aeris*" (,,*With regard to the properties and motion of the elastic fluid environments, especially of air*").

Fig. 3. Daniel Bernoulli (1700-1782).

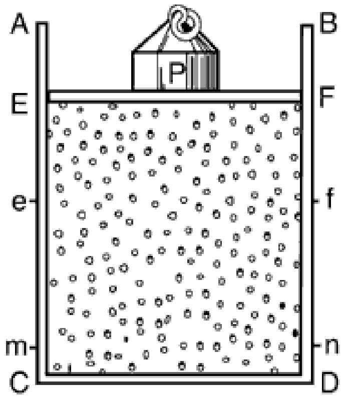

Fig. 4. The pressure of gas according to Bernoulli [12].

To study the composition and the behavior of gas Bernoulli firstly applies a reasoning based on the use of gas found in a cylinder equipped with a mobile piston (fig. 4). In the light of his theory, the gases are considered elastic fluid environments made of an infinitesimal number of small particles, that can move extremely fast in different directions and possess weight. The model proposed by Bernoulli is mostly similar to Newton's and Hermann's models. Bernoulli's biggest merit in the approached field is that he is the first who has explicitly established the kinetic origin of the pressure. Starting from the idea that the heat is the external manifestation of molecules' oscillatory motion, Bernoulli explains the pressure of the gas as a result of collision between molecules and cylinder's walls. Let's follow an excerpt from his book, where the author explains his point of view regarding the functional relationship between pressure and the volume of the gas [11]: ,,*The determination of weight's value* π *is required, that is capable of compressing the air contained in the volume* ECDF *up to the volume* eCDf, *in the hypothesis that the particles' speeds in those two volumes of air, natural and compressed, are equal. Let it be* EC=1 *and* eC=*S. When the cover is moving from initial position* EF *to final position* ef, *it supports an increased pressure from two* *reasons: firstly, due to the larger number of particles reported to the space where they are contained, and secondly, due to the larger number of collisions conducted by every particle*". Denotating by *S* the ratio eC/EC, meaning the ratio of the compressed and initial volumes, with *P* the weight force that compresses the air and with *m* the distance mC, namely that ,,*the distance to which the cover moves* EF *driven by an extremely large weight…, for what reason all the particles are touching*", Bernoulli obtains the relation:

$$\pi = \left(\frac{1-\sqrt[3]{m}}{S-\sqrt[3]{mS^2}} \right) P. \tag{1}$$

Because the distance *S* is much less than the height of the cylinder, it results $\pi = P/S$. Let it be now V_0 the initial volume of the gas and let V be the volume, corresponding to pressure P, a reason why $S = V_0/V$. With these notations he obtains the equation:

$$\pi V = PV_0, \tag{2}$$

that represents the mathematical expression of Boyle-Mariotte's law. Bernoulli writes further [11]: ,,*Therefore, between them the weight forces are basically in a reversed ratio with the volumes occupied by the compressed air in different degrees, a fact confirmed by numerous experiences. This rule can be extended as well on the rarer air than the natural one. But it could be applied also to the denser air, although this fact isn't yet elucidated. For the time being no experiments have been performed to confirm this fact. The entire problem is reduced to determination of letter m*…".
Whereas the frequency of collisions of air molecules with cylinder's walls has proved to be proportional to their speed of motion *v*, and the produced force by each collision is proportional to the transmitted quantity of motion *mv*, Bernoulli shows further that the pressure is proportional to particles' the kinetic energy $mv^2/2$, where m is the mass of a particle. His finding was put on the fact that the increases of pressure produced by the equal increase of the temperature are proportional to the density, suggesting the idea that the temperature itself could be defined in terms of air pressure, which means that the heat or the temperature could be identified with the kinetic energy of gas' particles. To trust the truth of his saying we quote a last fragment from his book [11]: ,,*Among other things the air's elasticity raises not just only due to the thickening, but also due to the increase of heat, because it's known that whenever the internal motion of the particles increases, the heat increases as well, resulting that the increase of the air's elasticity, without the change of its volume, leads to the increase of the intensity of particles' motion, a result that is in good agreement with our hypothesis. It's clear that to maintain the air in the position* ECDF *the higher a weight P is required, the higher the motion speed of air particles is. Moreover, it's not hard to prove that the weight force P must be proportional to the square of this speed, since the increase of the speed leads to the increase of both the number of collisions, as well as their intensity, so that both to be proportional to the weight P*".
Through the theory that he has developed, Bernoulli was one step away from discovering the fundamental relationship of the kinetic molecular theory of gases and the kinetic explanation of the concept of temperature. For the remarkable contributions brought to the development of the kinetic theory of gases, Daniel Bernoulli and his father, Johann Bernoulli (1667-1748), obtain the Paris Sciences Academy Award for the year 1746. But a lot of time still has to pass until this wonderful theory, initiated by Bernoulli, would gain the overall confidence of the scientists and would become part of the general physics. The influence of his ideas will be felt in the research activity of many scientists, and especially of James Maxwell.

7. The kinetic theory in Lomonosov's work

Newton's corpuscular hypothesis has been much improved by the great Russian encyclopedist *Mihail Vasilievich Lomonosov* (1711-1765) (fig. 5). When he initiated his first studies on the nature of heat in the years 1741 – 1743, Lomonosov relied on the ideas of corpuscular mechanics; he was already familiar with Robert Boyle's and Isaac Newton's works, as well as with Leonard Euler's and Daniel Bernoulli's realizations. Unlike his predecessors and contemporaries, he has essentially advanced in the problem of heat's nature. Generalizing and developing in a creative way the ideas of his ancestors, Lomonosov has in fact created the early kinetic molecular theory of heat.

Fig. 5. Mihail Vasilievich Lomonosov (1711-1765).

Lomonosov has dedicated several works to the corpuscular hypothesis of heat. In his most important work ,,*Размышление о причине теплоты и стужи*" (,,*Thinking about cause of warmth and cold*"), presented in 1745 at the Conference of Sciences Academy from Sankt Petersburg, he was writing that ,,*sufficient arguments exist of associating the heat with the matter's motion*", made of a certain type of corpuscles that are in a continuous rotation motion [13]. He has applied the corpuscular hypothesis to the thermal phenomena of decomposition, evaporation, melting and thermal conduction. Lomonosov was explaining the process of thermal conduction in this way [13]. When a warm body is in a direct contact with a cold body, the first one cools down, while the second body warms up. This is producing because the warm body's corpuscles are rotating faster than the cold body's corpuscles. At the touch of the two bodies the motion of the rapid corpuscles is transmitted to the corpuscles of the cold body, that are rotating slower. After transmitting the rotation motion, the warm body's corpuscles will rotate slower and the body will cool down, while the rotation motion of cold body's corpuscles will become faster, having as effect his warming.

An important problem of the heat physics of that time was the problem of existence of the extreme temperature's two values – inferior and superior. Thinking on this issue, Lomonosov was writing [13]: ,,*It can't be defined a however great speed to not imagine an even greater. That's why the superior grade of the heat is impossible. Inversely, the same motion may slow down until the absolute resting state is attained and no further slowing of the motion can take place. Therefore, the superior grade of bodies' cold must correspond to the particles' absolute resting*". Although this problem has been much debated in the special literature of that time, however Lomonosov was the first who has convincingly argued his ideas and has predicted the existence of the absolute zero temperature.

In the ,,*Опыт теории упругости воздуха*" work, meaning ,,*The experience of air's elasticity theory*", Lomonosov develops an elementary kinetic theory of gases, that he applies it to the

disordered corpuscles motion [13]: ,,*We understand … and certainly don't hesitate that the air particles – namely those that produce the elasticity seeking to move away from one another – are deprived of any physical constitution and organized structure. They certainly can be called atoms*". Another Lomonosov's notable realization was the corpuscular explanation of Boyle's-Mariotte's law [13]: ,,*The elasticities of the air will be inversely proportional to the volumes and proportional to the densities, that is the same*".
But Lomonosov wasn't destined to demonstrate the veracity of the enounced ideas. Probably because of this reason his kinetic theories of heat and gases weren't understood by his colleagues from the Sciences Academy and by many Western scientists, although some of them have made references to his work.

8. Conclusions

In the 18th century the kinetic molecular theory of gases wasn't accepted and taken seriously into account from many reasons. Firstly, in the examined period this theory was still in an embryonic development phase and the vast majority of the adopted assertions had no experimental support. Too little was known about the internal structure of the matter and its essential attribute, the motion, to create the scientific bases of the kinetic molecular theory of gases. Secondly, the physics and chemistry, that were just trying to constitute as separate sciences in the general framework of natural sciences, were dominated by the concept of caloric (phlogiston), inherited from ancient Greeks and perpetuated in 17th – 18th centuries. The success of the caloric theory in explaining the thermal phenomena and its dessimination among the European physicists have ultimately led to the stagnation of kinetic theory for a period of more than one hundred years.

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RESEARCHES ON THE DESIGN, MATHEMATICAL MODELING AND NUMERICAL SIMULATION OF THE COUNTERACTION MECHANISMS OF THE WAVES ACTION ON THE HANDLED LOADS BY CRAFT CRANES

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Abstract: *Marine gas and oil offshore operations requires the installation of special equipments on the floor sea. This is done by installing of vessel-specific mechanisms operating in a dynamic position at the floor. The authors of the article describe such a mechanism, found in project stage at INOE 2000-IHP, which is oil actuated and has the role of counteracting the action of the waves on the handled loads by craft cranes. In order to deepening, establishing and developing the new lines and directions of research related to this innovative topic, for the first time approached in Romania, in the paper is presented for comparison and performance analysis a typical hydraulic device operating in the wave compensator mode, made by foreign specialists. By mathematical modeling and numerical simulations were analyzed the performance limits and it was evaluated a control strategy*

Keywords*: Marine exploitation, wave compensator, hydraulic mechanism for counteracting the waves action, mathematical modeling, numerical simulations*

1. Introduction

The lifting and deployment of the marine equipments for the exploitation of oil and gas fields is achieved by the use cranes from ships operating in a dynamic position. Fig.1 shows a marine vessel used in these types of operations. Due to costs, offshore operations and lifting operations should preferably be carried out under special conditions. Depending on the state of agitation of the sea, the lifting movement of the ship relative to the lifting or lowering load may be significant. This generates oscillations that can damage the load when it approaches on the sea floor and endangers people's lives (divers who monitor the operation near the sea floor). One way to alleviate this is make by using a balancing compensation device that tracks the movement dissociation of the load from the motion of the ship [1].

Fig. 1. Marine vessel equipped with load balancing compensation device

In this paper, the authors describe a mechanism designed at **INOE 2000-IHP**, oil acting to counteract the action of waves on the loads handled by craft cranes. This mechanism has been designed to maintain at fixed point of a load regardless of the up and down movements of the vessel (floating platform) on which the crane is mounted. Since at present, internationally, the researches in the field is much more advanced, the authors present for comparison and performance analysis a typical hydraulic device made **abroad** operating in the wave compensator mode.

2. Description of the principle scheme and operation of a crane with a compensator waves (project of INOE 2000-IHP)

The compensating mechanism is interleaved on the cable route between the crane winch and load, as you can see în Fig. 2, in which is schematically shown a crane mounted on a floating platform.

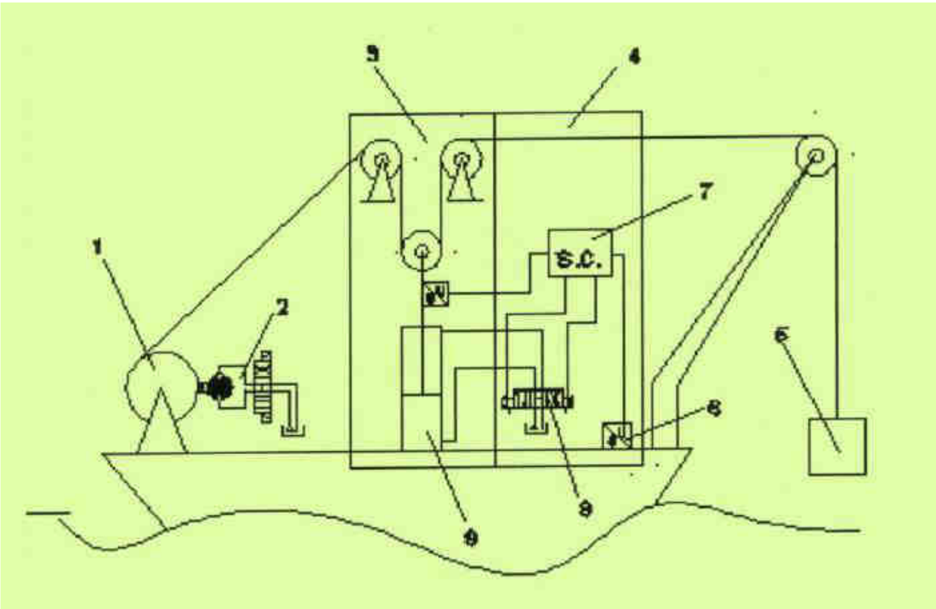

Fig. 2. Wave compensator crane schema

Caption

1-Winch; **2**-Winch action system; **3**-Waves compensator; **4**-Waves compensator action system; **5**-Load; **6**-Position transducer; **7**-Servocontroler; **8**-Proportional hydraulic directional valve ; **9**-Hydraulic cylinder with position transducer;

The operation of this mechanism is as follows: The position sensor 6 senses the up and down of the floating platform and in this moment controls by means of the servocontroller 7 and the proportional hydraulic directional valve 8, the extension and retraction of the hydraulic cylinder 9, maintaining as at fixed point the load 5, regardless of the floating platform movements on which crane stands. The extension or retraction of the hydraulic cylinder is proportional achieved with the amplitude of the floating platform motion, the hydraulic cylinder being actuated in a closed position regulating loop in order to obtain a minimum deviation of the load from the "zero level" position. The described mechanism will be referred to as the "**Wave Compensator**".

3. Wave compensation hydraulic device (international project)

3.1 Description

Some waves compensators use a hydraulic system to change the cable tension that feeds the load or to change the speed at which the cable is inserted and removed. Fig. 3 shows a simplified scheme of a particular model of such a device. The basic components are those using the cables connected to the load, as well as a strip connected to the hydraulic system. The winch normally runs at a constant speed, ie v_{ca1} is constant. The system can usually work in two ways: **passive** and **active**. In passive mode, the proportional valve is bypassed by another valve, so the fluid flows free into the active system; by adjusting the bypass valve the resistance to the fluid flow can be changed. The air pressure in the air accumulator is set to a value so as to offset the weight of the load in the water, and the pulley is positioned at the average stroke. It normally establishes the passive system's compliance and the weight compensation value depends on the weight of the load and the dominant frequency of the vessel's movement. In this way the system behaves like a spring-loaded damper. In active mode, the vessel movement is measured, and the proportional valve is used together with a pump to adjust the fluid flow in the active cylinder. Thus, the active cylinder behaves as a controlled force actuator according to the movement of the vessel, [1]

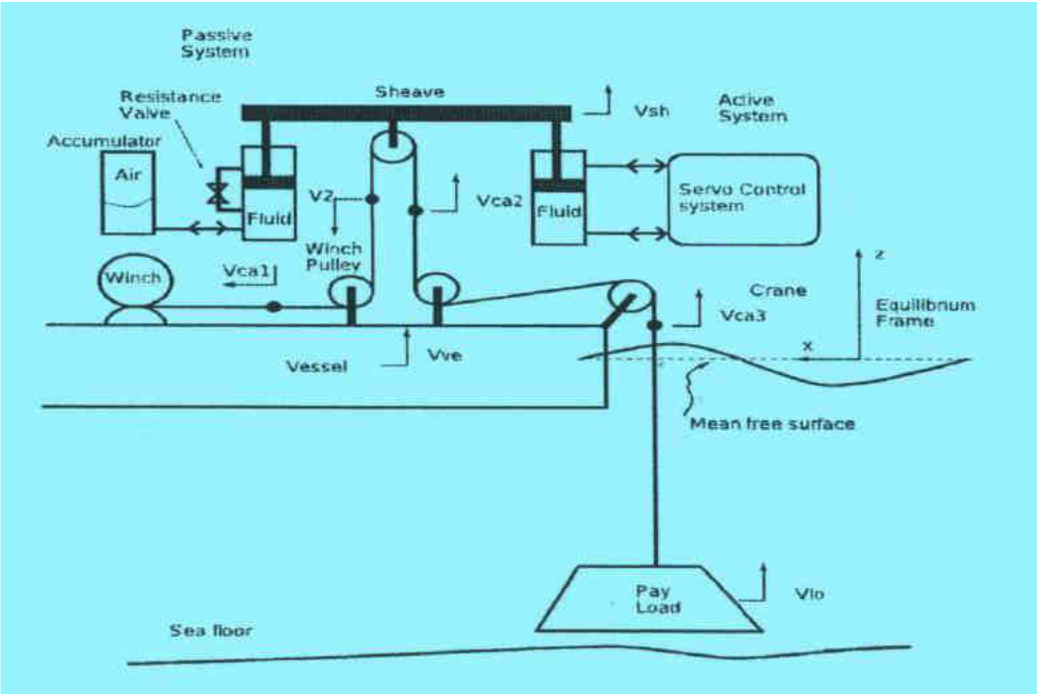

Fig. 3. Crane schema with wave compensator, [1]

3.2 Control objective and motion variables

The objective of the heave compensation control is to prevent the heave motion of the vessel reaching to the load. Tab. 1 shows the main motion variables associated with the wave compensator shown in the scheme in Fig. 3. This control objective(CO) can be achieved by obtaining a cable velocity from the crane as close as possible to the speed at which the winch feeds the cable , ie:

$$CO: v_{ca\,3} \approx v_{ca\,1} \tag{1}$$

Table 1: The relevant motion variables refer to the equilibrium frame on the average free floor, [1]

Description variable / + vessel's position	
$V_{ca\ 1}$	Cable velocity at the winch / +vessel releed in
$V_{ca\ 2}$	Cable velocity Crane side of sheave/ +vessel up
$V_{ca\ 3}$	Cable velocity after crane /+vessel up
V_{sh}	Sheave velocity / +sheave up
V_{ve} $(=\hat{z}_{ve})$	Vessel heave velocity / +vessel up
Z_{lo}	Load positiom/ +vessel up
Z_{vc}	Vessel heave displacement / +vessel up

It is assumed that the pulley is located near the shaft by which the load is lifted. This means that the vertical speed (due to the combined force,of the roller and the vessel) is the same at the pulley and the lifting point; and therefore, the movement of the vessel in these points can be simulated with only one degree of freedom, that is the lifting movement. The vertical speed of the vessel in these two positions will be called *Vve*. In addition, it is assumed that most of the wave compensator compliance is concentrated on the air accumulator so that the following constraints can be applied, [1]

$$V_{ca2} = V_{ca3} \tag{2}$$

From the diagram of the freebody of the pulley close to the winch (see Fig. 2), we have:

$$V_2 = V_{ca1} - V_{ve} \tag{3}$$

And from the moving pulley attached to the sheave, we have::

$$V_{sh} = ½ (V_{ca2} - V_{2)} \tag{4}$$

Therefore,

$$V_{ca2} = V_2 + 2V_{sh} = V_{ca1} - V_{ve\ +} 2V_{sh} \tag{5}$$

The above, and (1) and (2) translate to the next *control objective for the motion of the sheave:*

$$V_{sh} - ½ V_{ve} \approx 0 \tag{6}$$

That is, when viewed from a reference frame fixed to the average free floor, the sheave moves at half of the vertical vessel velocity. Alternatively, (6) can be write, as

$$V_{ve} - V_{sh} \approx ½ V_{ve} \tag{7}$$

Which specifies the control objective in terms of the sheave velocityof the sheave, in relation of the vessel, [1]

3.3 . Performance limitations

In this section, the conditions under which the system can achieve good compensation are analyzed. From the control objective and the constraints outlined above, we can have an optimal compensation in the situation that the next relations are satisfied, [1]

$$v_{sh} \approx \frac{1}{2} v_{ve} \tag{8}$$

$$|z_{ve} - z_{sh}| \leq \frac{1}{2}\ \textit{Stroke,}$$

where *Stroke is the maximum operational cylinders extension.* .
If consider a sinusoidal movement:

$$\begin{aligned} z_{ve} &= \bar{z}_{ve} \sin(\omega t) \\ v_{ve} &= \omega \bar{z}_{ve} \cos(\omega t) \end{aligned} \tag{9}$$

Then,from the control objective

$$v_{sh} = \frac{1}{2}\ \omega \bar{z}_{ve} \cos(\omega t) \Rightarrow z_{sh} = \frac{1}{2} \bar{z}_{ve} \sin(\omega t) \tag{10}$$

and

$$z_{ve} - z_{sh} = \frac{1}{2} \bar{z}_{ve} \sin(\omega t) \tag{11}$$

From the last expression , it follows that:

$$z_{ve} \leq Cursă \tag{12}$$

However, the movement of the vessel, is almost sinusoidal and can be more precisely modeled as a narrow Gaussian stochastic process. Under this association, the peaks of the process have a Rayleigh distribution (as Lloyd showed in 1989),[1, 2]. The amplitude $\bar{z}_P$, which is expected to exceeded with a probability P_r is,[1]:

$$\bar{z}_{Pr} = z_{RMS}\sqrt{-2logP_r}$$

Then, for example, we can consider the value P_r = 0,001 to be constant, and this would result a probability that peaks not exceeding Stroke of 0,999 m, value with condition:

$$z_{RMS} \leq \frac{1}{3{,}7}\ Cursă \tag{13}$$

This last formula establishes a fundamental conditioning between the cylinders stroke and the amplitude of the vessel's vertical movement. This conditioning must be met in order to obtain a good lift compensation. For a stroke of 3.0 m,for example, there is a vertical movement limit of 0.8 m RMS, [1].

3.4. Mathematical modelling

3.4.1 Modelling Hypothesis

Crane wave-induced motion

The vertical movement of the crane will be considered a series of time. This will be obtained as a sum of random phases sinusoids and amplitudes and frequencies calculated from the spectral density of the vertical motion computed from the wave spectrum and the vessel response amplitude operators (Perez 2005),[1, 3]. Also, the boom will be considered rigid compared to hydrostatic system compliance, [1]

Deployed load
Asssociated with the load, there are: Mass: (Mt), Displacement (ρV_{dl}), Added mass (A)

Viscous damping force is limited, using Morisson's Equation:
$Bv(u)\frac{\rho}{2}C_d A_p|u|u,$
where C_d is the drag coefficient and A_p is the projected transversal aria on the movement direction (Faltinsen,1990), [1, 4]

Dynamics of cable

The cable is considered a spring with a constant K_c [N/m], which varies with the deployed cable length. The upper end moves at the v_{ca3} velocity and the bottom end is connected to the payload, so it moves at the speed viteza v_{l0} – see Fig. 3,[1]

Sheave
The sheave will be considered have a mass of M_{sh}. The inertia of all the sheaves will be neglected , [1].

Winch
The winch will be controlled such that the velocity v_{ca1} în Fig. 3 is not affected by the load motion.. This is a good assumption because the active heave compensator control reduces the tension variations in the cable, [1].

Passive System

The passive system will be assimilated to a spring damper. The damper quantifies some small losses associated with the movement of the cylinder and of the fluid in the pipe. Referring to Fig. 3, we can assume that all compression is taken over by the pressurized air. For an isentropic system, the rate between the initial and the final pressure is, [1]:

$$PV^{\upsilon} = P_0 V_0^{\upsilon} \tag{14}$$

where υ = 1,4 (Karnopp and others, 2006), [1, 5]. The initial pressure is determined by the weight of the load in water plus the weight of the sheave:

$$P_0 = 2(M_l g - \rho V_{dl}) + M_{sh} g A_{pc},$$

where A_{pc}, is the transversal area of the passive cylinder.

The instantaneous volume of compressed air is:

$$V = V_0 - \int \dot{V}\mathrm{dt}$$

Therefore, results from (14) that:

$$\left[\frac{V_0}{V_0 - \int \dot{V}\mathrm{dt}}\right]^{\upsilon} P_0 \tag{15}$$

The total force of the passive system incorporating the hydraulic losses is:, [1]:

$$F_P = A_{pc}\left[\frac{V_0}{V_{0-}\,A_{pc}\int(v_{sh}-v_{ve})\,dt}\right]^{\upsilon} P_0 + R_P|V_{sh}-V_{ve}|(V_{sh}-V_{ve}), \quad (16)$$

Where R_P is hydraulic resistance representing the losses. Tab. 2 resume all the system's parameters, [1]:

Table 2: System parameters, [1]

Parameter	Description
M_l	Load mass
A	Added load mass
V_{dl}	Load volume displaced
C_d	Load drag coefficient
A_p	Load projected area
K_c	Cable stiffness at a given depth
M_{sh}	Sheave mass
P_0	Passive system initial pressure
V_0	Passive system initial volume
A_{pc}	Passive cylinder transversal area
R_p	Passive cylinder losses

Active Heave Compensator System

Consider the fluid in the incompressible active cylinder also in the ideal cylinder. Therefore, the active cylinder and the hydraulic energy that feeds the liquid into the cylinder will be collectively modeled as a source of effort (force) modulated by the amplifier of the controller. A first order system will be used to quantify the hydraulic and controller gap. Therefore, the active transfer model of the system is, [1]:

$$F_a(s) = \frac{1}{TS+1} K[v_{sh(s)} - \frac{1}{2} v_{e(s)}] \quad (17)$$

where K is the gain of the controller, and τ = 0,6s is the constant time that characterizes the hydraulic plus the response of the control system. The above control law dissipates energy - this ensures the stability of the system. The amount of dissipated energy depends on the amount of control gain, which will be determined according by the meteorological conditions and payload [1].

3.4.2 Bond Graph Model

Due to the physical domain interference in which the components of the system model are: mechanical, hydrodynamic and hydraulics, a Graph-Bond (GB) modeling approach is chosen. With this approach, a small set of components is used to obtain a model based on the modeling hypothesis mentioned above. Once GB is done, the computational models such as block diagrams and state space equations are obtained by applying simple rules. Fig. 4 shows the Bond Chart of the system. For more details on GB modeling see, for example, Karnopp et al (2006), [1,5].

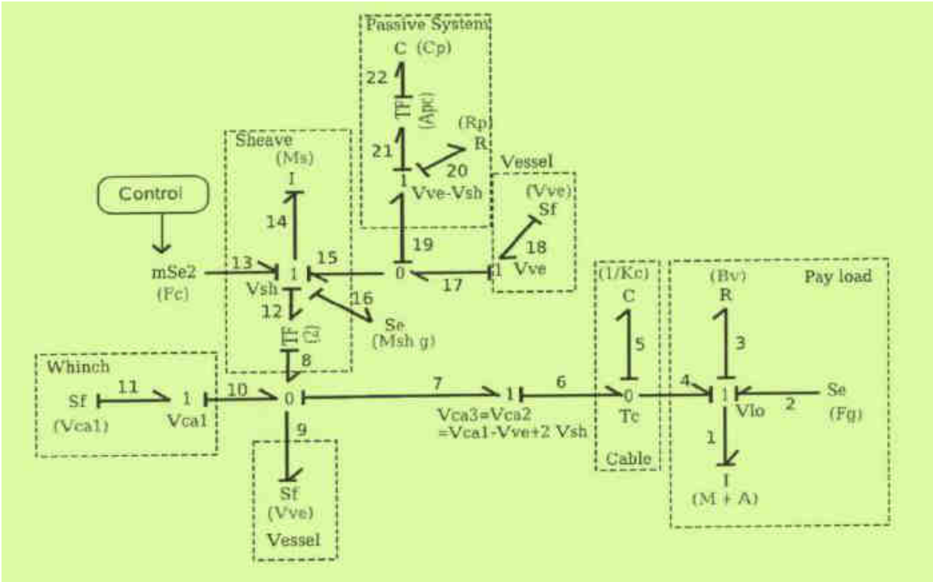

Fig. 4. Bond Graph System, [1]

3.4.3 State space equations

In accordance with the GB methodology, the following state variables are chosen:

$$x = [p_1, q_5, q_{22}, p_{14}]^T \tag{18}$$

Which correspond to the moment of the load $p_1 = (M_l + A)\dot{z_{l0}}$, cable deformation ($z_{ve}$ - z_{l0}), the instantaneous air volume in the passive system accumulator V, the sheave momentum, [1]:

$$p_{14} = M_{shvsh}$$

From Bond Graph BG, results:

$$\begin{aligned} \dot{p_1} &= e_2 - R_3(p_1/I_1) + q_5/C_5 \\ \dot{q_5} &= f_{11} + 2p_{14}/I_{14} - f_9 - p_1/I_1 \\ \dot{q_{22}} &= A_{PC}\,(f_{18} - p_{14}/I_{14}) \\ \dot{p_{14}} &= e_{13} - 2q_5/C_5 + R_{20}(f_{18} - p_{14}/I_{14}) + ApC_{22}^{-1}\,(q_{22}) - e_{16} \end{aligned} \tag{19}$$

Using variables x_i

$$\begin{aligned} \dot{x_1} &= g\rho V_{dl} - R_3(x_1/(M_l + A)) + K_c x_2, \\ \dot{x_2} &= V_{Ca1} + 2x_4/M_{sh} - Vve - x_1/(M_l + A), \\ \dot{x_3} &= A_{PC} + (V_{ve} - x_4/M_{sh}) \\ \dot{x_4} &= F_a - 2K_c x_2 + R_{20}\,(V_{ve} - 4/(M_{sh}) + + ApC_{22}^{-1}\,(x_3) - gM_{sh} \end{aligned} \tag{20}$$

where nonlinear relationship are R_3(u) and C_{22}^{-1} (V):

$$R_3(u) = \frac{\rho}{2} C_d A_P |u| u$$

$$C_{22}^{-1}(V) = \left[\frac{V_0}{V}\right]^{\upsilon} P_0 \tag{21}$$

and F_a is the force of the active system modeled as a modulated effort source – as shown în Fig. 4, with a constitutive law expressed in (17). The only two nonlinearities in system are the passive system compliance (isentropic process) and the viscous damping of the load, [1].

4. Numerical simulations

For the simulation scenarios, a marine environment representative of Australia's northwest reef was chosen for a summer period. The sea is composed of a crest (a significant height of 1 m and a dominant peak of 13 seconds) and waves created by the wind (a significant wave height is 2 m for a peak period of 9 seconds). Both components are represented with a **JONSWAP** spectrum. The ricrest reaches from the sea, while the waves form a 30 degree circle arc [1]

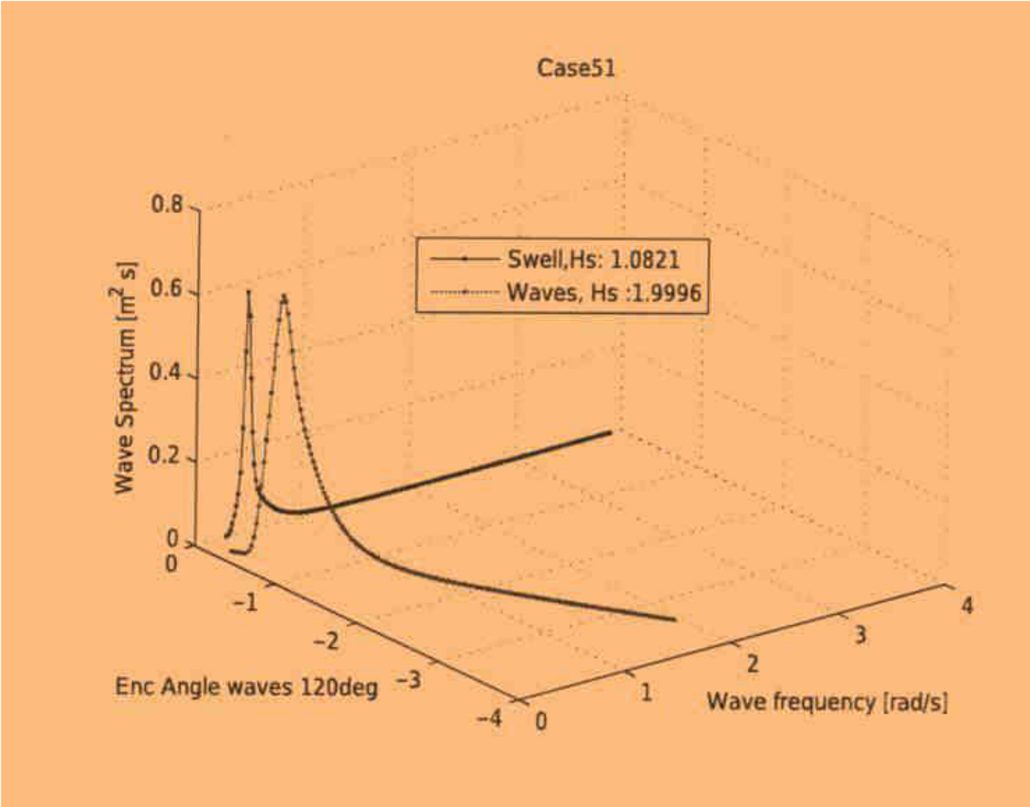

Fig. 5. Wave and crest spectrum, [1]

Fig.5 shows the corresponding spectra adopted. By combining the wave spectra with the vessels's response amplitude operators, the vertical motion spectrum was obtained where the crane is located This is shown in Fig. 6, [1]

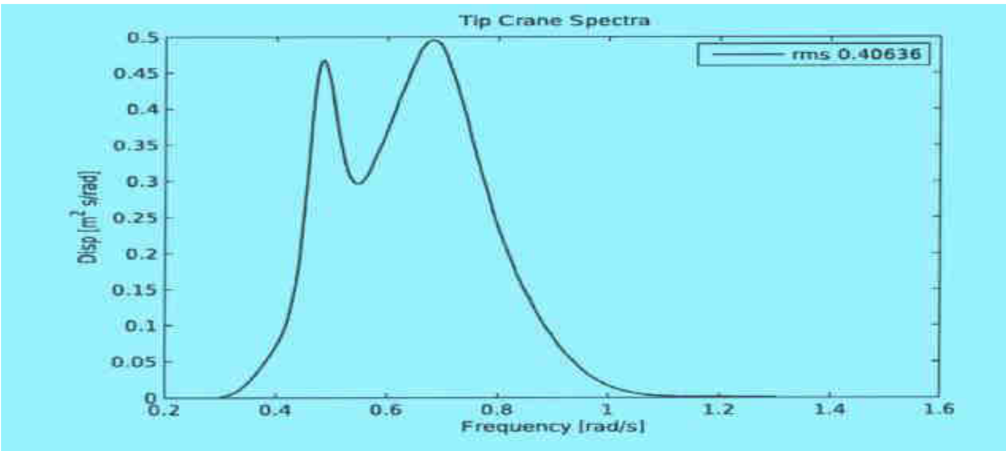

Fig. 6. The vertical motion spectrum where the crane is located, [1]

Timing simulations were conducted in a special environment chosen for various payloads commonly used in marine gas operations. Fig.7 shows an example of the vessel's lifting, cable tension and a 26000kg load displacement in relation to a depth of 150 m. The reduction in the **RMS (Root Mean Square)** value of the load displacement relative to the RMS of the vessel's displacement obtained in this the case was 99.1%. [1]

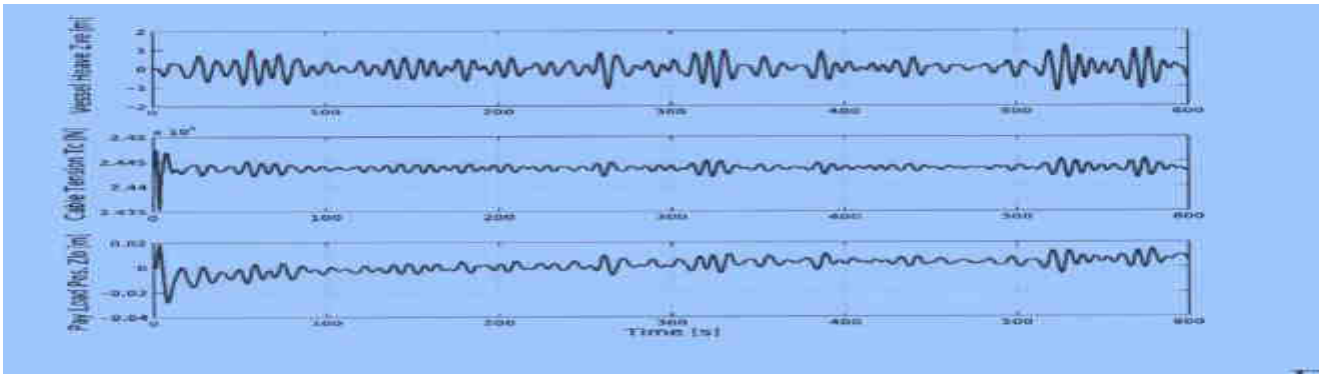

Fig. 7. Vessel movement, cable tension and load movement at a depth of 150 m, [1]

Fig. 8 shows the corresponding variables associated with the wave compensator, satisfying the constraints of +/- 1.5 x (half stroke)

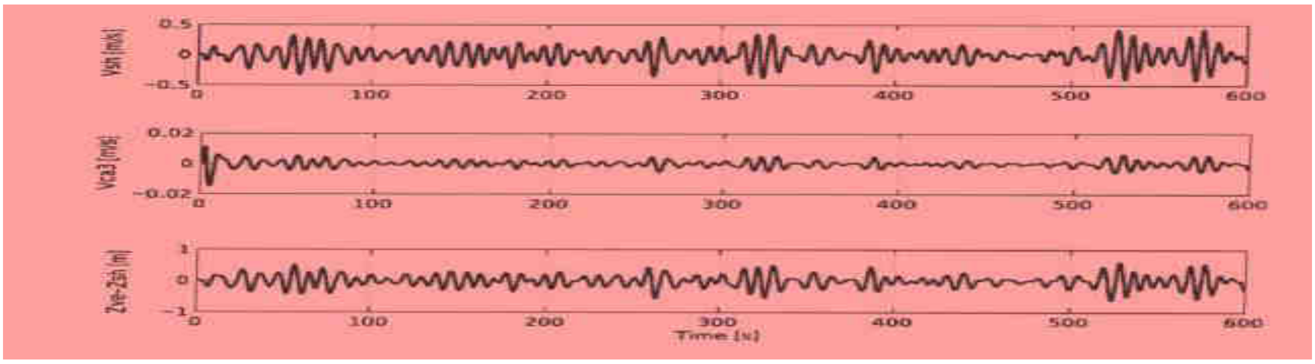

Fig. 8. Pulley speed, Cable speed and Relative displacement of the pulley relative to the vessel [1]

5. Discussions

In Chapters 3 and 4 the authors presented the modeling and performance analysis of a typical wave compensator for the handling of loads by cranes on seagoing vessels. An analysis of the operability and limitations of the vessel's movement and the capacity of the wave compensator stroke was made. These limitations represent a fundamental boundary that must not be overcome in order to achieve good performance. A mathematical model based on a Bond Graph approach has been described and all modeling hypotheses have been established. This model was then used to obtain a space state model of the system in terms of energy variables. Also, a simple control law has been proposed with an increase that can be used by the operator so as to obtain maximum performance without exceeding the limitations of the wave compensator. The system was tested in simulations with 8 different t loads, and the wave-effect mitigation (expressed in RMS) was over 95% in all the studied cases.

6. Conclusions

-The ongoing project at INOE 2000-IHP is in a field of smart specialization that belongs to energy, environment and climate change and wishes to contribute to energy efficiency.
-The innovative solution for achieving a wave compensator proposed by the authors of the article to be carried out in Romania is to use the hydraulic force in a closed-loop automatic regulation system to stabilize the loads handled by cranes boarded on floating platforms.
-Because the topic is for the first time approached in the field of research in our country, the authors considered it appropriate to deepen, establish and develop the necessary lines and directions to follow in order to achieve the proposed objective.
-When studying a similar project by specialists from abroad, the authors of the paper have proposed the realization and testing of a hydraulic mechanism to counteract the action of waves actually found in the project stage, and through mathematical modeling and repeated numerical simulations, to study its performances.
-By inventing and analyzing of these achievements in the field, INOE 2000-IHP is going to determine the optimal solution to compensate the disturbing effect of the waves on the floating cranes.

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LABORATORY SIMULATION /COMPENSATION DEVICE OF THE FLOATING CRANES PITCHING MOVEMENT

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***Abstract**: In recent years, floating cranes have been successfully used in offshore oil and gas operations. On the sea floor, there are installed specific mechanisms to vessels operating on the surface in a dynamic position, which are intended to counteract the action of the waves when the loads are handled by the cranes. In this paper, the authors present a test device developed at INOE 2000-IHP for the experimental study, on a small scale of the disturbing pitching movement. A test stand for two hydraulic servo-cylinders is also described and the results of the laboratory tests are presented.*

***Keywords:** Marine operations, waves compensator, hydraulic mechanism for counteracting the waves acting, mathematical modeling, numerical simulations*

1. Introduction

Floating cranes are installations used in ports and waterways at loading, unloading and reloading of heavy goods and parts, at the construction and rescue of failed vessels, at the installation of seaports and at the execution of various hydrotechnical works. They are also used in various handling operations of general merchandise with hook, respectively of ores, coals or other bulk products, with the grab or for transhipment of heavy loads. In recent years, these cranes have also been used in offshore oil and gas operations. They are provided with specific mechanisms to counteract the action of the waves on the handled loads. The vessels and floating platforms on which cranes are mounted are subjected to a specific roll and pitch movements, which can affect the handling of loads, in some cases even arriving at unwanted accidents, Fig. 1,[1].The disturbing pitch movement occurs around the transverse axis of a mobile system. In navigation, pitch is the longitudinal balancing motion of a vessel in march or stationary. It is due both to waving motion of the water, i.e. waves and wind, and consists of submersion in the water and the alternate lifting of the bow and stern. For experimental, small-scale study, of this phenomenon, in order to find of technical solutions for compensating the waves disturbance movement, applicable to the floating cranes, was carried out at INOE 2000-IHP Bucharest, the test device, shown in Fig. 2 ÷ Fig. 5, [2]

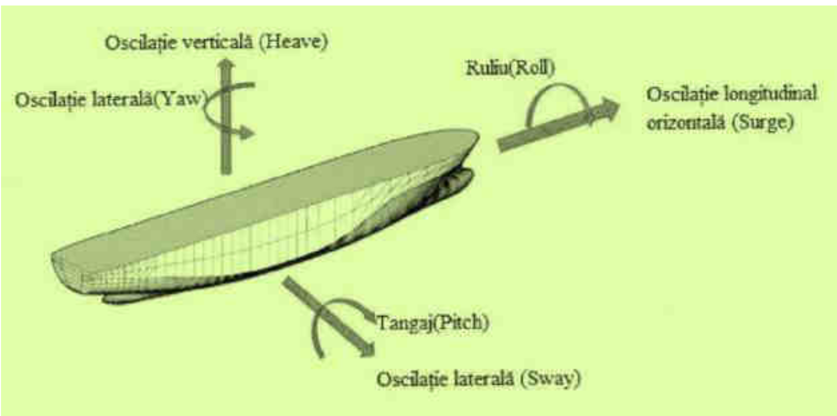

Fig. 1. The oscillatory movements of a vessel,[1]

Fig. 2. Device assembly,[2]   **Fig. 3.** Detail grip for servocylinders,[2]

Fig. 4. Double mobile slide detail ,[2]

Fig. 5. Driveway slides detail, [2]

2. Description of the test device

The device consists of two identical servo-cylinders, captured in a vertical position on a metal support made of a square calibrated metallic pipe (Fig.2). The body of the lower cylinder (Øpiston = 63,5mm, Ørod = 32mm, stroke = 300 mm) is attached to the metal support stand and its rod of a mobile double slide provided with four rollers; the body of the upper cylinder is attached to the same mobile double slide, and its rod of a mobile simple slide provided with two rollers. With this gripping system (Fig. 3), only the rod is movable at the lower cylinder, and both the body and the rod are movable to the upper cylinder. The two servo-cylinders also each includes a proportional hydraulic directional valve Dn 10 and a linear displacement transducer. The two movable slides have the displacement possibility on a driveway (Fig.4 and Fig.5).
The lower servocylinder simulate the disturbance movement caused by the waves in the vertical direction, and the upper servocylinder simulate the hydraulic compensation system of this disturbance, wiyh practical applicability at the floating cranes [2].

3. Description of the testing stand

The two hydraulic servo-cylinders were connected to a testing stand, Fig.6, with two pressure outlets, from the IHP laboratory. The stand has the following technical features [1]:
-pressure: max.40 bar (setting pressure safety valve stand);
-operating flows: max.30 l / min (for each pressure branch, adjustable flows rate from the adjustable pump of the stand); Laboratory tests useful power: 5 kW;
- maximum power installed on stand: 15 Kw;
-voltage supply drive motor variable flow volumetric pump: 380 VDC;
-voltage supply proportional electromagnets: 24 VDC;
-power control proportional hydraulic directional valves: 4 ... 20 mA;
-working domain displacement transducers: -10V ... + 10V

Fig. 6. Splitting the joint P of the stand in two cylinders power supplies,[2]

4. Results of laboratory tests

Laboratory tests were performed under the following conditions, [1]:
a) The testing device was placed in the servo-hydraulic and proportional equipments testing laboratory of IHP Bucharest, which contains a specialized stand;
b) The verticality of the test device has been checked and corrected by handling the four riding bolts mounted on the device frame;
c) The easy and unobstructed movement, on the drive-way of the two movable slides of the hydraulic cylinders was checked and found;
d) The two proportional hydraulic directional valves and the two hydraulic cylinders have been hydraulically connected;
e) The stand pressure valve was set at 30 bar and the adjustable volumetric pump flow rate at 60 l / min.
f)Ventilation of the hydraulic circuits has been performed by alternate manual switching of the hydraulic directional valves, followed by loosening and clamping of the screwed connections;
g)Through the programmable machine, the stroke transducers and the proportional electromagnets of the hydraulic directional vanes have been connected electrically.
h) Sinusoidal, trianguar, rectangular excitation signals of the servo-cylinder (the lower servo-cylinder) for vertical waves motion simulation were generated.

g) For these signals were drawn the graphs that represent the dynamic behavior of the hydraulic system for compensation the disturbances generated by the waves, of the type of hydraulic servomechanism tracking (the upper servocylinder).

For exemplify the tests, it shown in Fig. 7 the dynamics of the tracking hydraulic servosystem, when a constant sinusoidal signal with a frequency of 20 mHz and an amplitude of 120 mm is applied at the input of the hydraulic servomechanism for generation the disturbing motion of the waves. The test was conducted for 115 s.
The linear displacement inductive transducers of hydraulic cylinders have been set such that they also provide informations on the real movement direction (the upper servocylinder moves in the opposite direction to the lower servocylinder).
The results of the measurements, chosen from a stability interval of the laser-controlled tracking hydraulic servomechanism, between seconds 34 ... 100, are shown in Tab 1, [2].

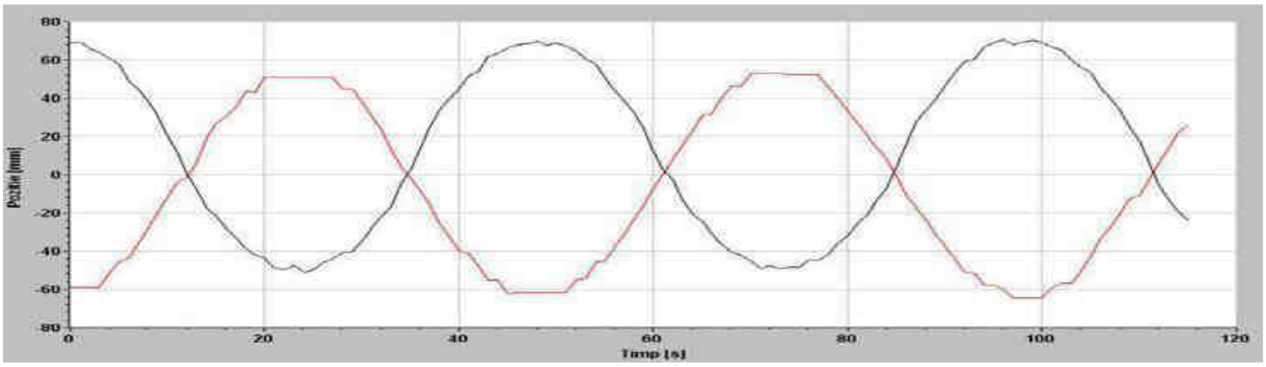

Fig. 7. The behavior of the tracking servomechanism (red) to the waves simulation servomechanism disturbance (black), which is excited with a frequence of 20 mHz sinusoidal signal, [2]

Table 1: The measurements's results represented by the graph in Fig.7, [2]

Time [s]	Waves profile [mm]	Displacement tracking system [mm]
34	-469,415,283,203,125	452,848,111,572,268
35	253,923,339,843,749	-199,534,489,257,812
36	140,272,521,972,656	-877,726,174,682,616
37	242,372,192,382,813	-155,293,231,738,281
38	332,293,273,925,781	-254,061,776,794,433
39	396,992,919,921,875	-326,088,010,791,015
40	4,482,587,890,625	-398,109,021,191,406
41	518,364,013,671,875	-413,960,533,581,543
42	543,018,981,933,594	-484,256,107,128,906
43	618,493,530,273,437	-552,978,695,056,152

Table 1: (continuation) The measurements's results represented by the graph in Fig.7, [2]

Time [s]	Waves profile [mm]	Displacement tracking system [mm]
44	635,161,376,953,125	-552,722,003,125
45	660,579,895,019,531	-62,022,502,322,998
46	678,940,734,863,281	-620,099,646,411,133
47	684,958,129,882,813	-619,887,717,651,367
48	697,086,669,921,875	-619,688,359,155,273
49	673,615,844,726,563	-619,464,616,870,117
50	689,706,970,214,844	-619,130,968,859,863
51	672,895,385,742,187	-618,801,451,379,394
52	646,726,623,535,156	-54,994,234,576,416
53	6,031,865,234,375	-540,645,311,486,816
54	577,966,491,699,219	-459,289,019,995,117
55	508,699,951,171,875	-4,526,859,109,375
56	441,773,620,605,469	-380,583,036,169,433
57	385,130,432,128,906	-310,622,676,660,156
58	325,839,660,644,531	-229,465,680,603,027
59	234,061,157,226,562	-157,224,690,588,379
60	126,471,130,371,094	-778,735,032,958,983
61	286,143,188,476,564	0.102380919189471
62	-261,438,598,632,813	780,153,814,208,987
63	-133,595,947,265,625	155,638,809,094,239
64	-210,845,275,878,906	232,299,255,773,926
65	-244,370,544,433,594	309,712,615,002,442
66	-309,001,831,054,688	317,416,883,361,816
67	-365,885,437,011,719	394,404,219,958,496
68	-404,054,138,183,594	462,255,959,777,832
69	-423,079,833,984,375	462,811,279,553,223
70	-451,504,943,847,656	526,763,914,868,164
71	-491,977,966,308,594	526,677,257,824,707
72	-474,029,479,980,469	526,618,726,220,703
73	-492,960,266,113,281	526,540,088,500,977
74	-483,058,166,503,906	526,368,287,890,625
75	-486,298,095,703,125	525,936,411,047,363

Table 1: (continuation) The measurements's results represented by the graph in Fig.7, [2]

Time [s]	Waves profile [mm]	Displacement tracking system [mm]
76	-445,271,545,410,156	524,980,965,905,762
77	-448,676,940,917,969	52,478,274,251,709
78	-418,021,423,339,844	463,711,861,169,434
79	-360,566,101,074,219	399,172,280,725,098
80	-319,608,276,367,188	330,113,207,019,043
81	-251,882,690,429,688	269,566,062,133,789
82	-211,139,526,367,188	201,172,192,907,715
83	-138,700,012,207,031	148,051,362,207,031
84	-704,994,506,835,936	823,437,141,845,704
85	408,278,198,242,186	-105,097,755,859,373
86	158,526,306,152,344	-106,098,254,138,183
87	275,133,178,710,938	-173,294,070,031,738
88	335,576,904,296,875	-240,064,189,111,328
89	387,102,355,957,031	-304,788,834,106,445
90	461,951,599,121,094	-373,395,388,830,566
91	534,602,233,886,719	-441,952,219,543,457
92	589,571,594,238,281	-512,032,742,785,645
93	605,573,181,152,344	-520,894,642,041,016
94	66,569,921,875	-579,551,244,494,629
95	686,786,743,164,063	-579,245,469,677,734
96	704,970,397,949,219	-599,941,567,993,164
97	681,842,163,085,938	-646,685,564,892,578
98	691,039,001,464,844	-646,569,994,140,625
99	70,250,634,765,625	-64,625,687,265,625
100	691,003,173,828,125	-646,074,898,120,117
101	668,007,690,429,687	-594,501,744,348,144
102	653,177,001,953,125	-567,164,353,222,656
103	599,284,057,617,188	-567,004,408,178,711

5. Conclusions

1. The results of the experimental tests indicate that the hydraulic tracking servomechanism is fast and stable in operation.
2. These dynamic performances recommend that the servomechanism tested in the laboratory is a technical solution to compensate the disruptive effect of the floating cranes.

Acknowledgments

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CAD-CAE MODEL FOR THE STRUCTURAL ANALYSIS OF A DRIP TAPE INJECTION EQUIPMENT FOR SUBSURFACE IRRIGATION

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Abstract: *Subsurface drip irrigation is a great irrigation system for field crops. With regard to drip irrigation on the surface, subsurface irrigation offers the possibility of performing all mechanized agricultural work. This system is all the more advantageous as it saturates the root, greatly reduces the risk of weeds, greatly reducing workload. The subsurface drip irrigation system can be installed at various depths, depending on the type of crop crops, germination bed preparation, roots depth. For field crops, the installation depth is 30 ... 40 cm. This article presents the way to obtain the structural model for elementary linear-elastic static analysis of main resistance structure of a drip tape injection equipment. Also, to prove the functionality of the structural model obtained, structural analysis results for the linear elastic static test are presented. These results are useful for estimating the safety factor and for assessing the behaviour in major overstress situations at the main part of the machine*

Keywords*: Structural model, structural analysis, tape injection platform, subsurface drip irrigation*

1. Introduction

Use of subsurface drip irrigation (SDI) has progressed from being a novelty employed by researchers to an accepted method of irrigation of both perennial and annual crops [1]. SDI is a management tool that allows precise control over the root zone environment of the crop. This control often results in consistently high yields. In addition, better water and fertilizer management can help reduce fertilizer inputs, water needs, and runoff. [2] The first step in the installation process of an SDI consists in the drip tape injection. Considering the long-term use of the subsurface drip irrigation system, the dripline must be buried below the plough layer [3]. The injector consists of a roll that holds the tape and a shank that opens the soil to bury the tape [4]. As the shank opens the soil, the tape is guided into the soil, usually through a curved pipe mounted behind the shank. The shank must be durable enough to resist the impact of rocks and other obstructions in the soil. The pipe that is mounted behind the shank should be smooth and curved so it does not tear the tape.

Optimal design or improvement of a complex mechanical structure are activities that are currently carried out in the work of advanced companies working in the field of mechanical and other types structures. Designing an optimal product (at least from some points of view) or optimizing existing products requires complex working tools that are nowadays integrated into CAD-CAE complex programs. The workflow in the CAD - CAE complex is often fragmented, due to the great workload and complex knowledge it requires. For these reasons, in general, the CAD model may come from suppliers who don't have the qualification to do the structural analysis and vice versa, CAE models are used by structuralists who don't have all the engineering knowledge needed to create manufacturing drawings. Moreover, it is known that, in order to make manufacturing drawings, in CAD drawings some gaps are left to be filled by weld seams or other techniques. Such a CAD model is not functional from the point of view of structural analysis. Another problem that generates difficulties in obtaining CAD models is that CAD model providers can work in a drawing program (often older and less performing) while the team performing structural analysis needs the CAD model appropriate to another program.

Considering these obstacles to the direct use of the original designer's CAD model in the structural analysis, a first part of the article is dedicated to transforming the original CAD model presented in figure1 into the CAE model undergoing structural analysis in the CAD-CAE SolidWorks program.

Fig. 1. CAD model of the structure in the usual form for SolidWorks program

The second part of the article presents the elementary results of the structure elastic-static analysis as proof that the transformation was correct. The fact that the results of the structural model are correct, so the results of the structural analysis are correct, can only be found experimentally. For the time being, as we don't have experimental results, we rely on the fact that the structure has worked in difficult conditions without the occurrence of deficiencies or damages. Experiments will be done after we have accumulated enough theoretical data to test as many of them within the same experiment. Global concerns in most of the directions that our research addresses are very common [5], [6], [7], [8], [9].

2. Material and method

2.1 Converting SolidWorks CAD model into simplified SolidWorks CAE model

CAD conversion to CAE resulted in an assembly that could not be used for structural analysis. To solve this impediment we isolated each benchmark, we revealed each piece and assembled it until it reached its final shape. After making the final assembly, with all its parts, it is necessary to check the existence of interferences in the structure, fig. 2, because the presence of interference (overlap or gap) can prevent the analysis program from running, or, even worse, make it run using wrong results.

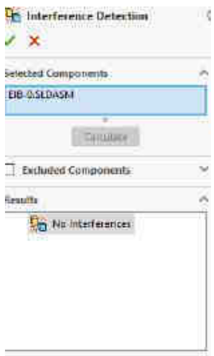

Fig. 2. Checking the interferences before starting structural analysis

2.2 CAE model structural analysis

The CAE model is simplified, fig.3. This model introduced in the structural analysis does not contain the rear superstructure of the machine or some small subassemblies. Not all subassemblies are important.

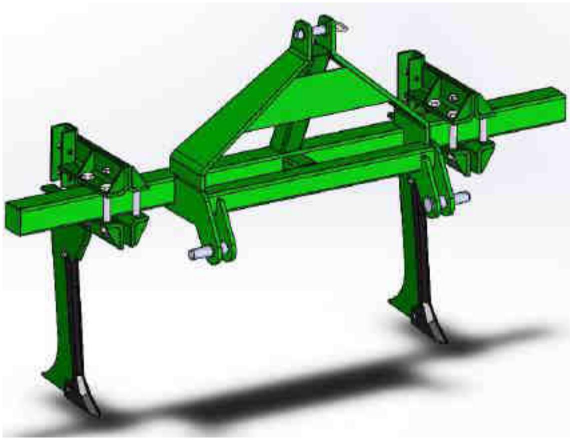

Fig. 3. The simplified CAD model subjected to finite element analysis

2.3 Fixing conditions (Structure bearing)

The structure is borne in three points by the tractor attachment system, Figure 4. The attachment to the tractor is (exaggeratedly) made by inserting (cancelling all degrees of freedom on the contact surfaces between the tractor and equipment attachment elements).

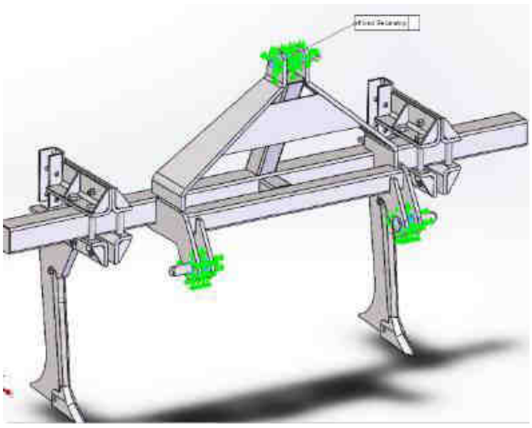

Fig. 4. Structure bearing

2.4 Structure loading

In this article, we study the response of the structure only for the normal maximum workload. The total force applied to the projection of working parts on the normal plane to the travel direction was calculated using the method of [10], [11], [12].

$$F = k a_0 b_0 + \varepsilon a_0 b_0 v^2 \tag{1}$$

where the sizes with index 0 correspond to the working parts, (corresponding to the working depth, up to the working parts level). In (1) F_0 are the resistance forces of the soil at the action of the two parts of the working body, a_0, b_0, are the working depth and width of the working body's respective parts, while k_0, ε_0, are soil specific resistances to deformation and soil resistance to deformation coefficients due to the working speed. The working speed has been noted with *v*. In the example

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considered with depth of work at 40 cm, we used the following values: $a_0 b_0 = 0{,}021$ m^2, k_0= 100000 Pa, ε= 2200 kg/m^3, v= 4 km/h. The calculated force was applied to the structure according to the graphical representation in Fig. 5.

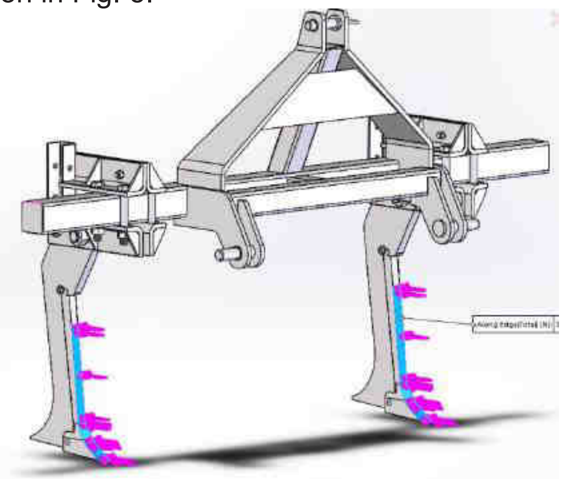

Fig. 5. Loads application (forces)

To perform linear-elastic static analysis, the global contact command was applied. This condition applied by the finite element analyser eliminates any kind of clearance, creating stress conditions corresponding to a more rigid structure than the real one. Thus, tensions will be higher than in reality, and relative displacements (deformations) are expected to have lower values than in reality. The discretization of the structure can be seen in Figure 6.

Fig. 6. Structure discretization: Projection of finite elements on the structure border

The materials used for the components of the analyses structure are shown in Figure 7 together with the respective properties. For the pipes, S275JR was used, S355 was used for the plate parts and 16MnCr5 was used for the working parts.

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	410000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	275000000	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	J/(kg·K)
Material Damping Ratio		N/A

a)

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	450000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	275000000	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	[illegible]

b)

Property	Value	Units
Elastic modulus	2.100000031e+011	N/m^2
Poisson's ratio	0.28	N/A
Shear modulus	7.9e+010	N/m^2
Mass density	7800	kg/m^3
Tensile strength	800000000	N/m^2
Compressive Strength in X		N/m^2
Yield strength	590593984	N/m^2
Thermal expansion coefficient	1.1e-005	/K
Thermal conductivity	14	W/(m·K)
Specific heat	440	J/(kg·K)

c)

Fig. 7. Material properties: a) S75JR, b) S355 and c) 16MnCr5

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3. Results

The main results of the static linear-elastic structural analysis are: the values of the reactions in the holders, vector field distribution of the relative - resultant displacement in the structure, tensor fields' distribution of the specific deformation and the Cauchy stress tensor in the same structure. Also, an important result for the structure safety is the distribution of the safety factor.
Table 1 shows the values of the resultant forces components, which are also found in the values of the reaction forces (in the three bearing areas).

Table 1: Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	5677.45	-0.230323	0.29408	5677.45
Reaction Moment(N·m)	0	0	0	0

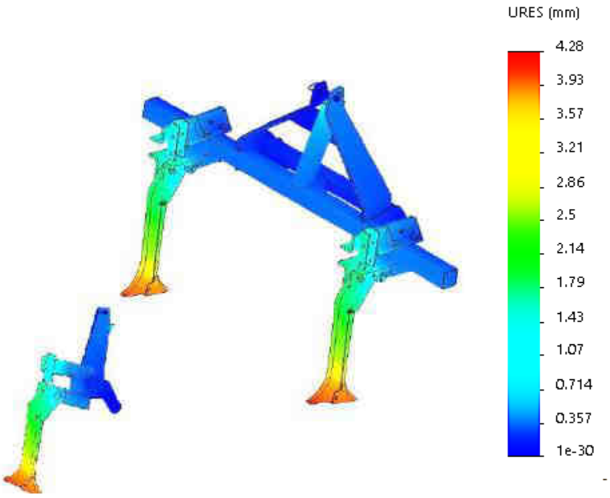

Fig. 8. Distribution of the relative displacement field values resulting on the structure border

Figure 8 graphically represents the distribution maps of the relative displacement field values on the structure border. It is noticed that the maximum value (about 4 mm) is located at the back of the structure. This maximum value can be exceeded if we take into account the clearances of the structure and of the connection system between the equipment and the tractor. Increasing the movement, in the conditions of the considered stress, admitting the clearances, contributes to the relaxation of the structure and consequently to the increase of the safety factor. However, exaggerated clearances generally lead to more or less premature wear.

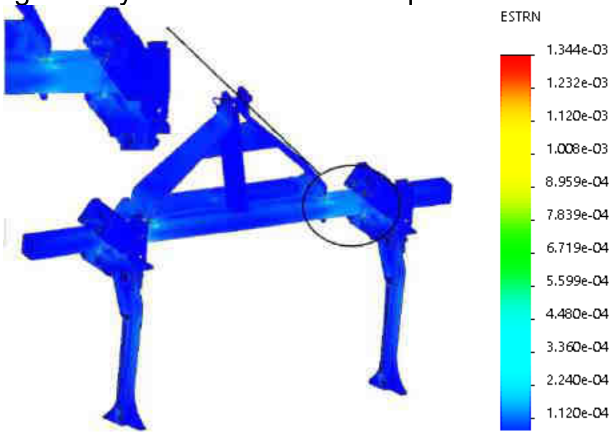

Fig. 9. Field values distribution of the total specific deformation on the structure border

In figure 9, the distribution of the total specific deformation values is graphically represented by color map. The maximum stress area is also indicated in detail. Due to the fact that we are working in the elastic-linear field, the maximum tension will be located in the same area as the maximum specific deformation. The maximum equivalent tension is graphically indicated in the same way in Figure 10.

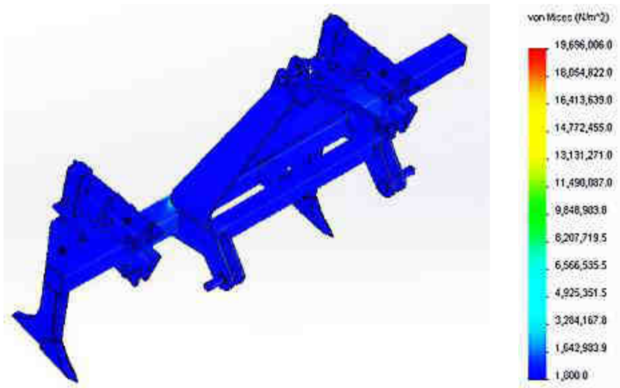

Fig. 10. Representation of the equivalent tension distribution on the structure border

Finally, Figure 11 shows the graphical representation of the safety factor distribution in the structure.

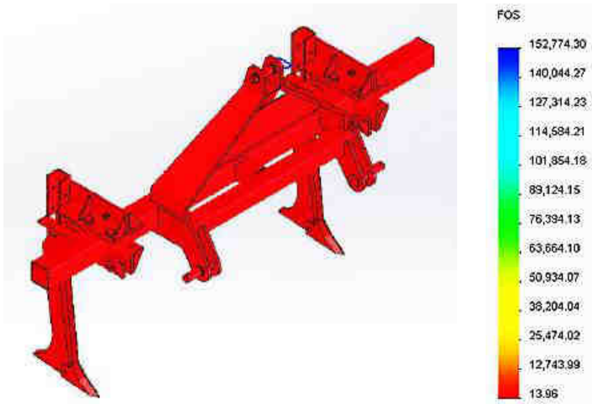

Fig. 11. Safety factor distribution in the structure border

The minimum safety coefficient value is 13.96. For agricultural machinery destined to soil works, the usual safety coefficient values are between 1.8 and 2.2. Therefore, this machine is either much oversized, or it works under much tougher conditions. The latter may appear either due to use under improper conditions or due to accidents (impact with hard rocks or roots in soil).

4. Conclusions

Following this first structural study on the drip tape injection equipment, several important conclusions can be drawn for further investigations.

For a normal load, calculated according to the criteria outlined in the paper, the load-bearing structure of the equipment is overestimated, leaving aside possible accidents in the soil (hard bodies) or the use under improper conditions.

Considering the maximum values of equivalent tension, there are no risks of structure material failure. Also, the maximum relative displacement values guarantee that deviations from working parameters dictated by agrotechnical requirements (working depth, in particular) are negligible, at least regarding the essential part of the equipment work.

The high value of the safety coefficient (13.96), in relation to its usual values in the practice of designing and manufacturing agricultural machinery for soil works, shows that there is an important potential for optimizing this machine. Since the equipment could be used on a land that has not been tilled for five to ten years, there is the possibility of accepting a coefficient of up to 7 - 8; therefore, it would be the case for a substantial optimization study.

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FUNCTIONAL FEATURES OF A ROLLER MOTOR PELLET PRESS

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Abstract: *The present paper presents the analysis of the constructive - functional solution of a pellet press made with TEHNIC ECO CDI S.R.L. on the basis of an idea developed by INOE 2000 - IHP, on the subsidiary contract of a single project on Axis POC - G. At the level of the experimental model a pellet press with a motorized sieve and it was tested in real conditions to see if it achieves the designed parameters. During the work the functional samples and the results obtained during the experiments are presented.*

Keywords*: Biomass, pellets, eco-innovative technologies, pellet press*

1. Introduction

Biomass includes all forms of material from vegetal and animal grown on land or water, as well substances produced by biological development [3].
The term biomass applies to the mass of matter generated by the development of living organisms, whether microorganisms, plants or animals. The term also includes agricultural products, agricultural crop waste, including grain straw, residues from the production of sugar, starch, beer, etc.
Plant biomass production is the result of the photosynthetic activity of all the individuals that make up a plant community (population or association). Biomass production of a plant cover (lawn, meadow, forest, etc.), referred to as primary production, is expressed by the mass of the organic substance produced per unit of land covered with vegetation (g / m2, t / ha) and in the unit of time considered (year) or expressed in energy equivalent (joule, kcal / ha-1 / year).
For any agricultural crop or natural vegetation association, four factors determine net productivity or net biomass growth: the amount of incident solar energy; the proportion of this energy intercepted by the green organs of the plant; the efficiency of photosynthetic conversion in the biomass of intercepted energy; breathing biomass losses. Only a small part of the solar radiation that reaches the earth's atmosphere is captured in the plant photosynthetic process and is transformed into biomass. It should be noted, however, that a 1% photosynthetic efficiency corresponds, in the absence of water stress, to a production of about 30-35 t of dry biomass / ha / year [2].
According to the European Union legislation, "biomass represents the biodegradable fraction of waste products and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of municipal and industrial waste" [2]. " Biomass "is a generic term for energy from organic matter, mainly represented by vegetable materials (agricultural crops, agricultural waste, organic waste, forestry and gardening waste) as well as other organic materials such as manure, waste pulp and paper industry, food industry, sewage sludge, solid municipal waste

2. Pelletizing / briquetting technologies for solid agricultural and forest biomass

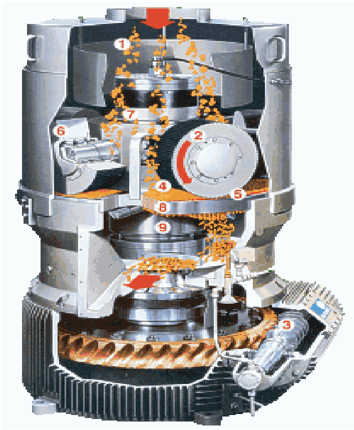
The degree of use for technologies based on renewable resources varies from one country to another. Biomass plants have found a market in Denmark, where about 20,000 units a year are sold, and those in cogeneration in Germany and England. The reduced purchasing power, as well as the poor ecological awareness of the Romanians, however, leads to an extremely low use of such equipment.
The production and distribution flow to the consumer for the production and use of pellets or briquettes (the green renewable fuel of the future) shown in Figure 1 starts from plant biomass as

raw material and goes through 9 phases until the consumer distributes and uses these fuels final, [52].

Fig. 1. The technological flow of pellet production and distribution, [8]

The operations performed in each production phase as well as the equipment contributing to the realization of each technological process, specifying also their technical characteristics, are:
The preparation of the materials starts from the basic concept that in the technological flux of pellets or briquettes the material is used only in the form of sawdust. For the transformation into sawdust of materials in different forms, such as wood waste resulting from the manufacture of lumber or the manufacture of furniture with massive elements, remains left from logging, logs, branches, cages, leaves or scrap agricultural crops, etc., the preparation of the material for the production of pellets or agricultural pellets requires additional machinery in addition to harvesting, transporting, chopping and shredding. The preparation of the materials consists in sorting and grinding of wet materials in order to obtain the granulation necessary for the use of the materials in the production stream by means of disk or drum (mobile or stationary) scrapers. But the main materials to be removed from sawdust that is coming from sawmills and woodworking remain wood waste in the form of edges from lumber cutting, lobes from cutting, pieces of wood from machining. All of these materials can be removed by dimensional sorting which besides the role of removing the wood pieces also have the role of selecting only the size of the grain allowed to be introduced into the sawdust dryer, knowing that only granules of certain sizes can be introduced in continuous flowing drying systems provided with various magnetic separation systems.
Drying of woody granular materials is carried out with equipment (dryers), in continuous flow and with fully automated systems, using biomass, sawdust or briquettes and wood waste, for producing the necessary thermal energy. The range of dryers, ranging from 400 kg / h to 12,000 kg / h, can be stationary or mobile.
The grinding of woody granular materials is a necessary operation to obtain a certain constant and homogeneous dimension for use in pelleting machines. Choosing a milling hammer mills is based on several criteria such as material type, assortment, degree of humidity, production capacity, etc. Each type of hammer mill requires special power and exhaust systems to integrate into the production stream.
Palletization / briquetting is the transformation process of materials specially prepared by the components of the manufacturing process fuel into the fuel. The palletization is carried out by extrusion, meaning by a forced and continuous passage of a very large quantity of material through a very small hole, in Figure 2 there is shown a section through a press used for the manufacture of pellets. The choice of the type of pelletizing machine as well as the systems for feeding, mixing and conditioning the material at the entrance to the machine must be made on the basis of several criteria which take into account besides the desired capacity of the type, assortment and humidity of the material, but also by the way preparation of the raw material in the equipment used before

introduction into the pelletizer [7]. The wood chips and wood pieces with a moisture content of less than 10% are introduced into the pellet press, the shreds being shredded to the size of the shank, then placed in a homogenization tank where the humidity required for the technological process is obtained (if necessary, a surplus spraying water). The pulp is then pressed by extrusion, where the wood binder becomes active, helping to form the pellets, while giving the glossy surface of the pellets, important in the initial automatic ignition stage. No adhesives are added to the pellets, after pressing the pellets are cooled, dosed and loaded into bags.



1. Loading the chips
2. Pressure roller
3. Motor
4. Contact surface
5. Mold for pellets
6. Bearing
7. Spreader
8. Extrusion plate
9. Schrader

Fig. 2. Section through a press for the production of pellets, [7]

Cooling after the pelletizing operation is a mandatory operation in the manufacturing process stream due to the high temperature of the finished product at the exit of the extrusion die. The outlet temperature can reach 90 ÷ 100°C which results in damage to the finished product if it is still stored or packaged at this temperature. The technological line must be fitted with a dust extraction system in the pellet cooling unit.

Packaging of the finished product - pellets is made in plastic bags weighing from 10 to 15 kg and up to 25 kg as required. It is also used to pack large bags of special material weighing 500 ÷ 1000 kg for the industrial use of these fuels. There are various packaging machines in plastic bags and bag sealing systems in both semi-automatic version and in the fully automated version with robots for picking up and positioning the bags with pellets on pallets.

Storage is the required operation especially for the final customer before the pellets are used to power the respective heat exchangers.

The final consumer is the user of the thermal power plants for the production of hot water or hot air.

3. The functional constructive solution developed by S.C. TEHNIC ECO CDI S.R.L.

The pelletizing presses can be with discontinuous operations and with hydraulic actuation and hydraulic cylinder pressing chamber, respectively with continuous operation, with the screw-operated press chamber.

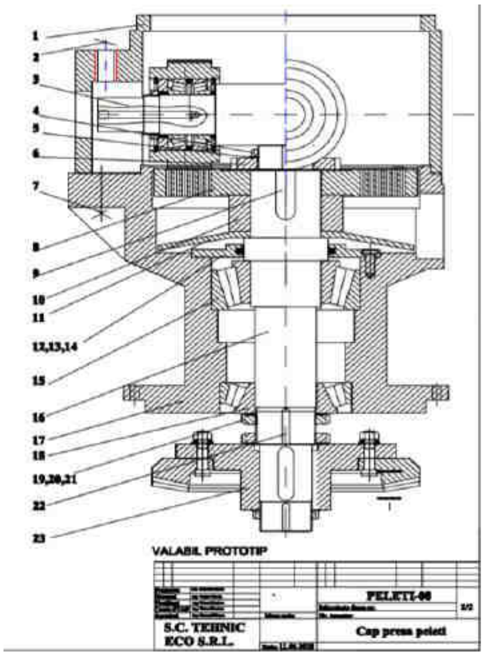
The company SC TEHNIC ECO S.R.L Bucuresti had as main objective assimilation in manufacturing and entering this market segment with production capacity equipment adapted to the requirements of individual agricultural producers or costly in small and medium associations, at a competitive price / quality ratio.

The pellet press proposed to be carried out within the project is a vertical motor shaft press with rotary extrusion plate and fixed press rollers.

The drive group consists of an electric motor with a power of 30 kW and a conical gear with an evolving profile to transmit the torque from the electric motor shaft to the press shaft.

The transmission is mounted in the lower case of the press, the motor shaft being provided with bearings with conical roller bearings, able to take over the forces developed in the conical gear and transmit them to the casing.
The two press rollers are mounted on a horizontal axis in the top housing of the press via conical bearings.
The distance between the pressing rollers and the extrusion plate with 6 mm holes is adjusted by means of screws and compression springs.
By rotating the extrusion plate between it and the pressing rollers, friction forces develop, causing the previously processed biomass to be pushed (fragmented to 15-30 mm and max. 15% humidity) through the holes, resulting in the pellets.
Between the extrusion and transmission chamber is placed a Tron conic shield with the role of biomass targeting and transmission protection.
The working capacity of the press is 500 kg of biomass per hour.
The technical solution is presented in figure 3 a and b in which is presented the functional constructive solution (variant), the roller motor.

a



b

Fig. 3. The technical solution chosen to be carried out within the project

Desired technical characteristics of pellets:
Diameter: 3-15 mm (6 mm diameters)
Length:<60 mm
Bulk weight: ~650 kg/mc

Density: >1200 kg/mc
Humidity: <8%
Ash: <1.5%
Heat power: between 3500 and 4500 kcal/kg
The equipment was developed in the experimental model phase and subjected to verification and operation tests to be validated in order to pass the prototype phase.

4. Experimental results obtained on the experimental model:

The equipment was connected to the power supply and the equipment was switched on (Figure 4) to check its functionality. This corresponded with the fact that the engine started and moved the engine sieve and the rollers.

Fig. 4.

Fig.5.

Verification at start-stop and verification of electrical safety systems were also carried out. The equipment was turned off and started several times and found to respond to orders. It tried to start with the door from the command and control system open and it did not start what corresponds to the designed function Check that the equipment stops when the metal elements enter the pressing area (fig. 5). To perform this test, some metal elements (nails) were inserted into the pellet press and it was observed that it stopped. It was necessary to remove and extract the metal parts between the pressure rollers and the motor sieve. The product also corresponds to this point of view. **Samples with unsorted compaction material to check for load performance.**
Prior to performing the tests, the possibility of priming the press and the technological process of pellet production was checked. Within these two activities, the compaction parts were also drilled by grinding the holes of the site with mined biomass, but also with specific material (fine sand, engine oil, etc.).
It has been observed that it is necessary to prepare the equipment for operation in real conditions by polishing the extrusion holes of the motorized web. This has been achieved by:
a) 6 times the abrasive material (consisting of a mixture of 5 kg of raw material (sawdust, straw pastry), 1 kg of fine sand and 1 kg of used motor oil)
b) Compaction samples resulted in low density pellets (Fig. 6) which led to the conclusion that an additional crossing of the abrasive mixture for grinding the holes of the motorized web
The samples from a) and b) were repeated three times so it was concluded that only after a passage of at least 18 times the material the specifics obtained were within the limits required by the design theme from point in view of the density (Fig. 6), (Fig. 7), (fig. 8).

5. Conclusion

Following the experiments, it was concluded that the pellet press projected and realized within the project is appropriate in terms of functioning. Make pellets at the desired size and density only after a proper start is made. It has been shown to be easy to make and use.
Analyzing the statistics that assess the current and prospective state of the development for the agricultural in Romania and Eastern Europe. The management of TEHNIC ECO CDI S.R.L. through its development strategy, it has proposed medium and long-term objectives, assimilation into production and development of innovative new products (pellet presses, biomass shredders, oil presses, vegetable-fruit driers, atomizers, machines to be packed, etc.). These products meet the

needs of small rural entrepreneurs to help them achieve their goals and implementation indicators, ensuring their economic efficiency and sustainability.

Fig. 6.

Fig. 7.

Fig. 8.

Since the financing of the projects of the small entrepreneurs in the rural area is still in the beginning in Romania, the assimilation in production and the approval of the new products, in order to put them on the market in a short time, represents a major strategic objective and a challenge of managerial on short and medium term.

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COGENERATION WITH BIOMASS IN CHPAB CONCEPT

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Abstract: *The paper analyzes the use of the* ***CHPAB*** *concept to produce from biomass electric energy, thermal energy and biogas by cogeneration with a negative carbon footprint. Cogeneration with biomass in CHPAB concept is easy to incorporate into a Smart Grid energy system to maximize energetic efficiency and security. To maximize the energy efficiency of cogeneration, the gasifier and the thermal engine operate in an optimal regime. From 1870 kg. biomass produces 1 MWhe of electricity, 2.42 MWh of thermal energy and 282 kg. biochar. The energy efficiency for electricity production is 11.5%, for heating is 27.8% and for cogeneration is 39.3%, with a negative carbon foot print –0.282 kg.C/kWhe.*

Keywords*: Cogeneration, biomass, CHPAB concept, carbon foot print, smart grid*

1. Introduction

For sustainable development, it is necessary to make the most of the renewable energy resources: solar, wind and biomass to meet future energy demands for a growing population with growing needs. One problem with systems that harness the solar and wind resource is that they cannot deliver energy immediately and as needed, that is, they are not dispatcable. Biomass is still a cheap renewable source from which energy is produced by direct burning, pyrolysis or gasification when and as needed.
Cogeneration is the most energy-efficient and economical option to produce electric and thermal energy from solid, liquid or gaseous fuels, but also has a positive or near-zero carbon footprint.
For farms and small communities, the intelligent network type **Smart Grid** concept represents the trend of decentralizing power supply from various sources of energy through the organization of energy network. The Smart Grid system identifies the status and charging of all network elements, it can provide basic loading and can prevent real-time overhead from managing network-connected power sources
The production of thermal and electric energy with wood or charcoal gasifiers has been widely used in World War II due to oil fuel shortages. At present, the requirements of sustainable development have brought back the current thermo-chemical gasification processes of biomass to a higher level of knowledge and technology to produce electricity with a negative carbon footprint in a low-power power plants, accessible to agricultural farms and for more isolated areas. [1, 2, 3, 4, 7, 9]
As an alternative to current methods of thermal energy production from biomass it is the **CHAB** (**C**ombined **H**eat **A**nd **B**iochar production) concept which includes also the biochar (BC) generation. BC is a sterile organic material obtained from biomass pyrolysis in an oxygen-free environment or with a sub stoichiometric concentration, with alkaline pH. It has a carbon content of 80-95% and it is characterized by high porosity and adsorption capacity. [3, 4, 6, 7, 8, 14]
The biomass gasification in **CHAB** concept uses the biochar byproduct gasification during thermal power generation, as the carbon store that can be collected and sequestered. Sequestration is much easier than flue stack CO2 gas capture and storage, as char is a solid and easy to handle. Biochar is equally important as a soil amendment, with surprisingly powerful benefits to plant productivity, soil biological activity, water retention, pest management and mineral uptake in plants. And as it is known to be stable in soil for 100s to 1000s of year timeframes, it is a low tech and cheap method for carbon storage, already with a scaled infrastructure via global agriculture. [1, 2, 3, 6, 7, 16, 17]
Biomass-based cogeneration-based on the **CHPAB** (Combined Heat Power and Biochar production) concept that synergistically combine the production of electricity, heat and biochar,

providing the most energy-efficient, economical and environmentally-friendly use of local residual biomass. Cogeneration plants with CHPAB can easily integrate into a Smart Grid energy network by making a valuable contribution to local energy resources by increasing safety and energy independence with low operating costs. [15, 19, 20]
Current combustion plants with internal combustion engines are simpler, smaller in size, displaceable and affordable for small biomass producers in agriculture or forestry. For the use of biomass as a primary energy resource in cogeneration the CHPAB concept is integrated. Examples are the current achievements of: ALL POWER LABS, V-GRID ENERGY SYSTEMS, DIACARBON, ECOERA and EPRIDA. [11, 13, 14, 15]
ALL POWER LABS has developed a cogeneration plant in CHPAB concept with which it is possible to change the proportion of bio-produced produced as needed and biomass used, with high values for real energy efficiency coefficients in cogeneration. It is stated that one tone of dry gas biomass produces 1 MWh with zero production of biochar. Increasing the proportion of biochar reduces the energy resource for cogeneration and produces less electricity. [11, 21, 22]
V-GRID ENERGY SYSTEMS has developed a 100 kW generator that runs on farm waste biomass and can generate electricity for as ˆ0.02 per kWhe. In contrast, farm utility power in California average ˆ0.15 and diesel costs over ˆ0.20 per kWhe. Solar require a 10 year + commitment whereas our mobile system require just a few month lease trial. Our systems can also co-produce biochar soil enhancers optimized for farm’s needs. [15]
The below is an example of a 500 kW V-Grid Server Array, figure 1, with one month capacity fuel silo for 24/7 on-demand Power V-Grid’s Bioenergy Servers can be both mobile and stationary. Each Bioenergy Server consists of a gasifier and a generator pairing, that can be deployed to remote well sites or be linked together into an array to produce 24/7 on-demand power for large scale operations. [15, 19, 20]

Fig. 1. V-GRID power station generating 500 kW V-GRID on a farm

Internal combustion engines powered by syngas operate at maximum efficiency on the minimum fuel consumption characteristic (MCC) feature at which the power output consumption is minimal. [5, 19, 20, 22]
Also, the yield of the gasifier is determined by the operating mode and biomass properties used, which limits the optimal operating range. Consequently, the combination of gasifier and internal combustion engine has a limited operating range for maximum operating efficiency. [17, 23]
An example of optimal cogeneration with a system consisting of a biomass gasifier and an internal combustion engine is disclosed in patent **FR3016005**, a gasifier energy-production device, with an application for driving an electric + mechanical hybrid propulsion. It is an object of the invention to provide an electrical power generating device comprising an internal combustion engine fueled from syngas produced by a biomass gasifier, an electric motor driven by the internal combustion engine and at least one battery such that at a stationary the production of syngas by the gasifier

and the shutdown of the engine, all the fuel gas produced serves to supply the engine and produce mechanical energy. [18]
Recent development by EPRIDA, Inc. have made this technology more scalable to agricultural industries with two sizes of pyrolysis units. The first processes 1-ton of biomass per hour unit and produces 1 MWhe of electricity, 1 MWhth of usable heat and 136 kg. biochar per hour. The second processes 25 kg of biomass per hour, producing 25 kWth of heat and 25 kWe of electricity and 9 kg. biochar per hour. The Eprida process was developed through research conducted with the National Renewable Energy Labs, Oak Ridge National Laboratory, the Pacific Northwest National Laboratory, U.S. Dept. of Energy, USDA EPRIDA, Inc. Agricultural Research Service, University of Georgia and Iowa State University. [13]
Most gardeners and farmers would excitedly embrace any method that results in increasing their yields by even a few percentage points. The results of Diacarbon's initial growth trials that studied the application of biochar to tomato plants should truly give them reason to celebrate. Recently, Diacarbon's research and development team showcased our biochar in a few landmark growth trials that revealed dramatic improvements in plants survival alongside yield increases of nearly 70%. [14]
The paper aims to analyze the operation regime of a cogeneration plant with CHPAB concept, consisting of a biomass gasification system that produces syngas and biochar, an internal combustion engine that operates an asynchronous electric generator so that the engine can function on the minimum fuel consumption characteristic (MCC).

2. Material and method

For analysis, has been chosen a down-draft stratified biomass gasifier [16] top fed with air and biomass, with flame-controlled pyrolysis air flow and a extractor for biochar near the oxidation and carbon reduction zone working at high temperatures > 1100 °C to obtain a syngas with very little tar. [21, 22]
The block diagram of the cogeneration system analyzed is shown in figure 2.

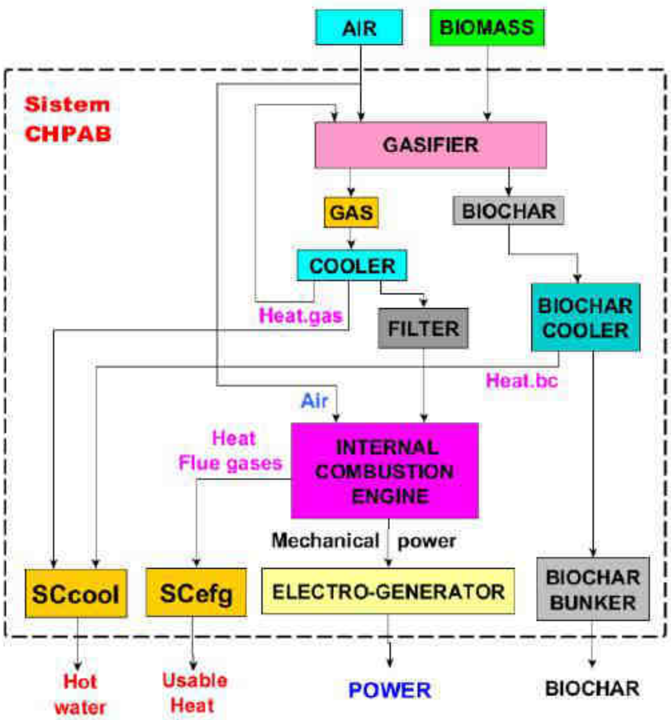

Fig. 2. Block diagram for cogeneration system with CHPAB concept

In the gasifier get biomass (index -bm) and air for gasification and exhaust combustible gas, referred to as syngas, and biochar. The syngas mass is the sum of the mass of air for gasification and the portion of the total gasified biomass (index -bmg). Ash from biomass remains in the biochar. [1, 5, 7]
For the analysis of the cogeneration system in the gasifier is processed M_{bm} = 1 kg. biomass and air for gasification is $M_{air} = K_{dag} * M_{bmg}$. At the exit, a biochar is obtained in the proportion of $K_{bc} = M_{bc} / M_{bm}$ in the range (0-0.20) and mass of syngas $M_{gas} = (M_{bm} - M_{bc}) + M_{air}$.
For different K_{bc} biochar proportions, the useful heat and electricity produced by these inputs and the energy efficiency coefficients for heat, electricity and total cogeneration are determined. [3, 7]
The gasifier operates continuously in optimal energy regimes for biochar in the range proportions $K_{bc} \in$ [0, 0.05, 0.10, 0.15], the final gasification produces hot syngas with very little tar at a conversion efficiency of η_{gas} = 93 %. The syngas is cooled, the humidity is removed, filtered and sent to the thermal engine to produce mechanical energy at a high efficiency, η_{ice} = 25% corresponding to the operation on the MCC characteristic.
Since the engine will operate at a speed, in accordance with MCC characteristic, different from the synchronization with the grid, it operates an asynchronous generator with a ac/ac converter operating in the optimum mode with a yield η_{ge} = 95%.
Syngas is cooled down to 40 °C, heat Heat.gas is transferred from the thermal engine, and the biochar is cooled down to 40 °C, with Heat.bc to storage in the hopper. Heat.gas and Heat.bc are taken over by **SC**cool coolers having water transfer agent and have a medium efficiency η_{cold} = 75%.
A **SC**efg heat exchanger with an average h_{cold} = 90% heat exchanger is used to recover the Heat.efg waste heat of the heat engine. Because the insulation of the system components cannot be ideal, for good thermal insulation, the values in the external environment are estimated to be minus 97%.
Table 1 presents the main data for biomass and cogeneration system analyzed.

Table 1: Main data for biomass and cogeneration system (bm – biomass)

Feature	**M.U.**	**Var.1**	**Var.2**	**Var.3**	**Var.4**
Biomass preparation	type	pellets	pellets	pellets	pellets
Relative humidity	adim	0,00	0,10	0,10	0,10
LHV biomass	MJ/kg.bm	**18,87**	**16,74**	**16,74**	**16,74**
Gasification yield hot syngas	adim	0,93	0,93	0,93	0,93
Thermal loss yield	adim	0,97	0,97	0,97	0,97
Internal combustion engine yield	adim	0,25	0,25	0,25	0,25
Electric generator yield	adim	0,95	0,95	0,95	0,95
Chillers yield	adim	0,75	0,75	0,75	0,75
Exhaust gas SCefg yield	adim	0,90	0,90	0,90	0,90

3. Results and discussions

The operation of the gasifier was simulated with a simulation program developed for the down-draft gasifiers [4] and extended to inverted down-draft gasifiers [5, 6], with which the regimes corresponding to the K_{bc} biochar proportions were selected from the ALL POWER LABS data. Table 2 presents the cogeneration process data for four variants for consumption 1 kilogram of processed biomass.

Table 2: Data for cogeneration processes (bm – biomass; bc – biochar; gas – syngas)

Feature	M.U.	Var.1	Var.2	Var.3	Var.4
Cogeneration process load	type	full	partial	partial	partial
Biomass processed	kg.bm	**1,00**	**1,00**	**1,00**	**1,00**
Biochar (BC) production	kg.bc/kg.bm	**0,00**	**0,05**	**0,10**	**0,15**
Carbon content in BC	kg.C/kg.bm	**0,000**	**0,032**	**0,078**	**0,124**
LHV full gasified biomass	MJ/kg.bmg	18,87	14.62	13.93	13.17
LHV biochar	MJ/kg.bc	0,00	19.6	24,58	26.20
Specific flow hot syngas	kg.gas/kg.bm	3,000	2,850	2,700	2,550
Energy in hot syngas	MJ/kg.bm	**17.023**	**12.500**	**11.254**	**10.015**
Gasification yield cold syngas	adim	0,860	0,819	0,817	0,806
Energy in cold syngaz	MJ/kg.bm	**14,346**	**10,899**	**8,913**	**6,868**
Specific flow cold syngas	kg.gas/kg.bm	2,760	2,280	2.160	2.040
LHV cold syngas	MJ/kg.gas	5,305	4.493	4,258	3,959
Potential energy in BC	MJ/kg.bm	0,000	0,980	2,458	3,930
Energy from BC cooling	MJ/kg.bm	0,000	0,029	0,058	0,086
Energy from syngas cooling	MJ/kg.bm	2,380	2.258	2.057	1.938
Useful energy in warm water	MJ/kg.bm	1.731	1.664	1.538	1.473
Mechanical energy produced	MJ/kg.bm	**3,661**	**2,561**	**2,299**	**2.019**
Energy in engine exhaust gases	MJ/kg.bm	6,589	4,609	4.138	3.634
Useful energy from exhaust gas	MJ/kg.bm	5,753	4,024	3,613	3.173
Electric energy produced	MJe/kg.bm	3,478	2,433	2,184	1,918

Table 3 presents the energy balances and the energy efficiency coefficients for the four analyzed alternatives. For variant 4, which also provides a large amount of biochar, 15%, figure 3 shows the corresponding inputs and outputs for a **1 MWhe** output cogenerated. Electricity is produced with 11.5% efficiency, 282 kg. biochar is produced with a 23.5% efficiency and is consumed **1.877 tons** of biomass with 10% moisture for produced and **2.24 MWh** of thermal energy with a 27.8% efficiency. Global cogeneration efficiency is 39.2% for CHP regime and 62.7% in CHPAB concept, with a negative carbon foot print of -0.233 kg.C/kWhe, which indicates a very good utilization of the potential energy of the biomass used.

Table 3: Energy balance and efficiency for cogeneration system

Feature	M.U.	Var.1	Var.2	Var.3	Var.4
Useful energy in warm water	kWth/kg.bm	0,481	0.462	0.427	0.409
Useful energy from exhaust gas	kWth/kg.bm	1,598	1,118	1.004	0.881
Total useful heat	kWth/kg.bm	**2,079**	**1,580**	**1,431**	**1.291**
Electric energy	kWhe/kgbm	**0,966**	**0,676**	**0,607**	**0,533**
Potenţial energy in BC	kWhth/kg.bm	0,000	0,272	0.683	1.092
Specific consumption of biomass	kg.bm/kWhe	**1,035**	**1,480**	**1,648**	**1.887**
Electrical energy efficiency	adim	0,184	0,145	0,130	0,115
Thermal energy efficiency	adim	0,397	0,340	0,308	0,278
CHP energy efficiency	adim	**0,581**	**0,485**	**0,438**	**0,393**
BC production efficiency	adim	0,000	0,059	0,147	0,235
CHPAB energy efficiency	adim	**0,581**	**0,544**	**0,585**	**0,627**
Electric energy Carbon foot print	kg.C/kWhe	**0.00**	**-0,047**	**-0,129**	**-0,233**

For cogeneration systems produced by A.P.Ls in the CHPAB concept, 1 MWhe is produced from 1 tone of biomass consumption is specified as the performance for electricity generation. The analysis shows that for the same amount of biomass it is obtained 0.966 MWhe, which confirms the announced performances, with a CHP efficiency of 58.1%, very good value, given a carbon footprint close to zero.

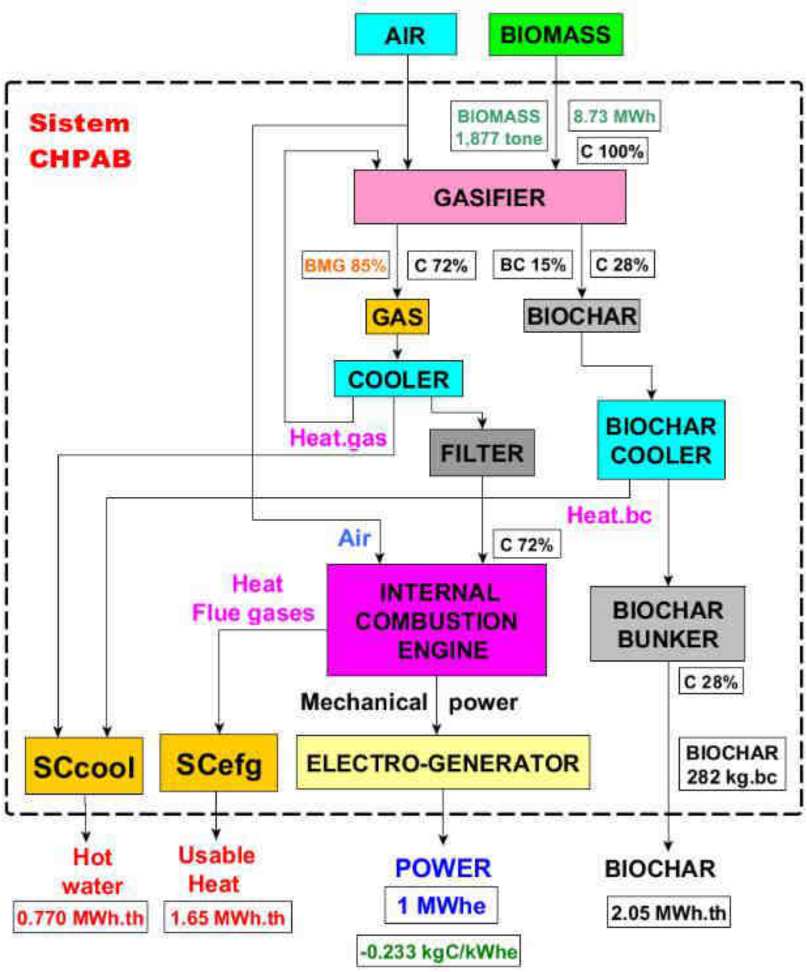

Fig. 3. Energy balance, efficiency and foot print for **1 MWhe** cogenerated

4. Conclusions

For produce thermal energy and biochar from biomass most used **CHAB (**Combined Heat and Biochar production) concept, to produce energy in cogeneration systems with internal combustion engine can be used **CHPAB** (Combined Heat Power And Biochar production) concept for produce electrical, thermal energy and biochar with a negative carbon foot print in environment.

The **CHPAB** concept is usable for low-power cogeneration systems, easy to integrate into a small energy intelligent network type Smart Grid that manages all available energy sources, renewable or classical, which increases energy efficiency and reduces the cost of use

Low-power cogeneration systems with **CHPAB** concept have low weight, are mobile, blended with biomass from local sources, produce biochar incorporated in agricultural land, contribute to their productive potential, contribute to sustainable development and are financially accessible for agricultural farms and isolated communities.

The system analyzed to produce **1 MWhe** with an efficiency of 11.5% and **282 kg**. biochar with 23.5% efficiency consumed 1,877 tons biomass with humidity of 10% and produced **2.24 MWhth** of thermal energy with an efficiency of 27.8% on a negative carbon footprint of **-0.233 kg**.C/kWhe.

Only in CHP mode, the cogeneration energy efficiency is 39.2%, comparable to other commercial CHP systems, and with CHPAB concept is 62.7%, which indicates a very good capitalization of the local biomass energy potential for increasing energy safety and independence in agriculture and in isolated communities.

The plethora of current patents relating to the use of the CHPAB concept in cogeneration with biomass indicates a new direction of efficient use of the energy potential of biomass and, in particular, of agricultural waste which occurs annually in very large quantities, helping to reduce agricultural production costs with a negative carbon foot print.

Combined CHPAB Cogeneration plants with biomass in CHPAB concept have a direct use to consumers with continuous heat and power requirements such as greenhouses, plants for drying and processing agricultural products that can be optimally disposed of the power grid and can use biochar to increase the productive potential of cultivated land.

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CONSIDERATIONS ON IRRIGATION AND FERTILIZATION OF AGRICULTURAL CROPS ON SANDY SOILS IN ARID, SEMIARID AND DRY SUB-HUMID CLIMATE

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Abstract: *Project PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III proposes the development of innovative technologies for irrigation of agricultural crops on sandy soils, in arid, semiarid and dry sub-humid climate, applicable to project partners SCDCPN Dabuleni and SCDP Constanta. Expansion and intensity of extreme weather phenomena reduce agricultural output by at least 30-50% per year. In Romania, about 14.7 million hectares of agricultural land, of which 9.4 million hectares of arable land (64% of the arable land), the soils are affected, to a greater or lesser extent, by frequent droughts, over periods long and consecutive years.*
Sandy soils fall into the soil group with a more pronounced manifestation of extreme phenomena (atmospheric, pedological and agricultural drought, strong burning and a major shortage of rainfall, unevenly distributed throughout the vegetation period).
All this leads in the great majority of the growing years to the drastic diminution of the production of large crops, of orchards and vineyards, often going to the compromise of the respective crops. [1]

Keywords: *Sandy soils, arid climate, fertigation equipment*

1. Introduction

The sandy soils in Romania occupy 460 thousand hectares, most of them 208 thousand hectares, in a true "Bermuda Triangle", with the tip at the southern border of Craiova and based on the Danube, in the counties of Dolj, Olt and Mehedinti [2]. In the area of sandy soils in southern Oltenia, the multiannual average of precipitation P is 540 mm, the temperature is 11,2 °C and the potential evapotranspiration ETP of 700-755 mm. These values lead to a De Martonne moisture index of I = 25-26, to a P-ETP aridity index of -160 ... -210 mm and 100P / ETP of 72-75%. The value of the indices encompasses the sandy area of the Sadova - Corabia settlement in the semiarid and excessively dry type of climate (Donciu C., 1986). Existing hydric resources are insufficient for the optimal growth and development of plants, predominantly drought during the vegetation period. The analysis of thermal and hydric resources has highlighted a tendency to increase the drought over the past two decades, with unfavorable effects on agriculture in southern Oltenia.
On sandy soils, periods of drought can occur at shorter intervals than other soil types. The range of relatively limited humidity on these lands determines the essential feature of watering - small watering standards applied at short intervals.
Low values of water capacity in the field are compensated by the property of sandy soils to provide much of the retained water to plants. Soil retention capacity for water assimilable by plants is low compared to soils with loamy or clayey texture. This is due to the high content of these lands in coarse sand and the low percentage of humus and clay.
Dobrogea is the driest region in Romania, with the lowest amount of atmospheric precipitation. Dobrogea is generally characterized by the existence of two distinct climatic units [3]:

- the eastern part, in the form of a narrow strip (12-15 km) along the Black Sea, where its influence is felt, but where the least rainfall is;
- the central and western parts, where continentalism increases.

The aridity of Dobrogea was previously highlighted by a series of researchers [4] not only due to the lack of atmospheric precipitation but also by the strong winds and the high wind velocity, which are caused in most cases by the existence of continental anticyclones.

The climate is semiarid, continental with hot and dry summers, with frequent dry winds throughout the year, with temperate winters, generally without snow. The average annual temperature is 11.0 °C and the total active temperature is 3988 °C, of which 3170 °C in the growing season, the absolute minimum temperature of -21,4 °C (1987) and the absolute maximum of 38,4 °C (1988); annual precipitation 400 mm, out of which 240.7 mm during the vegetation period. The average water deficit (about 400 mm) is covered by irrigation. Once at 10-15 years, temperatures below -20 ° C are recorded, but what causes damage to plantations is spring return frosts (especially April).

The predominant type of soil is limestone chernozem, loosely formed, with loamy texture and good storage and circulation of water. The humus content is between 2.5 and 4%; The pH of the soil is neutral slightly alkaline (7.0-8.1) across the profile.

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Thermal resources, strong sunstroke and irrigation during periods of drought can favorably affect agricultural crops on sandy soils. The possibility of capitalizing on these poorly fertile soils and the early production (7-10 days in advance of other areas) are some arguments for the development of horticulture in these areas. The soils of Dobrogea are mostly favorable to the cultivation of fruit trees, especially peach (including nectarine), apricot and almond. Generally, the fertility and production potential of these soils decreases from south to north, to the mountainous area and the delta area [5].

2. Considerations on irrigation and fertilization of agricultural crops on sandy soils in arid, semiarid and dry sub-humid climate

The need for water is different during the vegetation period, because the passage of plants through different stages of development requires different living conditions, so the need for water cannot be the same throughout the vegetation period. In plant life, depending on the vegetation phases and stages of development, periods (relatively short) occur during which the water deficit is reflected in production. These periods are known as "critical phases for humidity".

The critical phase for humidity coincides with the most intense growth period, overlapping in general with the breeding phase. Reproduction organs are formed in several stages, namely: differentiation, formation of reproductive organs, fertilization and formation of the fruit. Meteorological factors (air humidity, heat, light, precipitation) also have a direct influence on the need for irrigation. Precipitation is the most important source of soil moisture and an important indicator for appreciating the need for irrigation; they are characterized by multi-annual average, with high variability for different climatic zones.

In the correct management of the supplementation of irrigation plants' irrigation water, an essential role is the knowledge of the water consumption of plants under the given soil and climate conditions, tab. 1

Table 1: Climatic characterization of the area of sandy soils in southern Oltenia during the period of vegetation (1985-2002) (Ploae P., 2002)

Month	Climatic indexes					
	12 p / (t+10) (De Martonne)		100 p / ETP % (Donciu)		(Δ p/ Δ t)10 (Seleaninov)	
	Value	Qualifying	Value	Qualifying	Value	Qualifying
IV	24.8	moderately dry	79.5	dry	1.5	suficiently
V	26.1	moderately dry	55.8	very dry	1.1	suficiently
VI	22.0	semiarid	42.6	excesively dry	0.9	insuficiently
VII	20.2	semiarid	31.4	excesively dry	0.8	insuficiently
VIII	11.1	arid	23.2	excesively dry	0.5	insecure agriculture
IX	13.1	arid	50.6	very dry	0.7	insecure agriculture

Research by Marinica Gh. et al. at CCDCPN Dabuleni points out that for the water consumption of different species of agricultural plants, sandy soils provide between 4 and 9% of their own reserve. The rest of the consumption needs are provided by irrigation of 29 - 60% and of precipitation 34 - 62%.
Among the studied species, bean, rye, wheat, sorghum, early potatoes are highlighted with low water consumption (2850 - 4900 m3 / ha). Maize and soybean recorded the highest water consumption (7340 - 7760 m3 water / ha).
Behavior of sandy soils in water and plant interrelations, tab. 2, has led to some peculiarities in the design of irrigation on these lands. Hydrotechnical schemes of facilities should ensure that small watering standards (300-400 m3 / ha) and frequent (5-7 days) are built on decentralized organizational structures (small plots) that are permanently operational in time and space.

Table 2: Water consumption and sources of coverage for some plant species grown on sandy soils

Crop	Medium production (q/ha)	Water consumtion (m^3/ha)	Sources of coverage					
			Soil store		Rainfall		Irrigations	
			%	m^3/ha	%	m^3/ha	%	m^3/ha
Rye	34.2	4165	9	385	62	2580	29	1200
Wheat	40.7	4680	8	400	55	2580	37	1700
Sorgh grains	85.4	4900	9	440	60	2960	31	1500
Maize	70.8	7760	8	624	38	2960	54	4176
Bean	25.7	4160	4	160	60	2500	36	1500
Soybean	30.2	7340	6	450	34	2500	60	4480

The contribution of irrigation water to the production of sandy soils is greatest in the dry years, when the production increases in irrigated crops increase up to 10 times the non-irrigated crops. Administration of these quantities of water by irrigation, tab. 3, involves fairly high costs with the application of watering, requiring between 8-12 watering at soybeans and 2-3 watering at bean.

Table 3: Elements of the irrigation regime for some cultivated plant species on sandy soils

Crop	Elementes of irrigation regime			
	P min. recommandate	Watering standard (m^3/ha)	Number of watering	Irrigation standard (m^3/ha)
Rye	1/2 i.u.a/ 50 cm	300-450	2-4	750-1650
Sorgh grains	1/2 i.u.a/ 50 cm	300-450	3-4	1200-1650
Bean	1/3 i.u.a/ 50 cm	500-550	2-3	1050-1600
Wheat	1/2 i.u.a/ 50 cm	350-450	3-5	1250-2150
Maize	1/2 i.u.a/ 70 cm	350-450	7-11	3150-4800
Soybean	2/3 i.u.a/ 50 cm	300-400	8-12	3200-4700
Tomatoes	2/3 i.u.a/ 50 cm	300-400	5-7	2100-2850
Peach	1/2 i.u.a/ 100 cm	450-550	4-5	2000-2500
Grapevine	1/2 i.u.a/ 100 cm	450-550	4-5	2000-2500

The direct effect of the addition of water in the soil through irrigation is reflected in crop yields obtained from irrigated crops compared to non-irrigated crops. Irrigated harvest yields are higher on sandy soils compared to zonal soils, ranging from 4630 kg / ha to sorghum, 39.0 t / ha in tomatoes and 8.0-10.1 t / ha in vines and fruit trees.
In the climatic conditions specific to Dobrogea, the difference between the ETc values and the mean average rainfall values calculated with probabilities of 50 and 80% [6] resulted in the optimum irrigation water requirements NAI), for thermophilic tree species with the largest share, peach and apricot. Methods of irrigation arrangements for fruit crops and technical elements of watering (watering standard, minimum ceiling, application rate and water spray) depend fundamentally on the type and properties of soils.
The useful water capacity (CU) is different for the main soils in Dobrogea. On the 100 cm depth, chernozems and chernozems (gray soils) show CU values of approximately 150-210 mm. The recommended watering regime, depending on the useful water capacity, has relatively high and medium values in Dobrogea's agricultural soils, about 600-900 m3 / ha for chernozems and 400-600 m3 / ha for Greek chernozems [7].
The average water application rate should not exceed 5-7 mm / h in the soils with moderately permeable soils, respectively 7-9 mm / h in the soils with chernozem type.
Recommended watering methods are primarily methods characterized as localized watering (dripping, micro-sprinkling).
The fertilization of agricultural crops aims at maintaining the high fertility status of the soil, human intervention by the administration of organic and chemical fertilizers in order to restore the nutritional balance of the soil, being an indispensable practice.
The research carried out for 6 years on sandy soils from Dabuleni, which aimed to increase the soil's trophic potential through the annual administration of organic fertilizers in large quantities of 20-80 t of manure / ha, 30-120 t of compost / ha and 1-4 t of vegetal debris / ha, have highlighted the improvement in the supply of organic matter and easily accessible mineral elements in the surface layer of the soil). The bioaccumulation process is more intense in variants with added organic matter than the control, which is evidenced by higher values of organic carbon. Organic fertilization also had a beneficial effect on the state of assurance of the soil with total nitrogen, mobile phosphorus and accessible potassium, with higher values especially in the case of manure and composted marc.

Table 4: The influence of ameliorative fertilization on the soil chemical properties is presented (Ion P. et al.,1996)

Source of organic matter	C. org (%)	N_t (%)	P-AL (ppm)	K-AL (ppm)	T (me/100 g sol)	PH (H_2O)
N200 P80 K80 (Mt)	0.240	0.037	46	83	4,8	6.2
Manure	0.282	0.041	60	111	7.1	6.6*
Composted marc	0.323*	0.050	56	127	7.0	6.7*
Vegetable debris	0.265	0.042	48	103	5.6	6.5
DL5%=	0.079	0.018	25	55	3.4	0.4

Improving the state of soil supply with organic matter has led to the improvement of the adsorbent soil complex, reflected in the total cation exchange capacity. With the increase of the cationic exchange capacity, there is also an improvement in soil buffering capacity, with pH values being higher for all organic fertilized variants.
The large and annual administration of organic fertilizers (manure, compost seed) has boosted the biological activity of the soil expressed by the global index - dehydrogenase activity, also increasing the number of bacteria, tab. 5.

Table 5: The Influence of Ameliorative Fertilization on Soil Biological Activity, 0-20cm (Ion P. et al., 1996)

Source of organic matter	Dehydrogenase activity (mg formazan/100g sol)	Number of bacteria (mil./1 g sol)	Number of microscopic mushrooms (mii/1 g sol)
Mineral fertilizers	5.19	25.12	15.25
Manure	6.86	67.37	16.16
Composted marc	8.52	62.62	18.62
Vegetable debris	5.68	26.00	245.75

Nitrogen fertilizer administration must be correlated with the maximum plant absorption period, which coincides with the intense increase of the vegetative part and the achievement of the production. Most of the unused plant nitrogen is lost by leaching, contributing to the pollution of soil and groundwater with nitrates (Table 6) (Mihaela Croitoru, 1996, 2001).

Table 6: Nitric nitrogen distribution on the soil profile in plum plantations (Mihaela Croitoru, 1996)

Version	Depth(cm)	N - NO_3 (ppm)
N200P80K100	0 - 20	28.0
	20 - 40	30.8
	40 - 60	24.0
	60 - 80	28.4
	80 - 100	75.2

For the climatic conditions in Dobrogea, a normally supplied soil should contain over 0.5% of total nitrogen, 150-200 kg / ha of phosphorus, 500-800 kg / ha of potassium [8]. Peaches, the main fruit growing in Dobrogea, require more nitrogen fertilization than other tree species.
For normal growth and optimal production, peach requires 13 essential nutrients, which must be found in the plant in different amounts, tab. 7. Phosphorus, potassium, a portion of nitrogen and

organic fertilizers are incorporated in the autumn at the time of planting, and the rest of the nitrogen is applied fractionally in bloom and in the intensive growth phase of the sprouts.

Table 7: Necessary for nutrients on peach and nectarine [9]

Macroelementes	Level of nutrients in leaves			Level in mature fruits (%)	Motility in plant *
	Deficiency (%)	Optim level (%)	Excess (%)		
Nitrogen	2.3	2.6-3.0	-	1.0-1.5	medium
Phosphorus	-	0.1-0.3	-	0.1-0.3	high
Potassium	1.0	over 1.2	-	1.5-2.5	high
Calcium	-	over1.0	-	0.05-0.15	lower
Magnesium	0.25	over 0.25	-	0.05-0.15	high
Chlorine	-	-	0.3	-	high
Sulfur	-	-	-	-	lower
Microelementes	**Deficiency (mg/kg)**	**Optim level (mg/kg)**	**Excess (mg/kg)**	**Level in mature fruits (mg/kg)**	**Motility in plant ***
Iron	60^{++}	over 60^{++}	-	20-80	lower
Manganese	20	over 20	-	5-10	medium
Zinc	15	over 20	-	10-20	lower
Boron	18	20-80	100	20-50	lower
Copper	-	over 4	-	5-10	lower
molybdenum	-	-	-	-	medium

* Indicates the ability to pass from old leaves to young leaves and fruit
++ Leaves samples will be harvested in April and May

In an irrigated orchard by the localized method, fractional doses of soluble minerals - fertilizers - can be applied depending on the specific phenological phases of peaches and the expected level of fruit production. Doses and fertilization recipes should be correlated with soil agrochemical analysis and foliar diagnosis.
Fruit plants with falling leaves, such as peaches, which are not nutritionally well-fed, especially with respect to nitrogen, are more exposed to frost damage. Flowering buds of poorly or poorly fertilized orchard species are less healthy and more easily damaged by frost. Using nitrogen application in the middle of summer or after harvesting, a stronger growth and development of tree buds may be induced and some flowering delays, especially in stone fruit species such as peach and apricot. Trees that are not properly fertilized tend to lose leaves earlier in the autumn and flowers earlier in the spring, which increases sensibility to frost damage [5].
Phosphorus is also important for cell division and is therefore important for tissue recovery after frost.
Potassium has a favorable effect on water balance and plant photosynthesis.

3. Considerations on fertigation equipment of agricultural crops

Fertilization is the process by which water and fertilizers are administered simultaneously, via an assembly of irrigation equipment and fertigation equipment.

As a rule, the fertigation equipment includes the injection device of the primary solution in the irrigation water, the primary solution preparation vessel, the measuring equipment and the adjustment of the working parameters, the hydraulic connection elements between the components of the equipment, respectively the equipment and the irrigation installation. Choosing the right fertilization equipment is just as important as choosing the correct nutrients. Incorrect selection may damage parts of the irrigation system, affect the efficient operation of the irrigation system or reduce the effectiveness of nutrients.
Injection of fertilizers in water is made by: differential pressure; vacuum; the absorption of fertilizer; pumping.
Of the equipment that performs the differential pressure injection, the diluent may be mentioned, fig. 1, which is a sealed container in which water-soluble solid fertilizer is introduced. The container is mounted in parallel with the main pipeline of the irrigation installation and the injection is made after the screen filter. In order to work in optimal conditions, a device (valve, diaphragm, diameter reduction) is installed on the supply pipe of the irrigation system, which creates a hydraulic load drop; the water dilution point of the diluent will be in front of the device that creates the hydraulic load drop and the fertilizer injection after the device.
The diluent consists of a recipient 1, a tap 2 located on the water inlet in the tank, a tap 3 on the discharge of the fertilizer solution in the tank, two hoses 4 and 5, a connection to the watering system circuit 7 and a 6 trunk with sieve, into which solid fertilizer soluble in water is added.

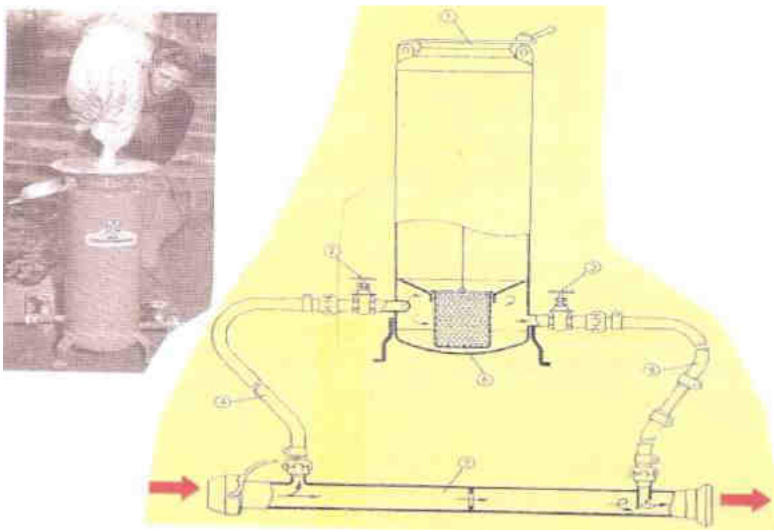
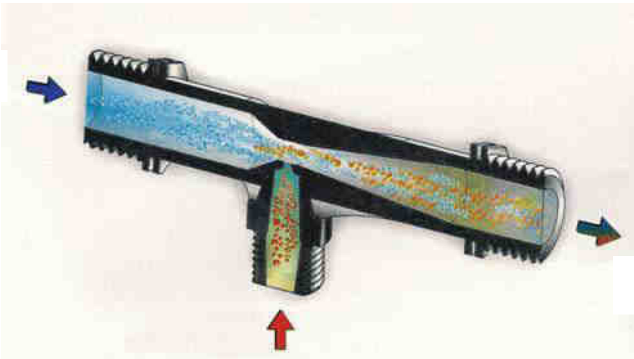


Fig. 1. Component of fertilizer equipment with diluent

Advantages of the diluent. The technical solution is simply constructive, it works hydraulically, the dilution is very convenient to achieve because it allows the direct use of soluble solid fertilizers. The investment is reduced and can be used with watering installations with a fixed watering position.
Disadvantages and precautions for use. The process of dissolving the fertilizer evolves differently during a load, the intensity of which decreases continuously. Thus, the injection dose is different and the time to dissolve the fertilizer is not always known. The concentration of the fertilizer solution is higher at the beginning of the fertilization and is lower at the end. At each change of fertilizer station, the container must be emptied and reloaded with fertilizer. The volume of the container (from 50 to 300 liters) limits the use of the diluent to fertilize the position of large areas (serving less than half a hectare of vegetables and one hectare in trees).
The container must be tight, not allow air to enter the enclosure or liquid loss during the process. When using a valve for injection control, the concentration of the fertilizer solution is less varied but

requires manual intervention; the loss of pressure / flow generated by the valve is high, influencing in the negative sense the parameters of the water distribution devices.
There is a risk of environmental pollution due to the increased fertilizer injection dose at the start of the injection, the uneven distribution of the solution in the crop and the lack of the anti-retardant valve.
When using corrosive substances there is a risk of damage to components of the injection equipment and the watering system.
Administration of fertilizer mixtures is possible only if they are compatible and if they permit the obtaining of homogeneous fertilizing solutions; it is necessary to know the way in which the different chemicals in the fertilizers used in the mixture react, to prevent accidents at work. **Vacuum injection** is based on the principle of the Venturi tube and the equipment is called Venturi injector. Venturi liquid chemical fertilizer injectors are based on the Venturi effect, illustrated in fig. 2, according to which, when a pressurized liquid flows through a given section with sudden constriction and progressive decomposition, the suction phenomenon occurs.

Water source



Water mixed with fertilizer

Fertlizer

Fig. 2. The operating principle of the Venturi injector

Venturi injectors, made within 3/ 4”-2” limits, require operating pressures higher than 4.5 bar, the ratio between the flow rate of the primary solution and the flow rate of the fertilizer solution being 1/5- 1/50 in the 3/4" model and 1/ 5- 1/100 in the 2” model. The fertilizer solution flow rates, depending on the size type (3/4” -2”), vary between 193-2640 l/h.
The absorption of the fertilizer solution depends on the type of fertilizer, the inlet pressure and the water flow rate. It operates with a minimum pressure difference that interferes between the input and output segments.
Venturi Injectors can be installed either on the main pipe of the irrigation plant (full flow) for the 3/4 "and 1" constructive dimensions or on a parallel bypass circuit for the 1¼ ", 1½" and 2", fig. 3.
The advantage of connecting the injector to the main column of the irrigation installation, fig. 3, is the realization of a relatively large flow of primary injection solution for small type (3/4 "and 1") sizes. The disadvantage of the connection technical solution is the loss of the hydraulic load created in the injector body, with implications for the sizing of the distribution network of the irrigation system.
The connection of the bypass injector, fig.4, eliminates the disadvantage of creating a hydraulic load loss on the main column of the irrigation installation, but in turn the disadvantage of lower injected primary solution flows compared to the full-flow connection, for the same type of injector size.

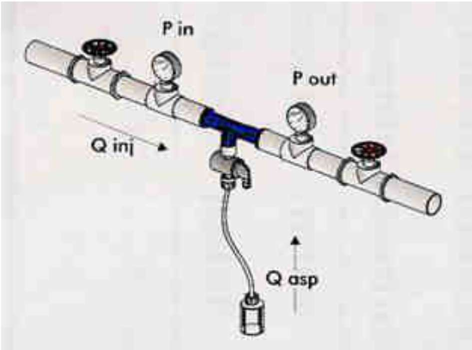


Fig. 3. Connecting the Venturi injector to main pipe

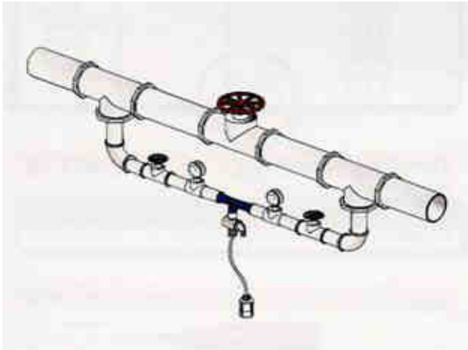


Fig. 4. Connecting the Venturi injector on by-pass

Advantages. The Venturi Injector is simple to construct, does not require large investment for purchase and has high operating reliability. It achieves a good proportional flow rate of the pump / plant and the injection dose is constant.
Disadvantages. The pressure loss on the plant circuit is about 1 bar, and the flow and the working capacity of the plant are reduced. This situation is specific to installations with large diameters and flows, to which Venturi injectors cannot be used; there is a risk of air absorption at the end of the injection or clogging of the nozzle with sedimentary impurities in the fertilization process; the quantitative regulation of the injected fertilizer solution is difficult to achieve and is therefore not suitable for automation.
Injection by fertilizer absorption, fig. 5, is accomplished by connecting a liquid fertilizer tank to the absorption circuit of a pump (or a gravitational water supply source with falling water), and to facilitate the process, the vessel must be at a higher rate.

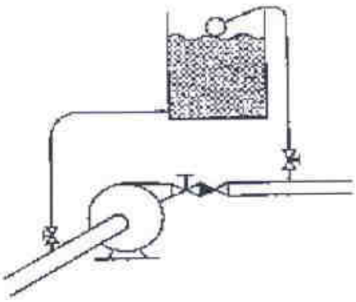


Fig. 5. Injection through absorption scheme

The vessel can be supplied with water from the pump discharge circuit for the primary solution, and at the end of the fertilization, the valves are closed to prevent the introduction of air, which causes the cavitation phenomenon.
Advantages: the construction solution is very simple; does not use additional energy.
Disadvantages: the pump is worn because of the fertilizer solution it is driving; the rotor of the pump can be destroyed by the cavitation phenomenon, the air absorption in the primary solution container at the end of the administration process; does not allow concentration variation in a large range.
The fertigation equipment to which the injection is made by pumping, consists of injection devices of the **volumetric pumps** with membrane type or piston pumps type, hydraulically, pneumatically or electrical actuated.
These pumps can perform active strokes on a moving direction of the mobile injection assembly (single effect pumps), respectively, on both moving directions (double-effect pumps).
Depending on the mounting position of the system, the pumps are mounted in series, on the main flow circuit of a full flow or on a bypass circuit.

4. INOE 2000-IHP contribution to the development of the fertigation equipment field

Injection device of double pump with membranes type, developed by INOE 2000-IHP during the collaborative project Innovative Technologies and Equipment for the Implementation in Irrigated Agriculture of the Modern Fertigation Concept (FERTIRIG) – Contract no.: 158/2014 [10] was made in a compact construction, the piston-membrane movable assembly, the hydraulic directional control valve, the drive of hydraulic directional control valve , the throttles of the control chambers of directional control valve, the primary solution suction / discharge valve block are incorporated in the body. The connection between the functional elements is achieved through holes in the body of the device and the piston of the mobile assembly, been eliminated the external connections, with the exception of those associated to the control chambers of the directional control valve.
The schematic diagram of the fertilization equipment is shown in fig. 6.
The mobile assembly, fig. 6 sect. D-D consists of piston, membranes, outer and inner flanges, special bolts for fixing the piston diaphragms.

Primary solution suction / discharge valve assembly; each injection chamber is connected to an intake and discharge valve. The suction / discharge valves of the two injection chambers are interconnected and connected to the primary and discharge solutions.

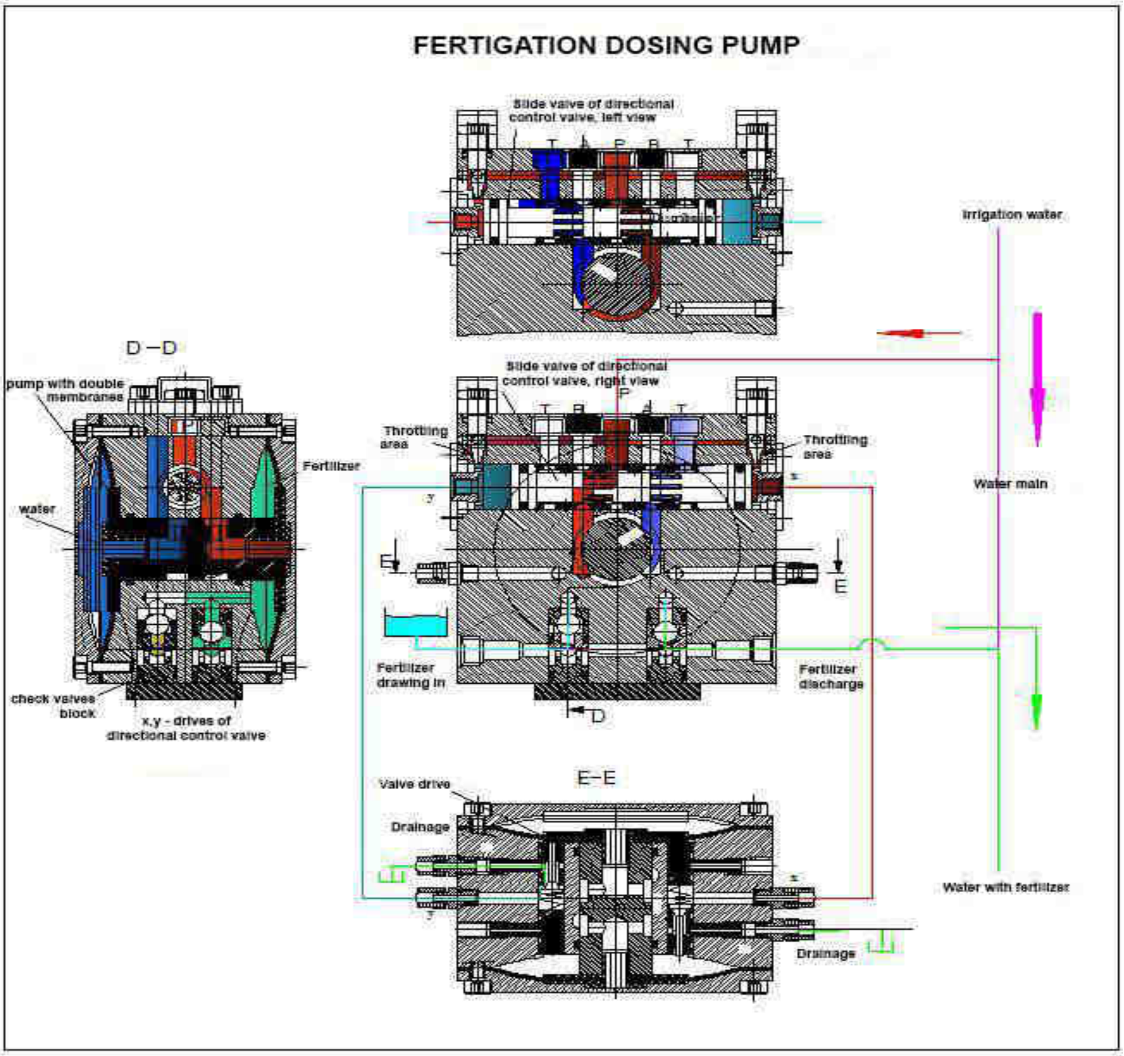


Fig. 6. The principle scheme of fertigation equipment

In the construction of the two-positions and four-orifices type directional control valve, the alternative with slide valve, with O-rings seal was chosen to allow the components to be executed in H8 / f7 tolerance fields, thus avoiding the extremely precise execution of the hydraulic directional control valve with classic slide valve, where the lost motions between the slide valve and the body are of the micron order. The constructive version of the directional control valve allows operation with irrigation water with a low level of filtration.
The seals have been designed and made with tightening as low as possible, so that the friction forces of the mobile elements are as small as possible.
The slide valve of the directional control valve has a positive coating, the switching is done without loss of pressure.
The control valve of the hydraulic directional control valve, fig. 6 sect. E-E are unblocking valves located in the water tank discharge holes in the control chambers operated in the pump body, to ensure hard closure and opening and to reduce the switching time of the directional control valve. The drive chambers are delimited by the outer surfaces of the membranes and the lids, and the injection chambers by the inner surfaces of the membranes and the body.
Depending on the position occupied by **the slide valve of the directional control valve**, the orifice P is connected with the orifices A or B, from which, through internal holes in the body and the piston, the pressurized water supply of the drive chambers is provided. Outside, holes A and B are plugged with technological plugs.
The T-holes alternately drain the water from the drive chambers (A to T or B to T) during the withdrawal phase of the membrane assembly (reducing the volume of the drive chambers). The water discharged from the drive chambers is distributed to the plants through an assignment tube with dropper built-in.
Also, from the P port, the Ccs-Ccd control chamber of the hydraulic directional control valve are continuously supplied with pressurized water. The mobile assembly alternately operates through the internal flanges the unblocking valves, which shortly before reaching the end of the stroke, connect one of the control chambers to the atmosphere, causing the switching of the slide valve of the directional control valve from the control chamber under pressure to the pressure discharge chamber.
The throttles, which regulate the flow of water that arrives into the control chambers, keep the slide valve of the directional control valve in an equilibrium position and dictate the frequency of the pump mobile assembly.

5. Worldwide top achievements in the fertigation equipment field

The most advanced fertilizer equipment with differential piston displacement pump is DOSATRON-France. The pump can be located both on the main circuit of the irrigation system and on a circuit parallel to it, and uses as the moving fluid the irrigating water that transits its feed line. The operating principle of the pump, illustrated in fig. 7 is the following:

Fig. 7. Operation principle of the DOSATRON metering pump with differential piston

The water acts on the movable assembly of the pump, consisting of the driving piston and metering piston, that moves together.
The shift of the moving direction of the pump mobile assembly is controlled by the flanged arc-tilting mechanism located on the driving piston and which, by actuating some valves, allows access to the water as a moving fluid underneath or above the piston.
The metering piston is provided with a translation sealing type sliding cuff which, in the upward stroke, rests on the lower seat, seals against the metering cylinder and creates the depression required to raise the seat valve, the access of the primary solution under the piston and the drive of the volume of the overhead primary solution, existing inside it from the previous stroke, inside the moving fluid - primary solution mixing chamber (the cylinder of the drive piston).
In the downward stroke, the seal cuff of the metering piston is placed on the upper seat of the piston, which put on the seat or intake valve of the primary solution and allows the access to the primary solution volume already introduced into the metering cylinder at the previous stroke above it, through the longitudinal slots practiced on the external generators.
By continuously varying the volume of the mixing chamber in order to reduce it, the fertilizer solution is injected through the pump discharge connection into the irrigation installation.
DOSATRON equipment is designed so that the volume of injected fertilizer solution is always strictly proportional to the volume of water entering the unit, regardless of the variations in flow or pressure that may occur in the main pipeline. The high dosing accuracy of DOSATRON equipment eliminates the risk of over-cropping, thus contributing to plant protection, consumer health and the environment.

6. Objectives of the complex project on fertigation of agricultural crops

During the project Innovative technologies for irrigation of agricultural crops in arid, semiarid and dry sub-humid climate, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III, a fertigation equipment will be developed for operation in aggregate with drip irrigation, micro-sprinkling and underground systems.
The injection device, of injection pump with differential piston type, will have to operate at values of the hydraulic parameters flow-pressure specific to the mentioned watering methods.
Critical parameters for the injection device of the fertigation equipment component, which work in a dynamic regime, are the flows and pressures specific to underground irrigation systems, lower than drip irrigation and micro-sprinkling.
Fertigation equipment will be designed to allow for primary solutions of concentrations and different dosages depending on the chemical (macro or micro elements) they are prepared from.
The mixture of the irrigation water used as the moving fluid and the primary solution will be made inside the injection device, which will result in higher hydraulic yields.

7. Conclusions

• Project PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018 within PNCDI III proposes the development of innovative technologies for irrigation of agricultural crops on sandy soils in arid, semiarid and dry sub-humid climate, applicable to project partners SCDCPN Dabuleni and SCDP Constanta, in the context in which the extension and the intensity of extreme meteorological phenomena decreases annual agricultural output by at least 30-50%.
• Sandy soils fall into the soil group with a more pronounced manifestation of extreme phenomena (atmospheric, pedological and agricultural drought, strong burning and a major shortage of rainfall, unevenly distributed throughout the vegetation period).
• On sandy soils, in arid, semiarid or dry sub-humid climate, the plants have specific water and fertilizer needs, which are administered with low norms and times of return, to satisfy optimally the soil-water-plant -atmosphere interrelationship.

• The contribution of INOE 2000-IHP to the development of the field of fertigation equipment resulted in the development of an injection device with technical-functional performance, of double pump with membrane type, validated in real exploitation conditions for the fertilization of horticultural crops from protected areas and of fruit crops at Vasile Adamache didactic farm within USAMV Iasi, ICDP Pitesti Maracineni

• During of the project Innovative technologies for irrigation of agricultural crops in arid, semiarid and dry sub-humid climate, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27PCCDI / 2018, within PNCDI III, a fertigation equipment will be made whose injection device will be of pump with differential piston type , with the mixture of the irrigation water (the moving fluid) - the primary solution inside it; the equipment will work in aggregate with drip irrigation, micro sprinkling and underground irrigation systems for the administration of liquid fertilizers of different concentrations, obtained from chemical compounds with macro and micro elements.

Acknowledgements

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RESEARCHES REGARDING AIR SOLUBILITY IN PRESSURIZED CAPSULE DESIGNED FOR WASTEWATER TREATMENT BY FLOTATION

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Abstract: *DAF (dissolved air flotation) systems are usually used in the last stage of a wastewater treatment stations. The purpose of these systems is to obtain optimum purity degrees by separating and collecting the colloidal particles in suspension in treated water using air microbubbles. For achieving this purpose, we designed a pressurized capsule with a maximum operating pressure of 10 bar. The efficiency of such a DAF system is characterized by the quantity of dissolved air in water equivalent with the number of generated microbubbles which could adhere to the surface of colloidal particles and collect them in a foam on top of the water level. Within this paper we observed the air solubility within the pressurized capsule function of the air-water mixture pressure and the fluid temperature.*

Keywords*: Wastewater, flotation, air solubility*

1. Introduction

The industries all over the world generate large quantities of wastewater which usually becomes an important source of pollution. Thus, the need for better treatment technologies arises especially for the last stage of wastewater treatment plants in which small to microscopic particles have to be removed.
Dissolved air flotation (DAF) systems are known to be efficient for removal of colloidal particles in suspension. The process operating such a system presumes the existence of a pressurized capsule in which a mixture air-water is formed in which under pressure air is dissolved, conducting to apparition of microbubbles. Later on, that mixture is injected in the water treatment tank and the microbubbles adhere to the colloidal particles present in the wastewater and get them to the surface where they form a foam which can be removed by mechanical means [1,2].
The performance of treatment technology using dissolved air flotation systems is dependent by the quantity of dissolved air, the number and dimension of the air bubbles and by their movement and capacity to carry the small particles to the top of the wastewater [3,4].
The compressed air pressure and the water pressure are important parameters for controlling air solubility in water. The volume and size of air bubbles produced on depressurization depends on the output pressure, the flow rate and the fluids temperatures. Larger microbubbles are produced at lower pressures and higher temperatures. The particles removal is more efficient using smaller air bubbles which have a lower rising speed and more time to adhere to particles and produce a higher effective bubble surface area. Within a DAF system will be separated particles of similar densities and sizes, which cannot be removed by other methods based on gravity alone. The process is efficient especially for particles below 100 μm, which are too light for gravity separation by sedimentation. The lower size limit for flotation separation is approximately 35 μm, although particles as small as 1 μm can be separated.
Within this paper we observed the air solubility within the pressurized capsule function of the air-water mixture pressure and the fluid temperature. The air solubility in water is the key element in treatment process optimization, for the separation of solids from a liquid.

2. Material and method

The quantity of air (gas mixture) which will dissolve into water is proportional with the air partial pressure. For air (gas mixture), Henry's law could be used to predict the percentage of each gas which will be soluble into the solution. But different gases have different solubilities. Solubility of air in water can be expressed as a solubility ratio:

$$S_{air} = \frac{m_{air}}{m_{water}}, \tag{1}$$

where
S_{air} = solubility ratio
m_{air} = mass of air (kg)
m_{water} = mass of water (kg)

Air solubility in water follows Henry's Law - "the amount of air dissolved in a fluid is proportional to the pressure in the system" - and can be expressed as:

$$c = \frac{P}{k}, \tag{2}$$

where
c = solubility of dissolved gas
k = proportionality constant depending on the nature of the gas and the solvent
P = partial pressure of gas (Pa)
Air is a mixture mainly formed from oxygen and nitrogen, from which oxygen has a higher solubility in water. Air dissolved in water contains approximately 35 – 36 % oxygen compared to 21% in air.
We designed a pressurized capsule of 0.3 m^3 volume and a maximum operating pressure of 10 bar in order to produce air microbubbles with variable size proportional to the working pressures.

Fig. 1. 3D model of the pressurized capsule

The imposed flow rate of the air-water mixture at the capsule output was of 100 litres per hour. The capsule had at inputs tap water and compressed air, the air-water mixture being outputted through a system of nozzles in a buffer tank. The control unit of the capsule allowed the control of the pressure within the capsule. The temperature of water was controlled using and industrial cooler. The process automation of the pressurised capsule supposed to maintain a steady level of water at the middle level of the capsule, with a cushion of compressed air above.

The pressure for the experiments was chosen to be within 3-7 bar, suitable for the bubble size between 20-100 µm, which represent the optimum dimensions for flotation process. The input water temperature was 10, 15 and 20 ºC in order to observe the air solubility. We collected the output mixture in a buffer tank in which we measured the dissolved oxygen concentration using an Oxygen portable meter ProfiLine Oxi 3205 fitted with a galvanic oxygen sensor CellOx. The measurements were performed in laboratory conditions, within INMA Bucharest Testing Department.

3. Results and discussion

For each experiment we performed 3 repetitions and reported the mean value obtained. The water input temperature was set at 10, 15 and 20 degrees Celsius and we measured the concentration of dissolved oxygen within the air-water mixture present at the output of the pressurized capsule, after depressurization and collection of the fluid in the buffer tank. First, we experimented with water at 10 ºC which was fed to the pressurized capsule together with the compressed air. The mean values for the dissolved oxygen concentration are presented in table 1.

Table 1: Experiments performed at 10ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.99	10	32.01
2	3.99	10	40.32
3	5.01	10	51.06
4	6.00	10	63.42
5	7.00	10	70.04

It can be observed that the concentration of dissolved oxygen in water rises as the pressure increases. In table 2 we have presented the mean values obtained for the mixture temperature of 15ºC, in the same conditions as the previous ones. We can see the same pattern for the dissolved oxygen concentration as seen for the first temperature, with a slight decrease of the mesured values.

Table 2: Experiments performed at 15ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.99	15	28.89
2	4	15	37.98
3	4.98	15	49.78
4	6.1	15	57.91
5	7.04	15	67.49

In table 3 are presented the experimental values obtained for the mixture temperature of 20ºC. The dissolved oxygen decreased to lower values, validating the fact that air solubility in water decrease with the rise of temperature.

Table 3: Experiments performed at 20ºC

Crt No	Working pressure (bar)	Mixture temperature (ºC)	Dissolved oxygen mg/l
1	2.98	20	26.12
2	3.98	20	35.55
3	4.96	20	44.26
4	6.01	20	52.04
5	7.03	20	59.64

Processing the experimental data, we obtained a 3D diagram representing the pattern in which the input parameters, fluid temperature and working pressure, are affecting the air solubility in water.

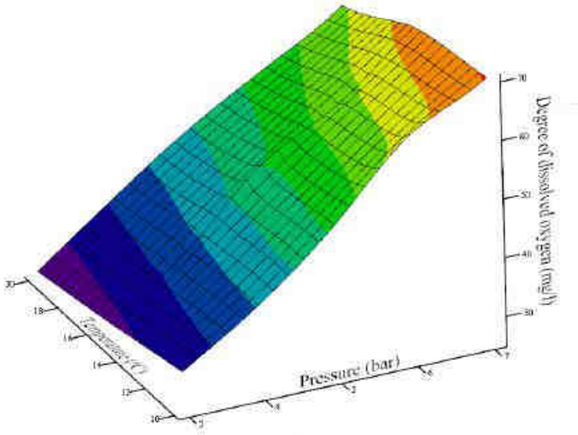

Fig. 2. 3D diagram of the dissolved oxygen concentration function of the working pressure and fluid temperature

Observing the diagram, we can see the linear characteristic of the experimental obtained results, fact that highlights the data consistency and validates the experiments.

4. Conclusions

The wastewater treatment by flotation represents a very important stage in the cleaning process of industrial and agricultural wastewater. Flotation could be achieved using dissolved air in a pressurized capsule. The most important parameter in flotation process is the quantity of dissolved air in water and this is influenced by the working pressure in the capsule and the fluid temperature. During our experiments, the best results were obtained for the minimum fluid temperature of 10 ºC and the maximum working pressure of 7 bar. These results could be used to optimize the wastewater treatment by flotation process in future applications.

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ANALYSIS OF THE FUNCTIONAL SOLUTION OF THE PELLET PRESS

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Abstract: *The present paper presents the analysis of the constructive - functional solution of a pellet press made with ROLIX IMPEX SERIES SRL on the basis of an idea developed by INOE 2000 - IHP, on the subsidiary contract of a single project on Axis POC - G. At the level of the experimental model a pellet press with a motorized sieve and it was tested in real conditions to see if it achieves the designed parameters. During the work the functional samples and the results obtained during the experiments are presented.*

Keywords*: Biomass, pellets, eco-innovative technologies, pellet press*

1. Introduction

Wood pellets (fig.1) are a new fuel that meets the new "clean" and regenerative energy requirements. They represent the best alternative to domestic heating, and in the conditions of aligning the prices of classic fuels with European prices, soon will be the most economical and at the same time comfortable alternative in Romania. They are produced from biomass materials, especially wood. Typically, these are produced by pressing the sawdust resulting from the saw blade, from the wood chips of the trees blow by the wind and generally from the waste resulting from the wood processing. Their production usually does not require additives or binders due to the naturally occurring resins in the basic raw material. [2,3]
Pellets are solid, low-moisture fuels made from sawdust, wood chips or even bark.
Short history**:**

- In the 1970s, the first production facility in the US Brownsville was built.
- In 1983 the first pellet plant in the US is sold.
- In the 1990s, in Sweden, industrial production of wood pellets was started as a fuel.
- In 1996 there are already more than 20 producers of thermal power plants and more than 80 pellet producers. Already about 1,000,000 tons of pellets heat homes in North America.
  In 1997 there were already over 500,000 pellet plants in North America alone.

Romania's rich forests can provide the raw material for the production of pellets. Poor quality wood resulting from their cleaning, wood resulting from scheduled cuttings as waste (sawdust, slurry) resulting from its processing in the industry, are in more quantities than necessary to cover the country's needs and currently almost no used. Let's think about 1,000,000 cubic meters can replace about 180,000,000 L of conventional fossil fuel. Ensuring energy needs is one of the greatest challenges of this early millennium. The huge volume of demand worldwide can only be covered by the ingenuity of new technologies. Pellets represent such an alternative technology with spectacular success in the West.
Pellets are a nonconventional fuel being:

- Ecological (the cleanest form of heating a home - burning almost no smoke).
- Regenerative (uses wood waste or plants as raw material).
- Economically advantageous.
- Adaptable - can be used both in heating plants for residential or industrial premises, as well as in apartment houses.

The raw material for pellets is more than abundant in Romania, which will be an asset in order to begin exporting them and comes from two variants:
• The first option is the use of wood waste: sawdust, chips, bark, trees cut down from forests as well as agricultural waste and vegetal remains.
• The second is the cultivation and processing of special plants for this purpose.

The primary resource for pellet factories remains the waste of timber and furniture factories, and therefore the location of mobile production units must be in the vicinity of the sawmills, or the construction of a factory should be in an area of tradition in this field. Pellet heating costs 60% less than heating oil and 40% less than electricity. Pellets are cheaper than fossil fuels, and are renewable.

Fig. 1. Pellets, [6]

2. Methodologies and production lines for the production of pellets

The usual pellet making system is the extrusion of the chopped material through a mold provided with a series of holes.
In general, pellet presses are the main equipment in a pellet production line. The technical characteristics of a pellet press greatly influence quantity and productivity. These characteristics are in general the dimensions of the mold, the mold speed and the distance between the workpieces.
Also, elements that influence equipment parameters are also the quality of friction materials that will affect friction and implicitly increase temperature during pelleting, the shape of the holes and their number with effects on productivity. Also, the die thickness (L) relative to the die diameter (D), known as the L: D ratio or the compression ratio, which is decisive in the density of the pellets. [1]
The block diagram of a pelletized compacting plant is according to Figure2

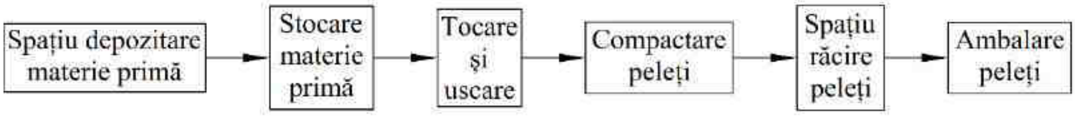

Fig. 2.

The pellet production process involves two stages [7]:
1. Obtaining the chopped material at the pellet size and the maximum admissible humidity ≤10: 15%;
The straw bales, with the help of the conveyor, reach the chopper where they are chopped into pieces of 10-90 mm in length. Supplied by a worm conveyor, through the stone separator, the chopped material reaches the hammer mill. The material is milled in 1-3 mm fractions and blown into the primary separation cyclone. The dust leaves the cyclone and is further filtered into the filtering equipment. From the cyclone, the milled material enters the worm conveyor, then into the silo, from which through the dozer and the mixer reaches a pellet press.
2. Pellet compacting.
The material, with the help of the rollers, is pressed through the mold, thus forming pellets. On the outside of the mold a knife cuts the pellets at the desired length. After extrusion, the pellets reach the temperature of 90-1000C and are transported to the cooler where their temperature drops to 250C. It fixes lignin and strengthens the product by contributing to its storage and transport quality.

Finally, they are sifted so that the residual fragments are separated and reused in the process. Dust-free pellets are ready for storage, shipped to packing equipment and stored.
A pellet making equipment is composed of * (see Figure 3) [5,6]:

-a helical feed system for dosing the compaction material;
-a funnel for directing the compacted material;
- pellet press;
- drive motor drive;
- Control box.

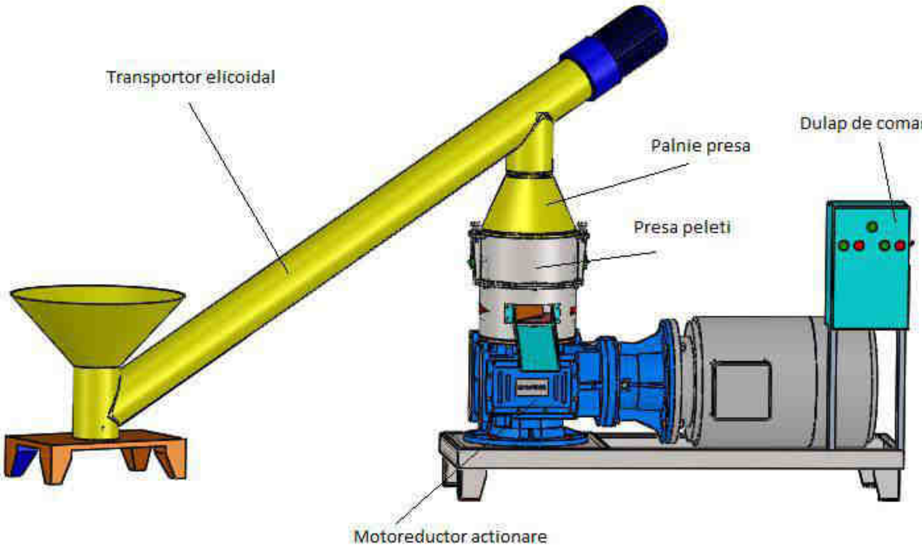

Fig. 3. Pellet feed and dosing with screw conveyor

3. The technical solution made by the company

For the introduction into production of a pelleting press S.C. ROLIX IMPEX SERIES S.R.L. together with INOE 2000-IHP made a technical-economic analysis of a small-medium series production of pellet presses [1]
The main criteria are:

- Productivity of the press;
- Manufacturing costs
- Costs of media maintenance
- Consumption of energy;
- Quality and composition of raw materials;
- The complexity of the technological line in which the pellet press will be included. The main constructive elements are presented in figure 4 a and b in which is presented the functional constructive solution (variant), the one with the motor sieve.

The pellet press was made by S.C. ROLIX IMPEX SERIES S.R.L. under a subsidiary contract of ctr. 129/2016 POC - G and tested under real conditions to see if it is reliable.

4. Pellet press testing and results

The pellet press was subjected to two types of samples [1]:

a. Functional tests:
- Running the equipment without material to check its functionality. The equipment corresponded with the fact that the engine started and moved the engine sieve for making the pellets.
- **Checking the electrical installation.** The press was electrically controlled and the start-stop operation checked. During this check, it was found that the machine is functional and makes all the

necessary moves. Verification with the door opened of the system command and control has shown that the press does not start, which is in line with the project prescriptions.

Fig. 4 a.

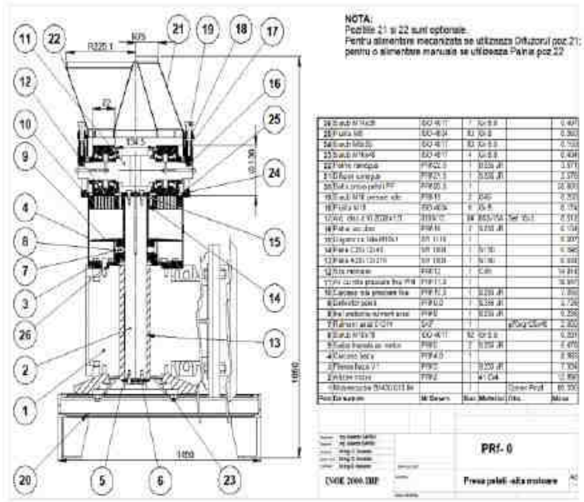

Fig. 4 b.

Pellet press with motor sieve

- **Check for stopping when metal elements enter the press area.** To perform this test, some metal elements (nails) were inserted into the pellet press and it was observed that it stopped. It is necessary to strip it down and extract the metal parts between the pressure rollers and the motor sieve. The product also corresponds to this point of view.
- **Checking the speed range.** It was checked and observed that it corresponds to a range between 300-1450 rpm

b. Samples with unsorted compaction material to check for load performance.

The material used in the verification process was wood sawdust. Prior to performing the tests the possibility of priming the press and the technological process of pellet production was checked. Within these two activities, the production of compacted parts was also carried out by grinding the holes of the site with grated biomass, but also with specific material (fine sand, engine oil etc.
Several steps were required to prepare the equipment for operation in real conditions these consist of polishing the motor web extrusion holes. We proceeded to:

a) 6 times the abrasive material (consisting of a mixture of 5 kg of raw material (sawdust, straw pastry), 1 kg of fine sand and 1 kg of used motor oil)

b) Compaction samples resulted in low density pellets (Fig. 5), which led to the conclusion that an additional crossing of the abrasive mixture for grinding the holes of the motorized

The samples from a) and b) were repeated three times so it was concluded that only after a pass of at least 18 times off the specific material, the pellets were within the limits required by the design theme from in terms of density (Fig. 6).
After these passes, the equipment technically corresponded to the execution validation samples.

The pellet press was verified at:

- Verification of movements in accordance with manufacturing technology.

It has been observed that depending on the type of press there is either a sieve (mould) or a roller (s). On this occasion the component of the machine was checked according to the execution documentation. The functional test was carried out both without starting material and with raw material according to the documentation and instructions for use, the raw material that was wood sawdust.

Fig. 5.

Fig. 6.

- Check the power consumption
This verification was carried out by measuring the electrical consumption in different stages of work, established by the designer and executor for each type of press. This measurement was made mandatory and, in the task, and it was found that for the accepted productivity the 15-kW motor is too high.
- Checking the possibility of adjusting the press rollers on the sieve. The check was carried out with the machine in a non-functioning state and it was found that the equipment fell into the areas indicated on each functional drawing. It has been found that it is very important to regulate this pressure, even if the actual value is relevant, since it depends on the level of grinding and the type of raw material. For wood sawdust, a pressure ranging from 20 to 600 N was used, useful in the range of 100-500 N.
- Measuring press productivity
A functional test of the machine was carried out with the type of biomass specified in the documentation as a raw material and its processing in the field accepted by the indicative prescriptions from the research-design program. Measurement was done by weighing the number of pellets produced in one hour under normal working conditions. The 50 kg / hour result is not final, and further evidence will be made.
- Dimensional inspection of pellets
It is a simple process of checking the machine settings by dimensionally measuring the pellets and checking the fitting in the press fabrication prescriptions. The range of presses designed within this project produced pellets with a diameter of 8 mm and a length of 12 mm, even if there were many deviations (15% of the pellets).
- Checking the density and compaction of the pellets
The test carried out a verification of the entire manufacturing technology and covered two stages. In the first stage you will be checked for the structural preservation and the shape of the pellets in time and the appearance of some small value shocks. In stage two, weighing the pellets and checking the compaction density. In principle, the density depends on the material and its previous processing and ranged from 0.9-1.3g /cubic cm.

5. Conclusions

After performing the functional samples at the pellet press it was found that important in the pelletizing process are:

- *the dimensions and granule-metric form of the mixture used for the compaction process;*
- *the moisture content of the mixture used;*
- *density;*
- *compactness;*
- *porosity and void volume;*

Granulometry of the mixture is a fundamental feature of a powdered product or suspension. It directly influences the deployment of a large number of unitary operations (shredding, separation, mixing, transfer of substance, etc.).

The need to determine particle size and shape as well as to determine the percentage distribution of particle size is implied by the fact that it influences how specific impulse and / or mass transfer operations are carried out. In mechanical or hydrodynamic operations, flow behavior, a characteristic that defines the relative displacement of dispersed system particles, depends on a series of properties that are related to particle geometry and mechanical characteristics of the surface.
Moisture content is an important physical feature that influences biomass retention, combustion process and calorific value. The transformation of biomass into combustion thermal energy requires certain values of fuel humidity as follows [16]:

- maximum biomass humidity for combustion in classical combustion plants = 25%;
- maximum humidity biomass for combustion in special combustion plants = 60%;
- optimal humidity biomass for combustion = 7 - 10%;
- maximum biomass humidity for gasification = 35%;
- maximum biomass moisture for transformation into pellets or briquettes = 10%.

Density is determined by appropriate methods for each type of material. It can be discussed: absolute density, apparent density, bulk density (bulk density) and stack density (especially for wood material).
Compaction characterizes the degree of solid material filling of the porous bulk unit.
Porosity represents, in percent, the total volume of pores and voids in the volume unit of porous material (apparent volume).

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RESEARCH ON ENVIRONMENTAL TECHNOLOGIES DESIGNED FOR ROMANIAN COMPANIES

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Abstract: *Research on environmental technologies offer information and instruments especially designed for Romanian companies. Creating a model for SMEs eco – innovative technologies is a part of an extensive research, being a component of a virtual hub for eco-innovation, to increase the competitiveness in recycling of waste electrical and electronic equipment. The user can check his own eco – innovative technologies by analyzing influence factors that act in the process, by following an Excel application, which gives the possibility to analyze and to test several technologies versions, under different influence factors; the company goal is to obtain the optimal eco – technology solution. The eco – innovative technologies implementation model in Romanian companies is basically a way to eco - innovation, helping the development and bringing to market of new ecological technologies, products and services, that reduce the overall environmental impact. The influence factors analysis can lead to sustainable solutions achievement, that can use more economically the resources and reduce environmental impacts.*

Keywords*: Environment, eco-innovation, technology, SME, sustainability*

1. Introduction

Current production and consumption of goods and services are focus on sustainable direction, in order to satisfy human needs and well-being without harming environment, depleting natural resources and damaging ecosystems. Friendly environmentally practices as reducing or eliminating waste levels and pollutants emissions, improving waste treatment, reducing raw materials demand and natural resources usage, are more and more present [1]. Sustaining these ideas, EU promotes sustainable consumption and production as overall objective in the EU Sustainable Development Strategy (EU SDS), “by addressing social and economic development within the carrying capacity of ecosystems and decoupling economic growth from environmental degradation and Improving the environmental and social performance of products and processes and encouraging their uptake by business and consumers”. One of the directions to follow by EU countries is “to increase global market share in the field of environmental technologies and eco – innovations” [2].

The concern about eco-innovation shows the society commitment on environment protection, the eco-innovation being defined as *“any innovation that makes progress towards the goal of sustainable development by reducing impacts on the environment, increasing resilience to environmental pressures or using natural resources more efficiently and responsibly”[3].*

2. Theoretical Framework

In 2008 the European Commission presented the *Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan,* which includes proposals on sustainable consumption and production “that will contribute to improving the environmental performance of products and increase the demand for more sustainable goods and production technologies” [1].

On 3 March 2010 European Commission proposed a 10-year strategy: *Europe 2020*, for advancement of the EU economy. It aims at "smart, sustainable, inclusive growth" with greater coordination of national and European policy [4]. The Eco-innovation Action Plan (EcoAP) development focuses on “specific bottlenecks, challenges and opportunities for achieving environmental objectives through innovation”, by complementing other Europe 2020 Flagship Initiatives. Sustainable growth of EU capacities represents a priority for Europe 2020 Strategy, also the transition towards a green economy is a target for the Eco-innovation Action Plan, this issue being tackled by two flagship initiatives:

- The achievement of a “Resource efficient Europe”, where the economic growth is related to a rational use of resources. “It supports the shift towards a low-carbon economy, an increased use of renewable energy sources, the modernization our transport sector and promotes energy efficiency”. Resources efficiency main ideas are promoted in “The Roadmap to a resource efficient Europe”.
- Business environment improvement and the key-role of small and medium enterprises (SMEs) to support sustainable industrial development are presented in “the Industrial Policy for the Globalization Era”, the purpose being to obtain “the development of a strong and sustainable industrial base able to compete globally” [5].

Regarding the involvement in eco – innovation, there are substantial differences across the EU, considering innovation in environmental technologies, products and services. “The eco – innovation index is based on 16 indicators in five areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, environmental outcomes and socio-economic outcomes” and it shows the performance level of an individual Member State compared with the EU average, [6].

In 2013 ten Member States performed better than the EU average in terms of eco-innovation activities, the eco – innovation leading group being formed by Finland, Sweden and Germany, with the highest scores, obtained especially from “a moderate correlation observed between a relatively high eco-innovation score and material consumption and greenhouse gas emissions” [7]. At the end of the scale the low eco-innovation index countries are Bulgaria, Poland, Cyprus and Slovakia.

According to European Council environment targets and to the Kyoto Protocol, Romania aligns to Members States to the implementation of energy-climate change package, that requires the development of “a new economic model to integrate environmental concerns into the production process and the resulting products” [8].

Romanian efforts to increase eco-innovation level of enterprises are present in the participation in the “Framework Programme for Competitiveness and Innovation 2007-2013” (CIP) – Eco-innovation component. The main idea was to improve competitiveness and innovation capacity of the European Community companies by supporting projects that aim first application or reproduction on the market of eco –innovative techniques, products or services relevant to the European Union, that have demonstrated technological success, but they didn’t yet penetrate on market because of residual risk. The program is composed of a sub-program regarding entrepreneurship and innovation, providing a budget of 430 million euros for investment activities in eco-innovation projects and facilitating the access to finance for the SMEs creation and development.

Despite some ecological recent improvements, Romania is still lagging behind the EU average, in the field of companies’ eco-innovation, and especially in SMEs, where the funds to support eco-innovation are insufficient.

One of the programme areas under the Norway Grants assistance is Green Industry Innovation, where Norway gave a total contribution more than EUR 110 mill., for the financial period 2009-2014. The overall objective was to “increase the competitiveness of green enterprises, including greening of existing industries, green innovation and green entrepreneurship. The expected outcomes from this programme area are: Realization of business opportunities of greening the European economy - Reduced production of waste and reduced emissions to air, water and ground - More use of environmentally friendly technologies - Increased green job creation and entrepreneurship” [9]. In the Green Industry Innovation Programme for Romania, financed by Norway, were available 26,6milions € to increase competitiveness of involved enterprises and informing the public about the benefits of ecological production and green products / services. The supported projects are for 53 Romanian private enterprises and NGOs and they are distributed all over the country.

Data show that the SME segment is interested in obtaining grants for eco –innovation, on account of limited ability to access capital markets. Analysis of implemented projects reveals that more than 50%

focuses on improvements processing facilities, equipment to increase productivity, optimization of the costs of raw materials, utilities, reducing CO2 emissions and creation of approximately 470 new jobs.
Another example of Romanian interest in eco – innovation is represented by ECO Partner -the **Swiss - Romanian Cooperation Program sustaining the Partnership for eco-innovation. The project was i**nitiated in May 2015 in Timisoara, by the Association National Centre for Sustainable Production and Consumption from Romania, in partnership with the Genovese Association for Circular Development of Circular Economy from Switzerland and the Romanian Clusters Association. I**ts goals are to** promote eco-innovation in the Romanian enterprises, to support eco-innovation services by Romanian experts, by giving contribution and models for businesses and policy makers. The project brings together representatives experts from businesses, academia specialists, research institutions and clusters, in order to participate in the project's activities and encouraging eco – innovation partnerships.

3. Methodology

The development of Romanian “clean” technologies market is due to legislation which obliges polluting companies and intensive resources consumers to retrofit. Aided by research institutes and participating in various consortia, they develop solutions and "clean" process technologies.
State and private companies have developed own solutions and green technologies in their research - development - innovation departments, some of them being patented [10].
Creating a model for the implementation of eco – innovative technologies is a part of an extensive research, being a component of a virtual hub for eco-innovation to increase the competitiveness in recycling of waste electrical and electronic equipment (EcoInnEWaste).
By identifying Romanian successful examples and presenting them in the eco – innovation Library of the EcoInnEWaste platform - authors provide the opportunity for an analysis of a relatively wide large range of eco - innovative technologies. It is a chance for entrepreneurs to be informed and to find possible solutions, compatibility or cooperation possibility with other companies involved in waste field [11].
The development of the eco – innovative technologies implementation model is based on the analysis of Romanian enterprises with successfull green technologies and on the possibility to bring their influence factors to a common denominator.
The user can access an .xlsx application, which presents a product applicable model, giving the possiblity to analyze and to test one or more variants of technologies, under the constraint of many influence factors; the target is represented by the achievement of the optimal eco-innovative technology.
The model uses the 6435 method, a relatively new method, which is proposed and used in the management of innovative products and services, in order to find the best managerial decision, in a rapid manner, with minimal risk. It represents a morphological analysis which is obtained from the combination of two methods: the 643 method, commonly used for innovative products; the 635 method, normally used to determine the response time limits for the function application to product development [12].
Developing new products, technologies or services, achieving their variants or enhancements are done by using morphological analysis, being based on functions analysis that describe their performance.
The model offers to Romanian entrepreneurs the possibility to choose optimal eco- innovative technologies variants by using functions and influence factors analysis that occur in the process.
The 6-4-3-5 method involves the organization of a 6 people team, which materializes every function in 3 constructive variants (or 3 ideas) in 5 minutes and it scores each variant from 1 to 4, where 4 represents the maximum severity. The most optimistic goal is to get 18 functions for each member of the team. Often, in the same defined period of time, each member is working, but he can not find only new solutions, different from others. For shortening the working time, while a team member materializes the "i" sub-function, another one works on "i + 1" or "i-1" sub-function. Finally, it is obtained the materialization of events conditions.

$$F_i = \begin{pmatrix} a_{11} & \cdots & a_{13} \\ \vdots & \ddots & \vdots \\ a_{61} & \cdots & a_{63} \end{pmatrix}; i \in \{a; b; c; d; e; f\}. \quad (1)$$

To get different viable solutions, for each function there are carried out different combinations between proposed solutions of the team, with the remarks that not all of these solutions are safe. Fig. 1 presents an example of possible solutions selection.

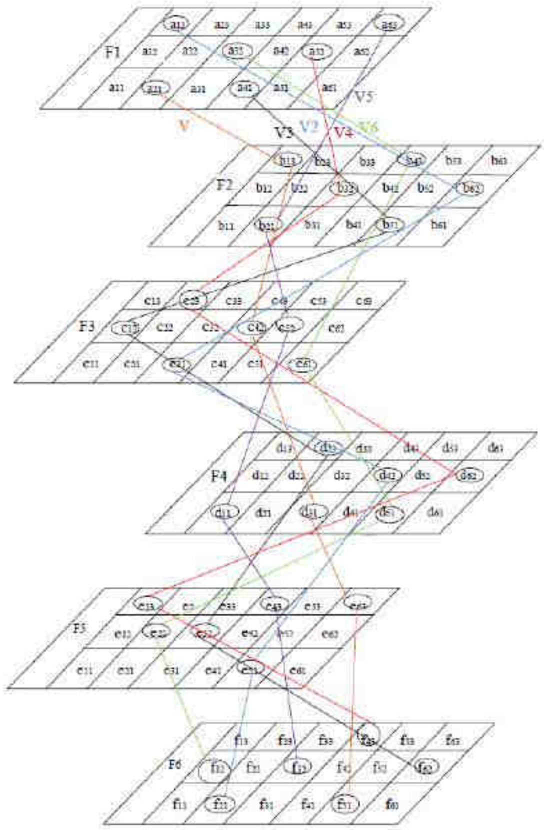

Fig. 1. An example of possible solutions selection in 6435 method

4. Results and Discussion

The chapter presents results and discussions for a product analysis example: an electric grill as model, in terms of sustainable development. The same procedure is offered to business environment to analyze and compare different environmental technologies solutions to find the best.
There is chosen a number of product variants selected to be analyzed comparatively. For these manufacturing versions there are analyzed most relevant factors and corresponding sub-factors, appreciating their shares over the total. For each version there will be specify the sub- factors shares involved in manufacturing, then it will be awarded with marks from 1 to 4. Finally, it results the sub-factor share over the total, for the analyzed versions. The highest value resulting for the sum of the shares of analyzed sub -factors will indicate the optimal version to choose. First step of the methodology is represented by the materialization of product functions variants (Fig. 2).
The possible solutions selection corresponding to 6435 method (Fig. 1) is used to obtain main manufacturing options for best versions of product (technology); in our case, for the product to be analyzed are mainly presented 3 manufacturing options, (Fig. 3).
To analyze the factors involved in product (technology) development (Fig. 4) is necessary to list them (e.g. ENVIRONMENT, COST, UTILITY, DESIGN) and to give them marks from 1 to 4 based on their importance. Next step is to divide the given mark to the total of all factor grades. Listing the

sub-factors involved in product (technology) carrying out (e.g. for ENVIRONMENT: phonic pollution, chemical pollution) and giving them marks from 1 to 4 are based on their importance; after that there is established the percentage over the sub-factors marks total. Finally, it is set overall share of the analyzed sub-factor over the properly factor. When product (technology) variants are analyzed, all factors are listed with their total shares. For each proposed version it will be appreciated each factor by a mark, then it will be calculated the appropriate related share, as a multiplication between the mark and initial share.

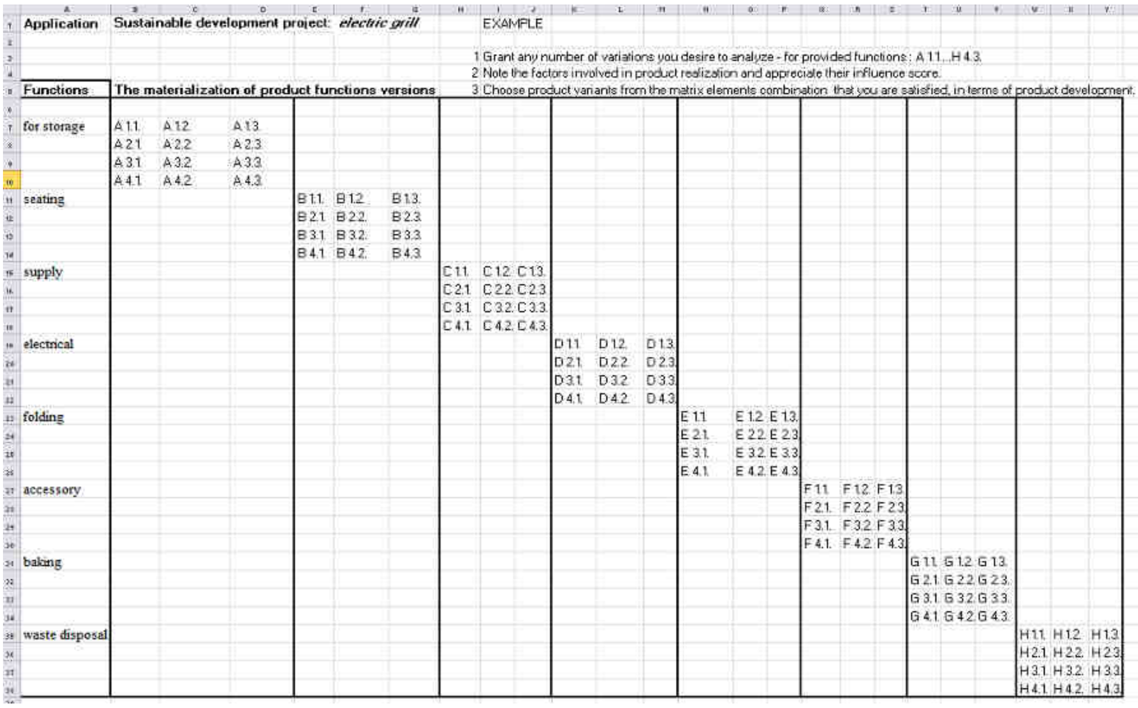

Fig. 2. The materialization of product functions variants for the electric grill example

Version 1	**A 1.1.**	**B 1.2.**	**C 4.3.**	**D 4.3.**	**E 2.3.**	**F 4.2.**	**G 2.2.**	**H 2.1.**
Version 2	**A 2.2.**	**B 2.2.**	**C 1.2.**	**D 3.1.**	**E 2.2.**	**F 3.2.**	**G 1.1.**	**H 1.1.**
Version 3	**A 1.3.**	**B 1.3.**	**C 4.2.**	**D 3.2.**	**E 4.1.**	**F 4.3.**	**G 3.1.**	**H 1.3.**

Fig. 3. Three manufacturing options to obtain the product

By adding the factors shares for analyzed versions it will be chosen the version with the highest value of the sum of factors shares, (Fig. 5). (In our example case, the optimal version is version 2, having the highest sum = 2.44).
Choosing the optimal technological solution for environment may be done same as product, the SMEs manager must know all information related to specific parameters and influence factors involved in the analyze. By adding the factors shares of analyzed versions the user can choose the optimum solution – the variant with the highest value of the factors shares sum.

5. Conclusions

The importance of eco –innovation and attracting investments in new green technologies are relevant for the achievement of sustainable economic growth, so, it is necessary for all companies to move towards sustainable development. SMEs must fight against numerous and difficult obstacles, as: lack of knowledge regarding benefits of environmental management, eco-innovation and lifecycle approach, insufficient access to information, tools or proper training activities, poor information on the environmental impact and risks, etc. SMEs can perform a dual key role, as eco-innovators and users of green technology; it is important to sustain their creativity and dynamism, to encourage their level in eco -innovation, to facilitate continuous improvement of quality products and services, according to their economic performance.

This work authors intend to help enterprises by developing research on eco – innovation database and bringing a tool for business environment. By offering useful information the research represents a way to increase competitiveness of Romanian enterprises, to develop SMEs green technologies and to disseminate best practices and technologies in this field of interest.

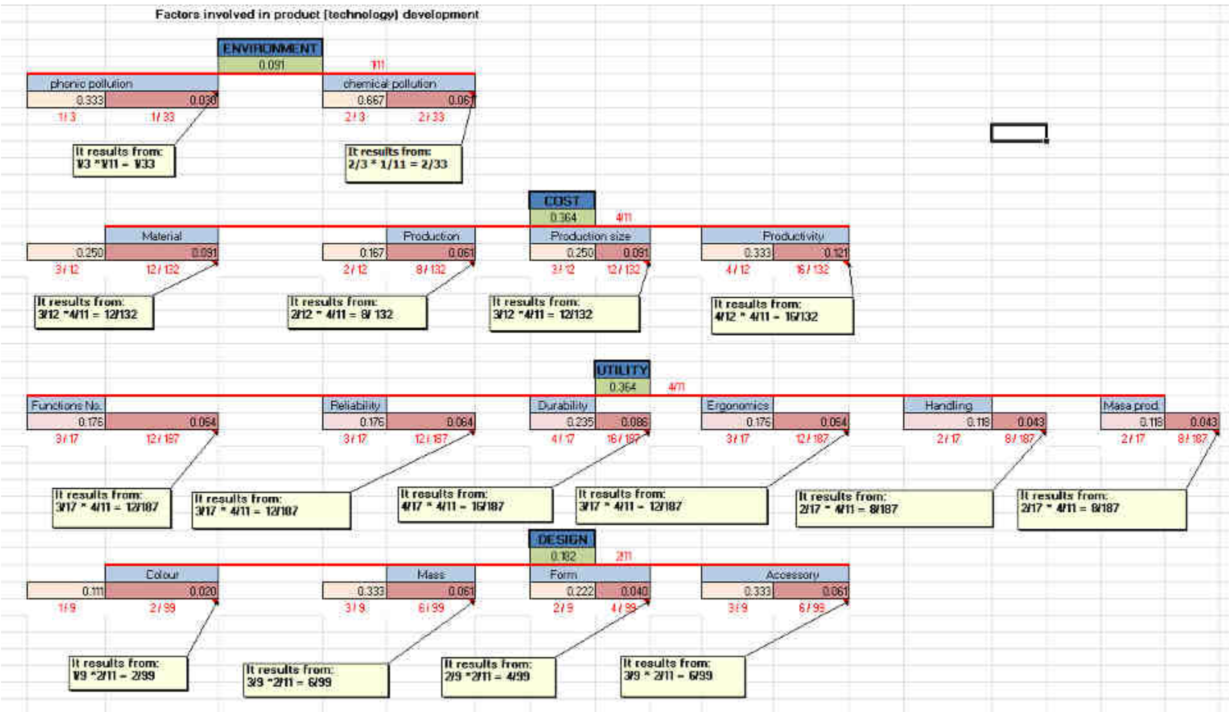

Fig. 4. Factors involved in product (technology) development

Analysis of product versions

Influence factors	share		Version 1		Version 2		Version 3	
	(fraction)	decimals	Mark (points)	share	Mark (points)	share	Mark (points)	share
Phonic pollution	1/33	0.030	1	0.03	3	0.09	2	0.06
Chemical pollution	2/33	0.061	3	0.18	1	0.06	3	0.18
Material	12/132	0.091	3	0.27	3	0.27	2	0.18
Production	8/132	0.061	4	0.24	2	0.12	2	0.12
Production size	12/132	0.091	1	0.09	1	0.09	1	0.09
Productivity	16/132	0.121	2	0.24	3	0.36	3	0.36
Functions number	12/187	0.064	3	0.19	4	0.26	4	0.26
Reliability	12/187	0.064	4	0.26	3	0.19	4	0.26
Durability	16/187	0.086	2	0.17	2	0.17	3	0.26
Handling	12/187	0.064	1	0.06	4	0.26	1	0.06
Colour	2/99	0.020	1	0.02	3	0.06	1	0.02
Mass	6/99	0.061	1	0.06	3	0.18	2	0.12
Form	4/99	0.040	3	0.12	2	0.08	4	0.16
Accessory	6/99	0.061	4	0.24	4	0.24	4	0.24
SUM				2.19		2.44		2.38

Fig. 5. The analysis of product versions

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ANALYSIS OF THE FUNCTIONAL SOLUTION OF THE GAZOGEN TLUD

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Abstract: *The paper presents a modern way of preparing and using the vegetal biomass for the ecological production of the cheap thermal energy required in the heating installations, technology specific to the rural economy based on agricultural activities. The goal of the project is to develop a prototype of a generating system based on the TLUD principle, consisting of the gas generator, the burner, the heat exchanger and the electronic drive and control system, intended for the heating of greenhouses, which operates with raw materials from secondary agricultural production, incorporating the latest innovative technical solutions and being clearly superior in performance, features and design compared to products of the same category on the market.*

Keywords*: Gas generator, TLUD, vegetal biomass, biochar*

1. Introduction

Romania has a great potential for renewable energy, especially hydro, wind and biomass. Biomass will play an important role in the National Renewable Energy Action Plan, which should be developed within the framework of the Renewable Energy Directive. The Ministry of Economy, Commerce and Business Environment takes the initiative to develop this action plan.
The Biomass Master Plan focuses on delivering sustainable energy, in which biomass plays an important role. Under the Biomass Master Plan we have identified the important role that biomass can play in our fuel mix. We have also identified the most important stakeholders from government and industry and have defined their role in biomass development as the most important renewable energy source in Romania. Together we can meet the EU's renewable energy obligations in 2020.
Romania has the opportunity to take an important step towards the efficient use of biomass at national level. This will contribute to the achievement of the guidelines set out in the new Directive 2009/28 / EC on the use of energy from renewable sources. It will also allow for the reduction of CO2 emissions in Romania, increase the efficiency of different industries and create new national and international market opportunities for private companies. The Ministry of Economy, Commerce and Business Environment (MECMA) in Romania is responsible for implementing renewable energy and bioenergy policies. The Ministry requested assistance from the Netherlands to implement the "Biomass Master Plan for Romania".
The available statistical data for 2006-2008 on biomass consumption indicate an average final consumption of approx. 140 PJ / year, divided by 121 PJ (2890 thousand tep / year) consumed in traditional rural heating (with about 18% yield) and 19 PJ (455 thousand tep / year) industry and the tertiary sector. Locals using local biomass will remain an important consumer but their contribution will decrease over time as the efficiency of new rural heating systems will increase. If the government will support the purchase of efficient biomass-based residential water heaters and promote the use of efficient residential heating units, the local biomass contribution will drop further.
Table 1 illustrates how modernization of existing rural heating systems leads, for upgraded systems, to the reduction of final gross biomass use.

Table 1: Possible evolution of biomass use from 140PJ (3350 mii tep/an) in present, at 112 PJ (2675 mii tep/an) in year 2020

Evolution beetwen 20110-2020		**Comments**
Replacement of traditional wood and waste stoves with new biomass-based district heating systems	Approx.20% din sobe	It leads to a decrease in consumption of approx.18 Pj
Replacement of traditional stoves with efficient biomass residential boilers *	Approx.8% din sobe	It leads to a decrease in consumption of approx. 7 PJ
Consumption of biomass for heating in stoves		**approx.86 PJ/an**
Biomass consumption for efficient residential boilers, which replace 8% stoves		**approx. 4PJ/an**
Consumption of biomass for new centralized heating systems, which replace 20% stove		**approx. 6 PJ/an**
Modernizarea unor boilere industriale existente	Cresterea mrdir a eficientei boilerelor cu aprox.15%	Conduce la scaderea consumului cu aprox.3 PJ
Consumul de biomasa in boilere industriale existente si modernizate		**aprox.16 PJ/an**
		TOTAL 112 PJ/an

* Directive SRE, Article 13.6 requires Member States to promote high efficiency boilers for residential heating

2. Analysis of the current state of the TLUD process

In order to cover the demand for heat, the use of residual or other biomass biomass from which thermal energy is obtained through a gasification process resulting in a hot combustible gas which is burned in a burner specific to this type of combustible gas is analyzed.
Large-scale pelletization and briquetting of woody biomass is currently being practiced. For pellet production, energy is consumed which represents an average of 8-10% of the calorific value of the biomass and emits in the atmosphere the amount of $CO2$ resulting from the production of the electrical energy consumed and the production of the production equipment. At the same time, pelletizing involves expensive, energy-intensive machines that make the price vary between 120-180 EURO / t depending on the biomass used, the drying needs, the biomass transport distance from the place of harvest to the biomass its processing
As a more environmentally friendly version, the TLUD (Top-Lit UpDraft) process proposes the use of local biomass gasification, minced at 10-50 mm and naturally or ventilated at 10 to 20% humidity. Energy consumption in this variant is less than 3% of the calorific energy used in the biomass and much less $CO2$ is emitted into the atmosphere. The cost per usable energy unit falls below 40% of the average pellet size.

The hot air generator system proposed in the project consists of:

1. way of supplying biofuels,
2. gasification mode,
3. burning mode,
4. Heat exchanger,
5. Electronic mode of monitoring and control process
6. tubing
7. Exhaust basket

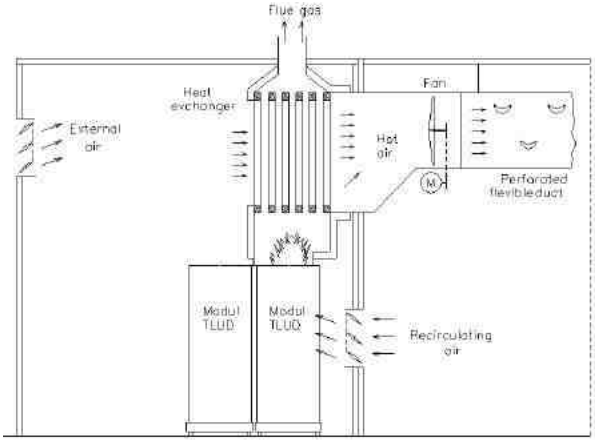

Fig. 1. The principle of the hot air generator with TLUD type biogas (Top-Lit UpDraft)

3. The up-draft procedure

This is the simplest type of fixed bed gasifier. Biomass is fed from the top of the gasifier, and it slowly moves down as its conversion and ash removing take place. The insertion of the gasification agent (the air) is done through the bottom of the gasifier beneath a bar grill, or with a rotary grill, version which has the advantage of adjusting the evacuated ash flow rate, so the possibility to adjust also the speed at which the biomass moves down inside the gasifier. The gases produced pass through the gasifier from the bottom upwards, crossing through the layer of biomass, and they leave the gasifier in the top, sideways, at a level slightly lower than the one at which biomass is fed. In this way, biomass and gas flow is countercurrent, and the sequence of the reaction zones is as shown in Figure 2 (a) [1].

The most important advantage is simplicity, and also intense burning of charcoal and internal heat transfer from gas to biomass, which causes the gas temperature at the outlet to be relatively low and to achieve high efficiency of gasification. In this way, even a gas with a high moisture content (>50 %) could be used [2].

The most important disadvantage is the tar content in the gas, as well as the presence of moisture and pyrolysis gases, because they no longer cross the oxidation zone and are no longer burned, no longer cross the reduction zone and are no longer cracked. This is a minor drawback if we consider direct combustion of gas in regular furnaces. But if it is intended to use the gas for engines, then it is a must to clean the dust and tar off from the gas, otherwise they can cause serious problems.

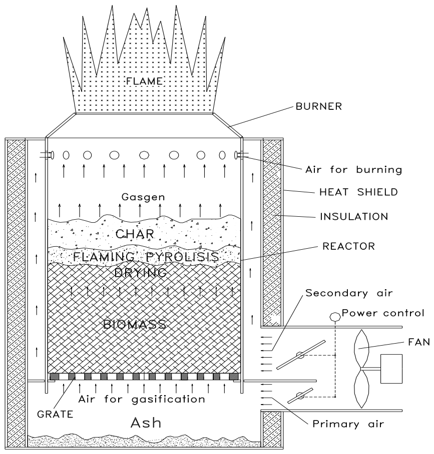

Fig. 2. Schema simplificata a arzatorului cu gazogen

4. Experimental Modeling and Testing

The paper presents a modern way of preparing and using the vegetal biomass for the ecological production of the cheap thermal energy required in the heating installations, technology specific to the rural economy based on agricultural activities.
In a research project, an experimental model (Figure 5) has been used; it is based on this procedure, which was tested in the laboratories of the Hydraulics and Pneumatics Research Institute (IHP) in Bucharest and CALORIS Group S.A. Thermal energy can be obtained by micro-gasification using the TLUD (Top-Lit UpDraft) process of vegetal biomass, which is characterized by high conversion efficiencies and very low CO and MP 2.5 pollutant emissions. Applying the TLUD process it is possible to efficiently gasify biomass with relatively large variations of the chemical composition, humidity (under 20% water) and granulation properties (1-5 cm), aspect which provides a wide base of usable plant biomass sources [6].
The long-term acceptability of gasification technology and the CHAB concept as well as its introduction on the market depend on the technical, economic and environmental performance of gasification and biofuel plants, efficiency and safety of power plants that is using the gas fuel produced [7].
In order to achieve these goals, the system must have high operational safety and be reliable, environmentally friendly, economically viable and be exploited by a user with a minimum of professional training, trained carefully through a monitored schooling system.
It is in the user and manufacturer's interest that the hot air generator is properly tested so as to achieve the desired performance. Therefore, a methodology has been developed for testing the hot air generator with the TLUD energy module, measuring quantities and necessary equipment, as well as calculation algorithms for the primary processing of experimental data.

Testing is carried out in four test steps:
1. Initial running test **(IRT)**
2. Start test **(ST)**
3. Load operational test **(LOT)**
4. The biochar discharge and off test **(BOT)**

The tests will be carried out in strict surveillance with the labor protection rules specific to hot combustion gases.

Following the mathematical modeling of the equipment, the project has been modified, resulting in the experimental model shown in Figure 3.

Fig. 3. Experimental model of a TLUD gasifier

The micro-gasification process is supplied with air from a variable speed ventilator. Biomass is introduced into the reactor and is based on a grid through which, from bottom to top, passes the air for gasification. Initialization process is done from the free upper layer biomass.
Thermal energy is obtained by burning hot gas generated, resulted during pyrolysis, it is mixed with preheated combustion air introduced into the combustion zone through holes located at the top of the reactor. Mixture with high turbulence burns with flame at the upper mouth of the generator with high temperature 900-1000°C. To adjust the heating power necessary it is varied the air flow for gasification and the air flow for combustion through two flaps, coupled mechanically, or by varying ventilator speed. The TLUD process, at an optimal excess of air for gasification of 25...30% does not consume entirely the carbon in biomass; at the end of the batch gasification process there remains ash and about 15% unconverted charcoal, also called biochar. To obtain a complete reduction of carbon in biomass, resulting in the end in only about 3% biochar, the heat loss through the reactor wall must be reduced to keep in the pyrolysis wall temperatures over 900°C.
The biochair can be gasified or burned to produce heat, or it can be used as a valuable agricultural amendment, procedure that helps seizure in the soil around 25% of the carbon from the gasified biomass, thus resulting in a negative balance of CO_2 [6, 8]. The TLUD process is with fixed bed of biomass and therefore the generator operates in batch mode to recharging.
In order to put into operation, the experimental model of the TLUD hot air generator, the reactor was filled with 15 kg of pellets (conifer, density ≤1.12 kg/dm^3, thermal efficiency 5KWh/kg) and the ignition with 4 pieces of fireplaces igniters was used. The draft fan and the hot air fan were started. After a start-up period, the gasification process stabilized and a stable, slightly turbulent flame of orange color was obtained.
There was observed a high increase in air temperature at the outlet of the heat exchanger. After about 1 hour and 30 minutes, a total blue flame appeared at the burner, indicating the occurrence of gasification of the biochar. At that moment the blower stopped, the gasification and combustion air were closed. At the complete extinction of the blue flame, the reactor was extracted from the generator and the biochar was discharged.
As a result of measurements made with a thermal camera, one can see the heating of the boiler on the entire surface of the boiler (Figure 4).
To achieve thermal performance and functional requirements imposed by current industrial consumers of thermal energy, TLUD heat generator can be equipped with an automatic driving device oriented PLC, as one can see in Figure 5.

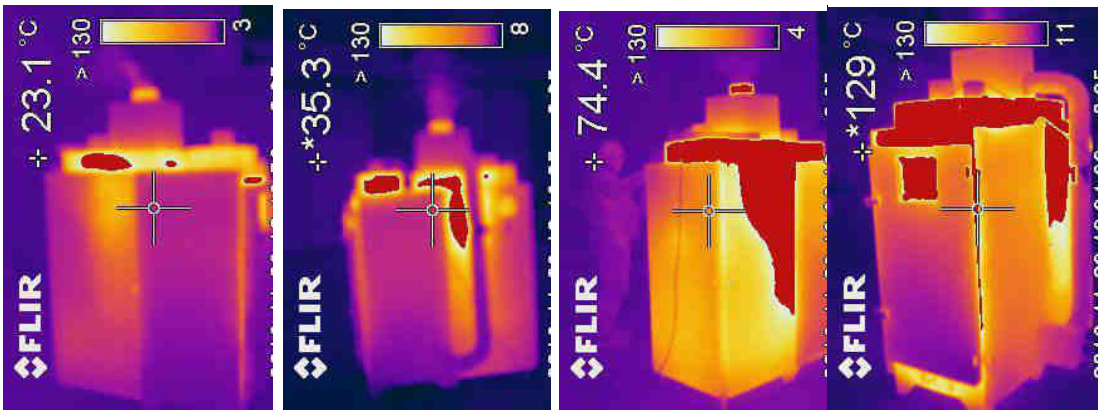

Fig. 4. Thermal camera records showing heating of the boiler

Fig. 5. PLC device equipping the TLUD heat generator

The boiler was equipped with temperature sensors PT1000 type on the hot air outlets, smoke exit, on the energy recovery zone and the gasification air, all connected via 4-20 mA amplifiers to the data acquisition board. Specialized software has been developed for this application, by using LabVIEW; this is shown in Figure 6.

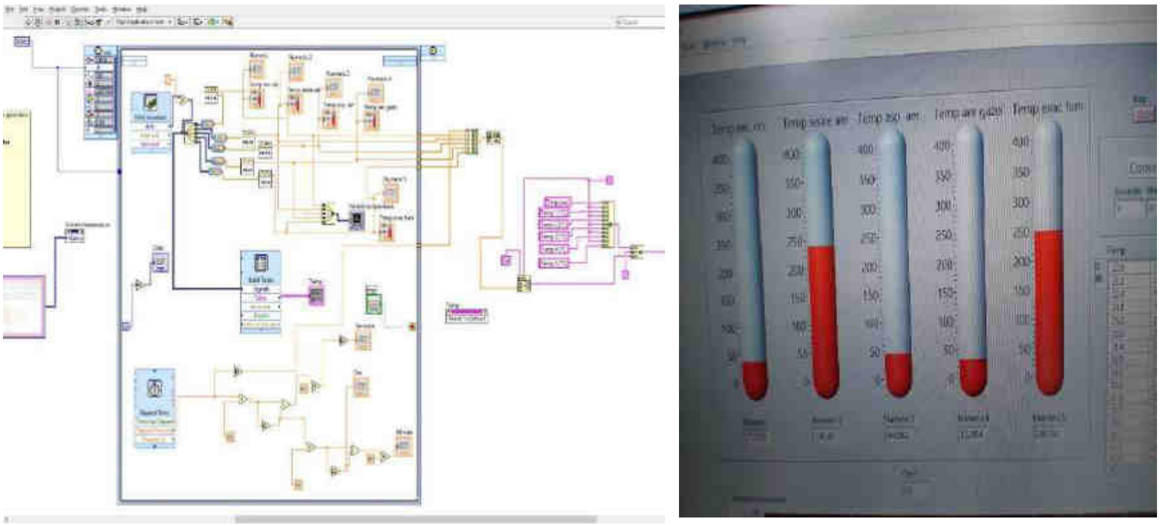

Fig. 6. Screen captures of the specialized software developed

The temperature is taken over at an interval of 30s over the entire duration of the cycle (about 2 h) on the above-mentioned ports, also noticing in the Figure 7 what the temperatures that we recorded were.

The graph below shows the temperature evolution at the end of the service cycle.

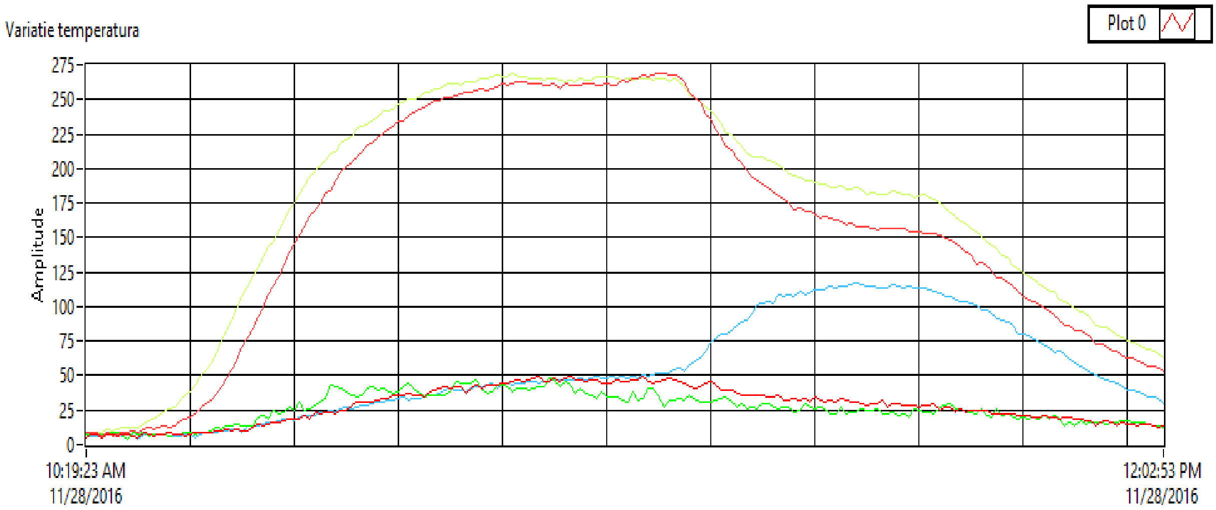

Fig. 7. Recorded temperature points and temperature evolution

5. Conclusions

Designing and testing a completely new prototype of hot air generator system based on the TLUD principle, used to control the heating of greenhouses and solariums, is a daring project. Real time control of exhaust gas temperature, recovering energy from the smoke flue and re-introducing it into the combustion and gasification circuit by using a fully automated system could lead to the development of a hot air generating system comparable in performance with a classic thermal plant but at an affordable price and with lower operating costs. At the same time, the implementation of the project and subsequent marketing would result into promotion of clean energy technologies, environmental protection measures and the reduction of greenhouse gas emissions, as well as an important saving of wood, thus observing the principles of sustainable development.

The ultimate goal of the project is to develop a prototype of a generating system based on the TLUD principle, consisting of the gas generator, the burner, the heat exchanger and the electronic drive and control system, intended for the heating of greenhouses, which operates with raw materials from secondary agricultural production, incorporating the latest innovative technical solutions and being clearly superior in performance, features and design compared to products of the same category on the market.

Results of research on combustion systems with gasification of wood fuels of TLUD type can also be used in other applications, *e.g.*: gas generators, biogas-based green energy cogeneration systems, or other applications detected during the dissemination activities.

It is possible to reduce the emissions of biomass-based plants by the following measures:

- By controlling the temperature in the gasification process, the occurrence of nitrogen oxides is greatly reduced resulting in a reduction of up to 20 times that of conventional combustion;
- By gasification the problems caused by the deposition of molten ash on the heat exchange surfaces, which causes the boilers to clog, are overcome;
- Adjustable thermal power of generator TLUD in the range 35-95% is made through ventilators speed variation; the generator is very easy to control from the level of the operator to the automatic drive controller to a PLC;
- Two types of biomass have been burned: wood pellets and wood chips;
- The amount of biochar was variable depending on the time and level of combustion and air supply.

Acknowledgements

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REMOVAL OF PATHOGENS FROM DAIRY WASTEWATER BY UV TREATMENT

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Abstract: *Nutrient-rich wastewater has become a valuable resource for farmers, but if used untreated, the wastewater can pose serious risks for human health. There is potential for wastewater reuse in Romanian agriculture, but different wastewater treatment for agricultural reuse is only tested experimentally. Wastewater samples collected from the lagoon of a cow farm in Romania were tested to determine the microbiological load, expressed as efficiency removal of pathogens at UV treatment with germicidal lamps. Duration of treatment were of 1, 5, 10, 15, 20 and 30 minutes, and highest efficiency was of 87%, showing that UV treatment can be used at large scale for the disinfection of dairy wastewater before its reuse as irrigation water.*

Keywords: *Wastewater, pathogens, health risk, disinfection, UV*

1. Introduction

In recent years, wastewater recycling in agriculture has gained importance as component of agricultural water supply in several water-scarce countries, [1] were farmers in many arid and semiarid areas were forced to find solutions to irrigate their crops. The composition of wastewaters depends on their origin but generally, major contaminants found include organic compounds, xenobiotics, metals, suspended soils, nutrients (mainly nitrogen and phosphorus) and pathogenic microorganisms, [2].
Various studies have pointed out that the pathogens contained in wastewater pose a serious threat to human health and increase the risk for bacterial, parasitic and viral infections in consumers of wastewater irrigated crops, estimating the risk of infection based on the microbial concentration of reused wastewater, [3, 4]. Human and animal pathogens, phytopathogens and antibiotic resistant bacteria and their genes are important biological contaminants that can be transported by wastewater and/or be enriched in soil. Many pathogens are able of survival in the environment (e.g., water, soil, crops) long enough to allow transmission to humans, [5].
Thus, many countries have introduced standards and regulations for the physical-chemical and microbiogical parameters of quality of wastewater used for irrigation of food and energy crops. Usually, limits are imposed for physical-chemical (turbidity, pH, salinity or electrical conductivity, suspended solids, heavy metals, BOD, COD, nutrients) and microbiological (*E. coli, Salmonella*, *Shigella*, fecal coliforms, fecal enterococci, nematode eggs) parameters, [6]. Regulatory frameworks on the quality of wastewater used in irrigation differ from country to country and compliance with these frameworks requires the analysis of the treated wastewater prior to its reuse.
Romania's accession to the European Union requires compliance with European requirements, and the reuse of wastewater effluents is in line with Objective 6 of the European Union's Sustainable Development Strategy. In Romania, reuse of irrigated water is not largely practiced (there is a low demand for the global use of treated wastewater), and different wastewater treatment methods for reuse are only addressed at the experimental level. In Romania, STAS 9450-88 imposes limits for the microbiological quality of wastewater used for irrigation, and refers to total coliform bacteria, faecal coliform bacteria, faecal *Streptococcus*, and Salmonella bacteria. Depending on the microbiological parameters, wastewater is classified into three categories of use:

category M1 – usable for all categories of soil and crops; category M2 – usable for all soils and crops, except very permeable soils and plants destined for food and fooder consumption in fresh state or conserved by freezing, without thermal processing; category M3 – usable for lands with ground level deeper than 4 meters and for crops whose products are processed thermally industrially, or for vegetable non-food crops.
Table 1 presents the limits of microbiolgical parameters allowed by the Romanian standards of wastewater reuse in irrigated agriculture.

Table 1**:** Romanian limits of microbiological parameters for wastewater reuse in agriculture

Parameter	**Category**		
	M1	**M2**	**M3**
Total coliform bacteria, probable number / dm^3	absent	> 100 - 100000	> 100000 - 10000000
Faecal coliform bacteria, probable number / dm^3	absent	Max. 10000	> 100000 - 1000000
Faecal *Streptococcus*, probable number / dm^3	absent	Max. 10000	> 100000 - 1000000
Salmonella bacteria	absent / 1000 cm^3	absent / 300 cm^3	absent / 100 cm^3

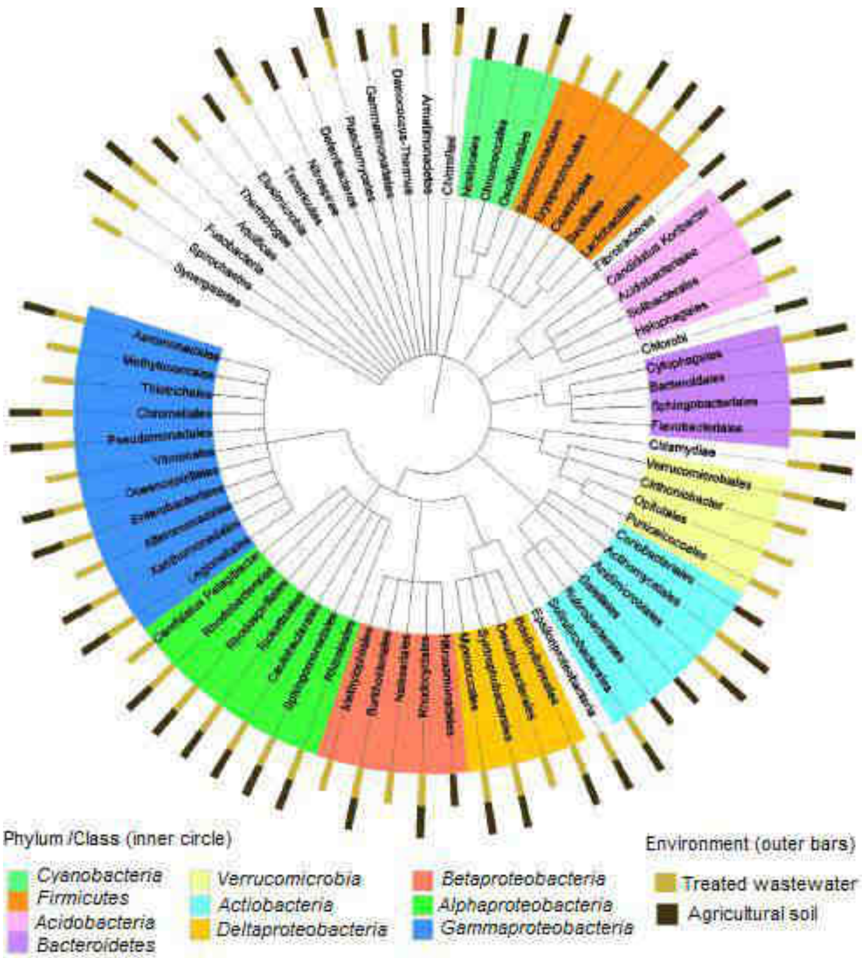

Fig. 1. Dendrogram representation of the bacterial diversity observed in treated wastewater and agricultural soil, [7]

Advanced treatment of wastewater can significantly reduce the concentrations of the specific pathogens in the wastewater and thus, the risk of disease transmission is reduced. However, treated wastewater still contains high loads of bacteria. Disinfection is a necessary step to destroy

or inactivate microorganisms and prevent the spread of dangerous diseases. Disinfection is the process of removing pathogenic micro-organisms from the wastewater. The application of the disinfection process is necessary in the case of industrial waters from slaughterhouses, breeding establishments, tanning, canning factories, food industry where fermentation processes take place. UV water disinfection has been successfully tested for many years, with no negative consequences, while the scope of application extends to many new areas. Of all the methods of wastewater disinfection, UV is one of the most efficient, economical and non-polluting methods available, being considered the fastest, most effective and safest.
UV disinfection has been increasingly developed for water and wastewater disinfection due to its broad-spectrum efficiency against various pathogens and non-formation of disinfection by products, [8]. UV disinfection has been recommended as a substitute for chemical additives for water treatment. Recently, UV disinfection systems have been installed in many water treatment plants in North America and Europe, and small household UV disinfection systems are also available, [9]. UV light disinfects water by permanently deactivating bacteria, spores, molds, viruses and other pathogens, thus destroying their ability to multiply and cause disease. For an effective UV disinfection, it is necessary that a sufficient amount of UV light penetrates through the water and is delivered to the target organisms, [10].
The most common UV sources for current UV disinfection systems are low-pressure (LP) and medium-pressure (MP) mercury lamps. LP lamps have monochromatic emission at a wavelength of 253.7 nm, while MP lamps have polychromatic emission light at a broad range of wavelengths, from 200 to 600 nm, [11]. The effectiveness of a UV disinfection system depends on the characteristics of the wastewater, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation and the reactor configuration.

2. Description of laboratory testing method

Wastewater samples were collected from the lagoon of an industrial level cow farm with a total of 570 heads, of which 370 mature cows and 200 calves. The irradiation of UV wastewater was performed using a germicidal UV lamp LBA-e.2 x 15 W, with the power of UV tubes of 30 W, dimensions (Lxhxa) 470x178x70 mm, with wavelength 253.7 nm, and working temperature 10-35 ° C. One liter of wastewater was introduced into a plexiglass parallelepiped tank so that the height of the liquid layer was 2 cm. The germicidal lamp, having a surface roughly equal to that of the wastewater tank, was suspended by means of a metallic device at a distance of 5 cm from the surface of the wastewater (Fig. 2).

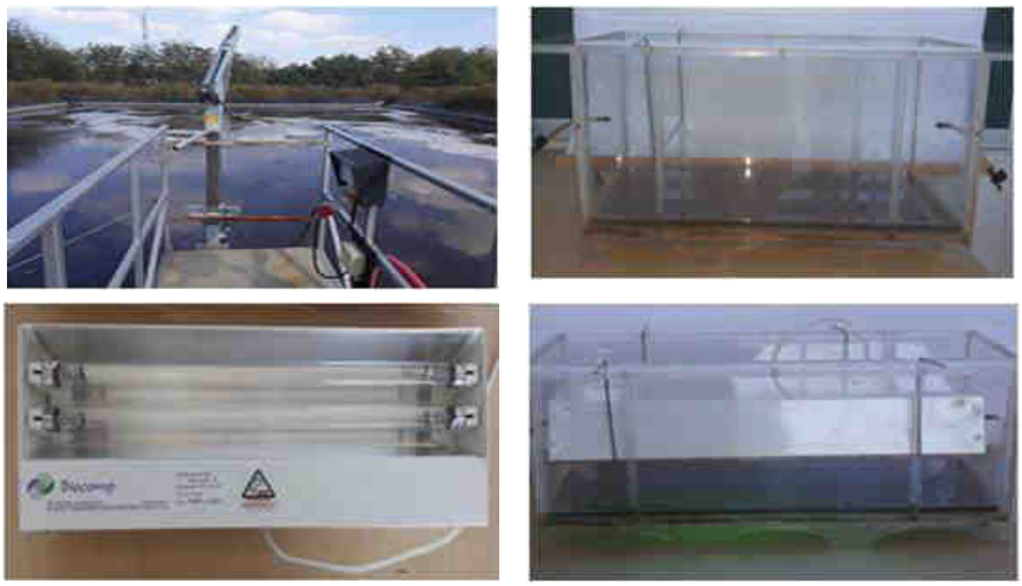

Fig. 2. Laboratory setup for UV treatment of dairy wastewater

In order to determine the total number of germs contained initially the wastewater, and the reduction of germs after UV treatment at different periods of time (1, 5, 10, 20 and 30 minutes), first it was prepared the Plate Count Agar culture medium, with the following composition (g / l): peptone 5.0; glucose 1.0; yeast extract 2.5; agar 15. Culture medium was weighed and prepared in 500 mL Erlenmeyer flasks and sterilized in the autoclave at 121 °C for 15 minutes (Fig. 3).

Fig. 3. Preparation of culture medium

During UV treatment, wastewater samples were taken on the side of the tank with a sterile tip pipette. In tubes containing 9 ml of sterile physiological saline serum, 1 ml volumes of UV-treated wastewater were pipetted at each established treatment time. The wastewater samples were homogenized on a Vortex device for a few seconds and then analyzed in order to determine the total number of germs, by the culture method in Petri dishes.
Into each sterile Petri dish was placed 1 ml of three dilutions of the UV-treated wastewater samples at different time intervals. The culture medium, sterilized and cooled to 45°C, was poured over the wastewater samples, then homogenized by circular movements. After solidification, the Petri dishes were incubated at 37 °C for 48 hours and the resulting colonies of pathogens (germs) were counted. All microbiological analyses were performed in a sterile microbiological hood.

Fig. 4. Inoculation of culture medium with UV treated wastewater and colonies of bacteria in Petri dishes

The result of the determination (expressed as colony forming units per ml - CFU / ml) was multiplied by the dilution factor.

3. Results obtained in wastewater treatment using UV germicidal lamp

The effectiveness of UV treatment, or the percentage inhibition of bacterial growth, was calculated with the equation:

$$UV\ rate\ of\ inhibition\ (\%) = \frac{No - Np}{No} \cdot 100$$

where: N_o – value of CFU/ml in untreated (initial) sample; N_p - value of CFU/ml in UV treated samples.

Table 2: Results of microbiological determinations on UV treatment

	Duration of UV treatment of wastewater					
	Initial sample	**1 minute**	**5 minutes**	**10 minutes**	**20 minutes**	**30 minutes**
Total number of germs, CFU/ml	$7 \cdot 10^7$	$7 \cdot 10^7$	$5 \cdot 10^7$	$4 \cdot 10^7$	$2 \cdot 10^7$	$9 \cdot 10^6$
Rate of inhibition, %	-	0	28%	42%	71%	87%

The results obtained show that the efficiency of UV treatment increases in proportion to the increase in treatment time. As expected for this high turbidity wastewater (529 FAU, determined with the Spectroquant Nova 60 Spectrophotometer before treatment), UV radiation was short-lived being absorbed only by the particles in suspension. Even though the height of the wastewater layer was relatively low (2 cm), the effectiveness of the treatment can be considered quite good under the tested conditions. For this type of wastewater, in treatment plants dedicated to dairy wastewaters, it is recommended to have a particulate removal treatment (decantation or filtration) in advance to UV or other disinfection treatment.
To assess the efficiency of UV treatment on the particulate matters in suspension from the wastewater, kinetic absorbance determinations at 600 nm for 2500 seconds were performed on a UV VIS spectrophotometer, with absorbance recording at 10 seconds, in 'kinetic' of the program.

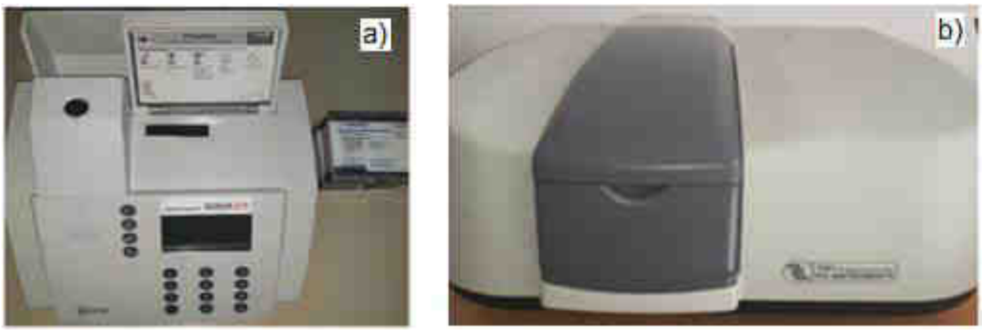

Fig. 5. Spectroquant Nova 60 Spectrophotometer (a) and T912+ PG Instruments UV VIS spectrophotometer (b)

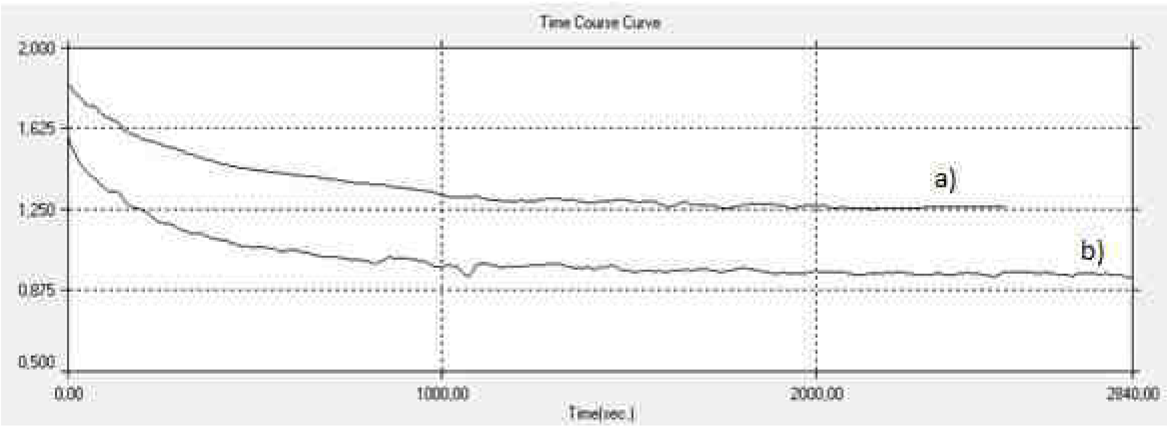

Fig. 6. Variation in time of absorption for wastewater samples:
a) sedimentation curve over time for the UV-treated sample for 30 minutes; b) untreated wastewater

Figure 6 shows that UV radiation caused an increase in wastewater turbidity, which was also easily observed visually at the end of the 30 minutes of UV treatment.

4. Conclusions

Inadequate microbial quality of treated wastewater is a challenge for developing countries, and limits agricultural reuse of wastewater. Human and animal pathogens, phytopathogens and antibiotic resistant bacteria and their genes are important biological contaminants that can be transported by wastewater and/or be enriched in soil, and further transmitted to humans and animals.
The microbial pathogens contained in the wastewater (bacteria, viruses, protozoa, and nematodes) can be removed by physical and biochemical treatment processes. Affordable technological solutions with minimal environmental impacts must be developed in order to enssure wastewater treatment processes compatible with sustainable uses.
For an effective UV disinfection, it is necessary that a sufficient amount of UV light penetrates through the water and be delivered to the targeted microorganisms. In the tested conditions, pathogen removal rate of 87% was achieved for a treatment period of 30 minutes, but at large scale, the removal rate can be of 100% and is influenced by wastewater initial characteristics, the length of wastewater tank and the characteristics of UV disinfection systems.

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MICROSPRAY IRRIGATION SYSTEM INTEGRATED WITH PHOTOVOLTAIC PANELS

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Abstract: *Global food security is endangered by rapid population growth and consequently increasing demand. Only an optimal combination of energy and water resources used for irrigation, mineral fertilization and organic soil of the Republic of Moldova will ensure a continued growth in agricultural production and food security. The microspray irrigation systems integrated with PV, a method of PV pump system calculation for small irrigation are presented. The numerical example contains pump flow rates, pumped water volumes (daily, monthly and for all irrigation period)*

Keywords*: Microspray photovoltaic installation, solar radiation, solar pump*

1. Introduction

Global food security is endangered by rapid population growth and consequently increasing demand. As result, world market food prices are continuously increasing. Climate change is manifested by increased severity and climate variability and this phenomenon is not a regional, but rather global. It is clear that sustainable agriculture development is closely related to irrigation and fertilization of the agricultural land. Only an optimal combination of energy and water resources used for irrigation, mineral fertilization and organic soil of the Republic of Moldova will ensure a continued growth in agricultural production and food security. Also, this will help to decrease soil degradation and climatic vagaries dependence of agricultural production.
The climatic conditions of the Republic of Moldova impose that the optimal water amount needed during the active growing season for most crops consists of 300-700 mm. According to long-term weather observations for the above-mentioned period, the average amount of rainfall is from 235 mm in the south up to 330 mm in the northern region. Natural moisture is insufficient to achieve the expected amount for fruits, or especially for vegetables, even in years with above average climatic characteristics. Often, the Republic of Moldova, Romania and Ukraine are subjects to long-term droughts.
After 1991, there were implemented the key agriculture reforms characterized primarily by restructuring large agricultural units, decentralization of agricultural production, land privatization, formation of new economic relations based on market economy. The changes that took place in agriculture and power supply sector influenced negatively in particular the existing irrigation systems [1]. The main causes that contributed to the aggravation of irrigation systems status are:
- sudden increase in electricity and fuel prices;
- reduced water demand from new landowners;
- parcellation of the land made impossible the efficient use of pumping stations, water supply systems and irrigation facilities, designed, developed and built to irrigate large areas;
- small or even negative economic efficiency of irrigation systems placed at great heights with respect to water sources;
- bad management of involved companies and local authorities led to disassembly of watering plants, removing and selling non-ferrous metal pipes;
- technical obsolescence of irrigation equipment and facilities. In the last 10 years there were not purchased any new equipment;
- lack of state subsidies for the electricity purchase.

Considering the above, the Government of RM adopted Decision no. 256 of 17 April 2001 „*On the rehabilitation of irrigation systems”* According to this decision it is expected to achieve the following objectives: rehabilitation of large irrigation on 124 300 ha (40% of the irrigable area), 1991 irrigation systems will be equipped with mobile irrigation equipment with high productivity, low energy and water consumption; small irrigation implemented on 36,000 ha (small irrigation is executed on areas from 1 ha to 100 ha). As water supply sources there will be used 3000 water reservoirs, of which the most important are 411 lakes, Dniester Prut and Raut rivers. Also, small irrigation will be done with mobile units, preferences given to modern and efficient methods including drip, sprinkler and aerosols irrigations, with the use of renewable energy as power supply. In order to minimize the negative effects on both humans and environment there will be developed and implemented the irrigation schedule techniques based on soil, crop and weather conditions monetarization. The existing technologies and methods range from water balance or control registers up to sophisticated sensor-based systems. There is a need for an automated from the point of view of quality for watering (e.g. Dropwise) co-cultivation and fertilization (for a drip irrigation fertilizer is brought to the root of the plant).

2. Prerequisites and solutions

The issue of global food security is amplified by the rapid growth of the number of population and, consequently, by the increased demand for food. As a result, food prices on the world market are rising. Climate change is manifested by the amplification of climate severity and variability. This phenomenon is not a regional one, but a global one (*Figure 1*).

It is obvious that the sustainable development of agriculture in the Republic of Moldova is indispensable for irrigation and fertilization of agricultural lands. Only an optimal combination of water and energy resources for irrigation, mineral and organic fertilizers with Moldovan soils will guarantee a continuous increase of agricultural production, food security, and will provide the processing industry with raw materials. It will also contribute to reducing soil degradation and the dependence of agricultural production on climate conditions.

In the climatic conditions of the Republic of Moldova, the optimal water requirement during the active vegetation period is an amount between 300 and 700 mm for most agricultural crops.

After 1991, there were essential reforms in the agrarian sector, characterized first by the restructuring of large agricultural units, decentralization of agricultural production, privatization of agricultural land, formation of new economic relations, based on the laws of the market economy. The increase in the price of electricity and fuel has caused the price increase of one cubic meter of pumped water, which has led to a drastic decrease in the demand for irrigation water from the new agricultural producers. The share of electricity cost often exceeded 50% of total irrigation costs. After 1994 there was a decrease of about 16 times of the irrigated areas and a sudden increase of the share of energy cost in the total cost. In order to redress the situation, the Development Strategy for Agriculture was elaborated in Moldova, which provides for a series of priorities and measures to achieve the proposed objective and to analyze the agrifood sector.

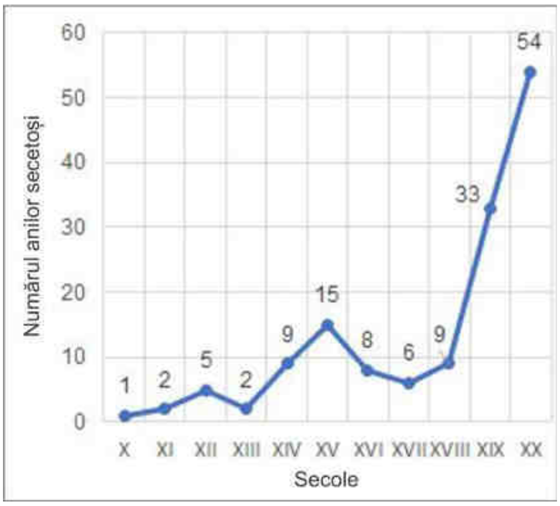

Fig. 1. Number of dry years during the second millennium.

Solar energy potential

The amount of solar energy received by the Earth’s surface depends on a number of factors, primarily the duration of the Sun’s sunshine and the Sun’s height above the horizon. In the Republic of Moldova, the possible (theoretical) sunshine duration is 4445-4452 h/year. Actual time is 47-52% or 2100-2300 hours of the possible one [2]. The variation of about 5% is due to the difference in latitude between the northern and southern areas, which is about 2,50. A considerable part of the sunshine hours are in the months from April to September and is about

1500 - 1650 hours. The global radiation (sum of the direct and diffuse radiation) on a horizontal surface, under medium nebulous conditions, is 1280 kWh/m^2/year in the northern area and 1370 kWh/m^2/year in the southern area (*Figure 2*). More than 75% of this radiation lasts from April to September. Global radiation in the northern area is 3,5% lower than in the central area, and in the southern area – 2,6% higher.
The irradiation values present the results of the systematic measurements carried out by the State *Hydro meteorological Service* between 1954 and 1980, in conditions of clear sky and medium nebulosity, at 6^{30}, 9^{30}, 12^{30}, 15^{30} and 18^{30}. With this data irradiation (exposure) can be defined over a concrete duration in kWh/m^2 or MJ/m^2, taking the irradiation integral over that time interval.

Fig. 2. Solar energy potential map of the Republic of Moldova.

3. Elaboration of microspray irrigation system integrated with photovoltaic panels [3,4]

To reduce costs, it was decided not to use battery packs. In this case irrigation will occur if the values of the solar radiation or the wind speed exceeds the minimum values necessary for the operation of the pump.
The functional scheme is shown in Figure 3, and the technological scheme of the autonomous irrigation system are shown in Figure 4.

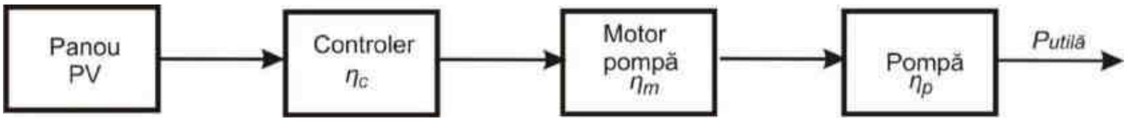

Fig. 3. The functional scheme of the irrigation system.

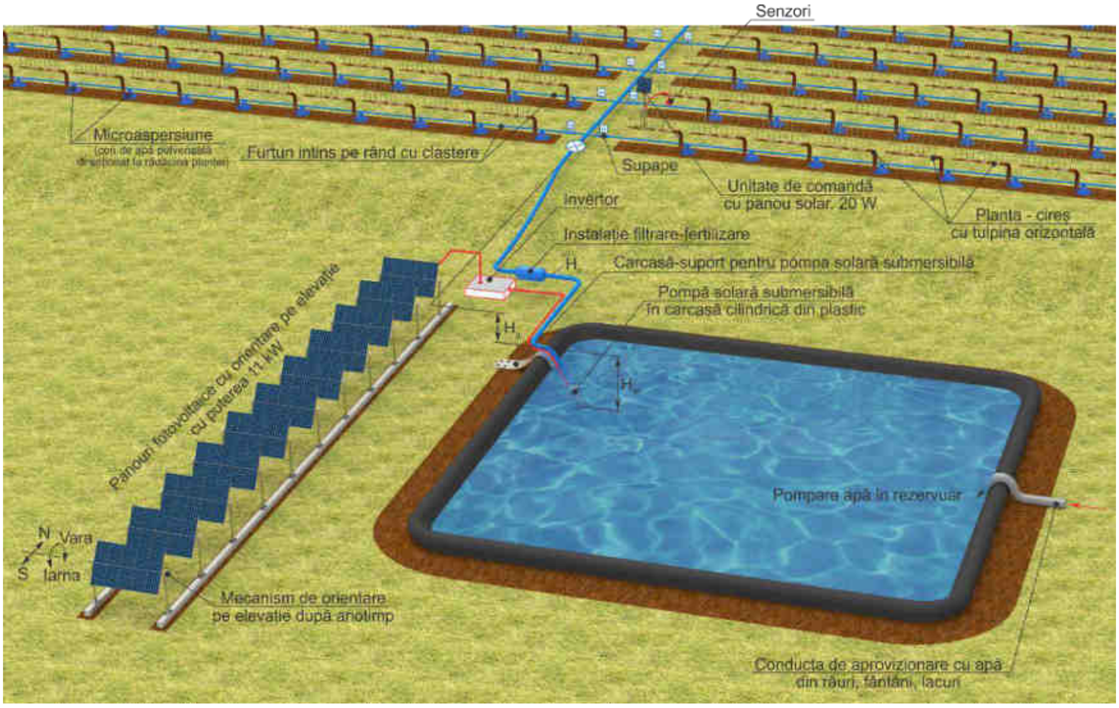

Fig. 4. The technological scheme of the autonomous irrigation system.

3.1. Microspray irrigation system integrated with photovoltaic installations (PV) developed for agricultural enterprise *„TriDenal”*, Criuleni

- Irrigated surface, S=7,0 ha or 2 land plots of 3,5 ha of cherry orchard comprising 22 rows (figure 5). Is located 10 km away from the Dniester River, with coordinates:
  - wide. 47°12'04,00 N";
  - longitude 29°07'36,33" E.

The land has no obvious inclinations, the altitude of the 4 corners: 97, 99, 105,103 m. A water tank is built for the storage of 9000 m^3 of water, being pumped from the Nistru River.

- Irrigation technology - Micro Sprinkler. Micro Sprinkler Type - SuperNet UD. Pressure and water flow of a Sprinkler: P_{SPmax} = 4,0 Bar and Q_{SPmax} = 0,058 m^3/h, P_{SPmin} = 1,5 Bar and Q_{SPmin} = 0,03 m^3/h.
- Period of irrigation season: April – September or T=183 days.
- The number of operating pump hours in the event that the number of operating hours per day is equal to N_{day} = 7 h, N_h= N_{day}.

T= 7·183=1281 h.

- Irrigation norm, N_I = 5000 m^3/ha.
- Watering rate, N_U = 300 m^3/ha.
- Length of row in a sector, A= 170 m.
- Watering rates per season, NR_{UD} = N_I / N_U = 5000/300= 16,7, accepting N_U =16.
- Width of sector, B=99 m.
- Row width, L_R = 4,5 m.

Fig. 5. Sectors with cherry orchard.

Necessary water volume

$V_{nec.}$=$S·N_I$ = 7·5000 = 35000 m^3.

Pump sizing

To ensure the necessary volume of pumped water we select a surface solar pump PS7k2 CS-F20-5, nominal flow, Q_n=27m^3, H=40m [10]:

- Minimal pressure – P_{Pmax} = 4,0 Bar;
- Maximum pressure – P_{Pmax} = 7,0 Bar;
- Maximum flow rate - Q_{Pmax} = 12 m^3/h;

Pump Controller Type: PS4000:

- Maximum power – P_{Cmax} = 4,0 kW; Maximum input voltage – U_{Cmax} = 375 V c.c.;
- Optimum input voltage - $U_{Copt.}$ > 238 V c.c.; Maximum motor current – I_{Mmot} = 15 A;
- Maximum efficiency – η_{Cmax} = 98 %;

Motor type ECDRIVE 4000 CS-F, brushless, d.c.:

- Rated power – P_{Mnom} = 3,5 kW; Maximum efficiency – η_{Mmax} = 92 %;
- Rotation speed – n=900=3300 tur/min.

Determining the solar radiation for your location

- Appropriate data should be used to determine the amount of solar radiation available at the site. These data are available in the archive of the State Hydro Meteorological Service (SHMS) or in [5]. With them, the global solar radiation, G_β in W/m^2, on tilted surface or PV pane can be calculated I. The used formula is the following [6]:

$$G_\beta = R_b B + \frac{1}{2}(1 + Cos\beta)D + \frac{1}{2}(1 - Cos\beta)\rho G \,, \tag{1}$$

- where R_β is the ratio of total radiation on the tilted surface at angle β to that on the horizontal surface; B – direct or beam radiation; D - diffuse radiation; G – global radiation on the horizontal surface; ρ – reflectance coefficient. The B, D and G values can be found in [5]. All data are for a horizontal surface as a possessing result of SHMS measurements for the period of 1954-1980.

- In [6] are presented numerical values of the ratio R_b for the difference of latitude ϕ and inclination angle β (every 5^0) and the latitude of the place (every 5^0). Based on these data the values of the report R_b for Moldova were interpolated. The territory was divided into three areas - south (latitude 46^0), center - (47^0 latitude) and north - (latitude 48^0). Linear interpolation was used, the difference ϕ-β ranges from 0 to ± 20^0 with a step of 5^0. Numerical data of R_b can be found in [7].
- Using (1) we can calculate the daily global solar radiation, G_β for a different month for each 3 hour: 6^{30}, 9^{30}, 12^{30}, 15^{30} and 18^{30}. In this case we should use data about *B, D* and *G* published in [6]. EU countries have developed a free online software for calculation of diurnal and monthly solar radiation. The diurnal radiation is calculated every 15 minutes. For the calculation a new database Climate-SAF PVGIS [8] is used. These data are based on satellite images performed by CM-SAF (Geostationary Meteosat and Polar EUMetSat). The database represents a total of 12 years of data. From the first generation of Meteosat satellites, known as MFG, there are data from 1998 to 2005 and from the second-generation Meteosat satellites, known as MSG, there are data from June 2006 to May 2010. The coverage extends from 0° N (equator) to 58° N and from 15° W to 35° E. These data are more representative of the last climate years, and show often higher irradiations than the classic PVGIS data.
- Using this software [8], we calculated the diurnal radiation at Chisinau meteorological station on horizontal surface and compared them with the ones from the 1954-1980 period.
- We note the following:
  - The average error from April to September in the period 9^{30} - 15^{30} does not exceed + 3,0%.
  - Early in the morning (6^{30}) and evening (18^{30}) the errors are high and may exceed 100 %. But this does not affect the calculations because at the respective hours the PV pump does not work.
  - The calculated diurnal radiation values based on the new Climate-SAF PVGIS database are higher compared to those from 1954 -1980. In our view, these are the consequences of global climate change.
- We used the new Climate-SAF PVGIS database and free online software for calculation of diurnal radiation [8].

3.2. Design and manufacturing of the photovoltaic installation with orientation to the sun in the axis of evolution [9]

Figure 6 illustrates the June setting: the selected point coordinate Latitude: *47,200768*, Longitude: *29,128662*, the optimal tilted angle is *130*, the panel is facing the south – Orientation: 00. The results are displayed every 15 minutes. In the same way, we did for all 6 months of the irrigation period. Diurnal radiation over each hour is shown in fig. 7.
According to the calculations, an 11 kW PV power plant is required for the supply with electricity of the micro-sprinkler irrigation system (*see p. 3.1*) necessary for the *TriDenal* Enterprise, Criuleni, with a 7,0 ha irrigated area which requires an 11 kW PV plant.

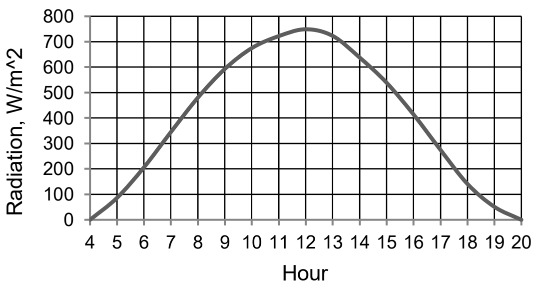

Fig. 7. Hourly radiation, September month.

For the solar radiation exposed on the target agricultural land, also taking into account the uncertainty meteorological factors and the deviation from the perpendicular direction of the surfaces of the PV panels towards solar rays, etc., the projected power P = 11 kW can be converted by 250W 44 panels each.
In the calculation of the photovoltaic installation presented in *Figures 8, 9* it was taken into consideration the proximal perpendicularity of the photovoltaic panels to the solar rays in the seasons when the Sun has relatively different *„heights”* in relation to the Earth (at latitude 47°).
Proximal perpendicularity of the surface of the photovoltaic panels at the elevation is ensured by the PV mounting panel structures (*figure 9*), which include: a body with the ability of rotating around its axis, installed at the end in sleeves 2 and 3 with the game ≈ 1 mm; perpendicular to the body 1, five wings 4 made of 1 mm thickness sheet fixed by welding, stiffened by the applied form

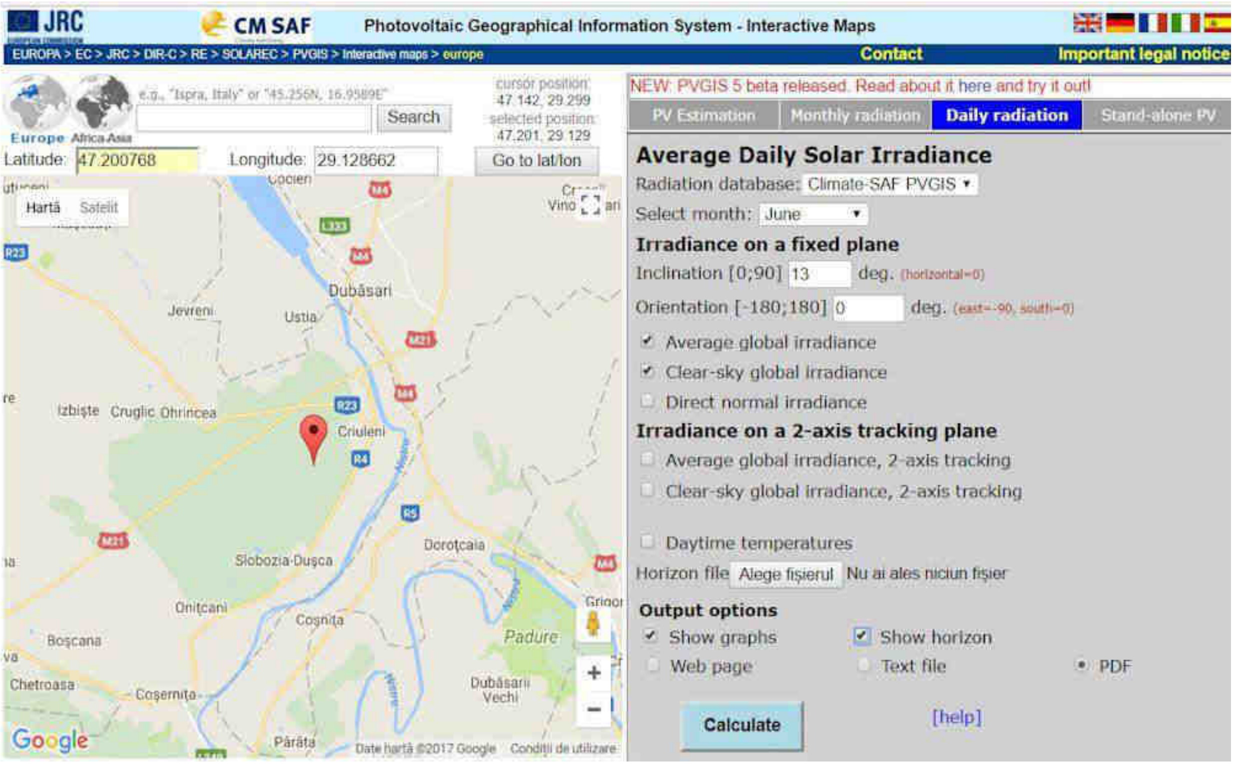

Fig. 6. PVGIS setting for June month.

in which the mounting holes of the PV panels 5 are made. From the constructive considerations, four photovoltaic panels 5 are installed on the wings 4 of each body 1. The housing is provided at one end with a perforated welded disc 8 on which the PV panels 5 are installed. The housing is mounted on the roof of the house or the ground by means of two legs 6 and 7, being fixed thereto by the nuts 10. The half-disc 8 with a series of holes is installed on one of the ends of the housing 1. Depending on the season and the need for the most perpendicular exposure of the PV surfaces to the sun's rays, the rotation of the body 1 with the photovoltaic panels 5 is done in such a way as to ensure the most efficient exposure of the panels to the sun. Subsequently, the axially aligned holes of the half-disc 8 are rigidly assembled with the fastening bolt 9 by the leg 6.

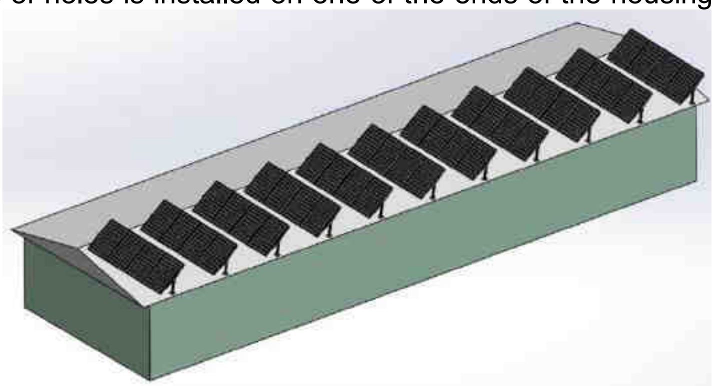

Fig. 8. *Photovoltaic panels installation scheme on the roof.*

Photovoltaic panels have been installed on the roof. This would allow the optimization of photovoltaic panel's orientation to the sun only in azimuthal plane. For this it was elaborated the steel structure design of photovoltaic panels installed on the roof (fig.7).

Below we present brief technical characteristic of selected standardized components.

PV module (fig. 10):

1. Module type AFP-255 ALTIUS, Romania;
2. Rated power - P_{PVmax} = 255 W;
3. Cell efficiency, η_C = 17,9-18,1 %;
4. Module efficiency, η_M = 15,7 - 16,0 %;
5. Open circuit voltage, U_0 = 37,1 V;

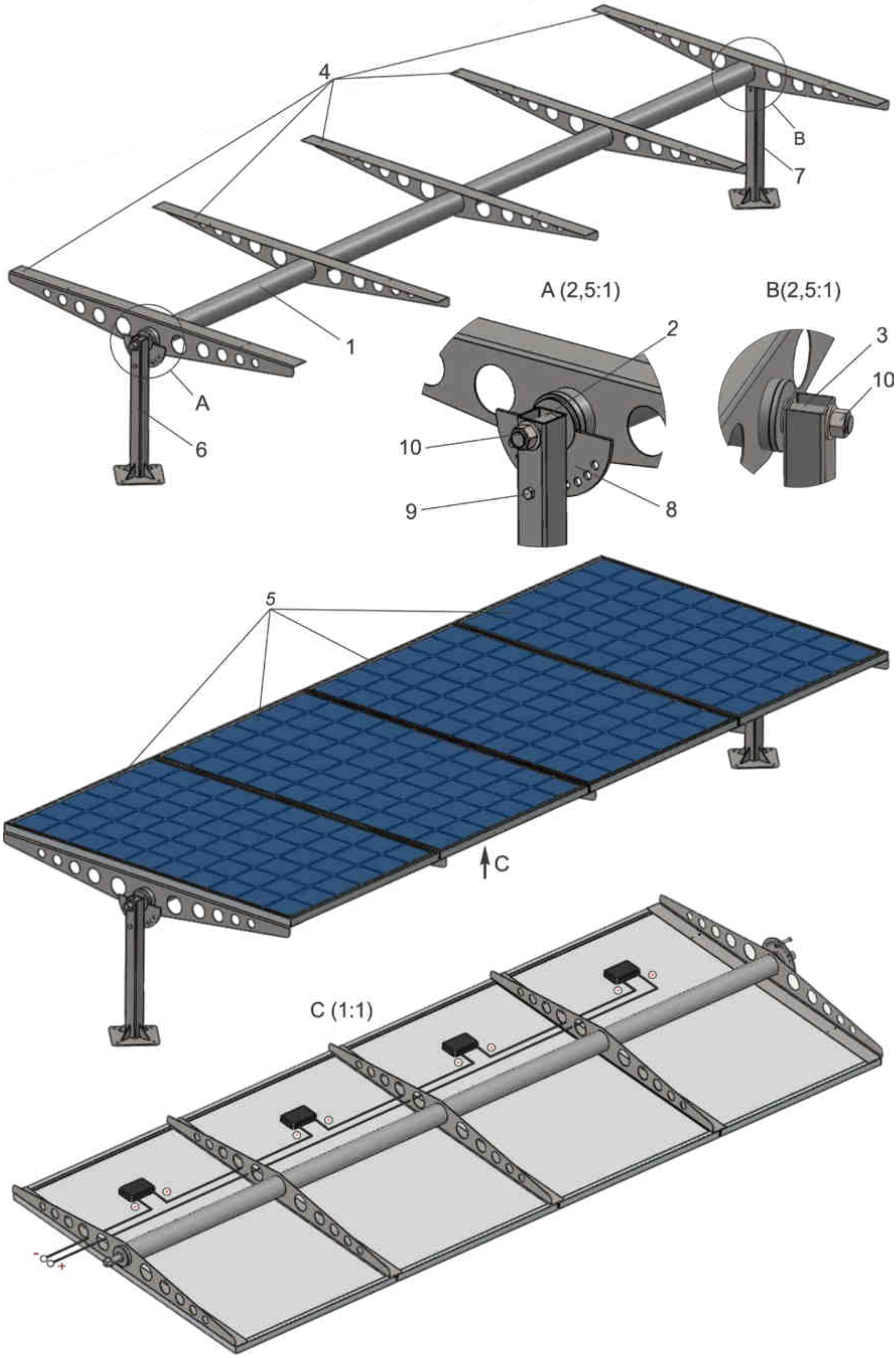

Fig. 9. Design of the PV photovoltaic system with rotary spindle discrete on seasons with 8 angular positions.

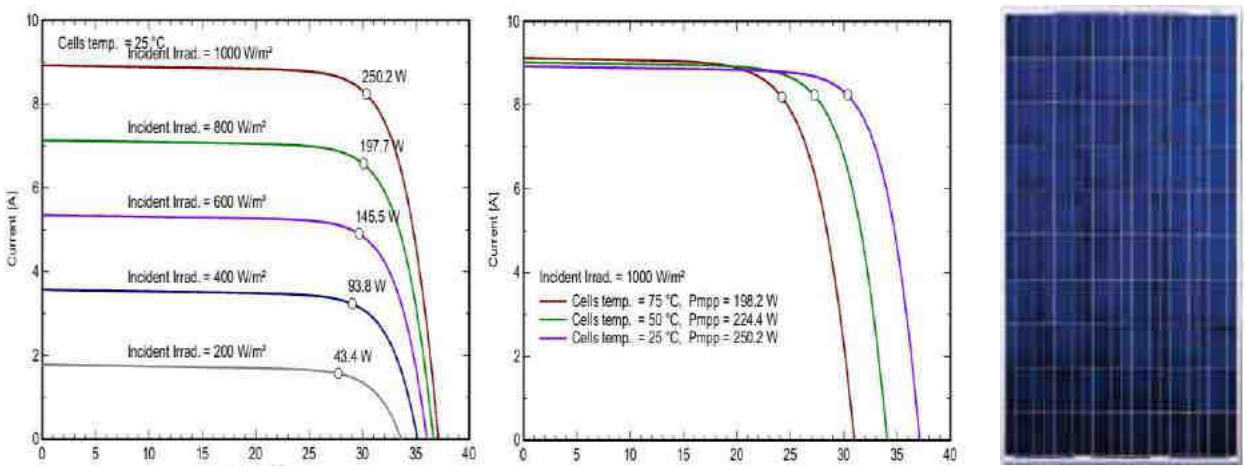

Fig. 10. PV module technical data.

6. Short circuit current, I_{sc} = 9,0 A;
7. Maximum power point voltage, U_M = 30,3 V;
8. Maximum power point, I_M = 8,43 A.
9. External dimensions 1640x992x40 mm.
10. Weigh 19 kg.

The total number of modules - 44, maximal photovoltaic panel power is equal to 11 kW. The PV module technical data is shown in Figure 10.

Solar Surface Pump System [10]

System Overview:

Head max. 40 m;

Flow rate max. 33 m³/h.

Controller PS7k2

- Control inputs for dry running protection, remote control etc.;
- Protected against overload and overtemperature;
- Integrated MPPT (Maximum Power Point Tracking).

Power - max. 11,0 kW
Input voltage - max. 850 V
Optimum - V_{mp} > 575 V
Motor current - max. 13 A
Efficiency - max. 98 %
Ambient temp. - 30...50 °C
Enclosure class - IP54

Motor AC DRIVE CS-F 5.5kW

- Highly efficient 3-phase AC motor;
- Frequency: 25...50 Hz;

Motor speed - 1.400...2.850 rpm;
Power factor - 0,84;
Insulation class – F;
Enclosure class - IPX4.

Pump End PE CS-F20-5 (figure 11)

- Premium materials
- Optional: dry running protection
- Centrifugal pump

Fig. 11. Pump system PS7 k2 CS-F20-5.

Standards: 2006/42/EC, 2004/108/EC, 2006/95/EC, IEC/EN 61702:1995, IEC/EN 62253 Ed.1.
Figure 12 show the photovoltaic installation oriented to elevation integrated in the microspray

irrigation system, designed for the „*TriDenal”* Agricultural Enterprise, Criuleni (PV panels installed on the roof).

Fig. 12. Components of the photovoltaic plant with installed power P = 11 kW: *(a) - Mounting of PV panels in housings with ability of rotating around the central axis; (b) – the pumping station hall; (c) – the central water supply pipeline of the irrigation system.*

4. Conclusion

- The feeding of irrigation system has been optimized with renewable electricity. The most suitable for irrigation process is solar energy, the variation of which during the day coincides with the need for water consumption;
- It was designed, realized and implemented the microspray irrigation system integrated with photovoltaic installations (PV) developed for agricultural enterprise „*TriDenal”*, Criuleni.

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TECHNOLOGICAL STAND FOR THE DETERMINATION OF THE DIE'S GEOMETRY USED IN BIOMASS PELLET MAKING EQUIPMENT

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Abstract: *The technological stand for determination of the mould's geometry, which are utilized in biomass pellet making equipment's, was developed by Hydraulics and Pneumatics Research Institute-INOE2000, under Contract 264 CI/2018 and now is being included in the Renewable Energy Laboratory. The objective of the project is the development of technical means of research for the optimization of the technical and functional parameters of the biomass pellet production equipment. The stand allows determination of the biomass extrusion forces (wood sawdust and straw resulting as a by-product in strobe technological processes) for different shapes, diameters and depths of the extrusion holes, optimal peripheral speed of the die/roller presses, as well as the physical-mechanical characteristics of the pellets obtained.*

Keywords: *Biomass pelletizing equipment, pellet extruding die*

1. Introduction

The anthropic impact of human activities on environmental factors was manifested in the early 17th century, with the beginning of the industrial age. In the last decades, monitoring of environmental factors has become a concern with increasing interest. It has been found that the anthropic impact modifies the natural environments of fauna and flora, even at great distances from pollution sources, and climatic changes have gained an accelerated character and a stronger impact. Mankind, in order to meet its energy needs, mainly uses fossil fuels. They are inexpensive from the point of view of exploitation, transport and processing technologies because they have reached economic maturity. Disadvantages of using fossil fuels are numerous, with devastating effects on ecosystems and even humans.

Biomass is considered a neutral CO_2 source, because it is part of the natural carbon cycle even if different combustion processes are applied.

The disadvantages of biomass energy resources are: the wide diversity of biomass types, which have different characteristics, low density, high moisture content, all of which contribute to chemical degradation during storage, thus limiting large-scale commercial application.

Applying compression densities, extrusions in properly dimensioned dies at optimum temperatures, one can achieve densities of up to 5 times greater than the initial ones, improving transport and increasing the calorific value.

2. General information about pelletizing processes and pellets

The term **"pellet"** usually designates a small piece of cylindrical material obtained by compressing the original material.

Pelletizing is the industrial process for producing pellets, usually using an extrusion press that presses the raw material by means of rollers through the holes of certain dimensions of an extrusion die.

Biomass pellets used for combustion in heating installations are usually made of wood or straw and have different characteristics depending on the material and its quality. In international regulations, pellets are divided into quality classes with different usage recommendations, depending on their size, ash content and various chemical components. Among the advantages of using pellets, we can point out that they can be used in automatic feeding systems and that, due to compression they offer a large amount of energy at a reduced volume.

Wood pellets are generally superior to those of straw and are also recommended for use in domestic burners (stoves, boilers, etc.), especially when the ash content is very low (below 0.5%). Usual dimensions are: diameters of 6 to 8 mm and lengths less than 40 mm.

Straw pellets, because of the high ash content and corrosive chemical elements, are recommended for use in industrial plants or specially designed for these pellets. They are similar to wood, from an energy point of view. Pellets can be made from most of wood and straw species without the addition of binders or additives, if suitable equipment's are used.

Pellets are currently a good option for producing thermal energy, which meets the requirements of using "green", "clean" and "renewable" energy, making it an economical and comfortable alternative to fossil fuels. Pellets are cheaper than fossil fuels and are from a renewable resource. Small emissions of carbon dioxide mean that it does not affect the environment, as proof for this is their non-inclusion among the pollutants by the Kyoto Protocol.

The history of pellets begins in the 1970s, in the United States, where their first production plant was built. Over time, due to oil market problems and new pollution requirements, this product along with combustion technologies have taken a special momentum, which has materialized in the rapid development in the market. In recent years, there has been a growing demand for the supply of pellet-based equipment, which means an increase in pellet requirement.

Pellets are produced from wood, sawdust and other wood waste, straw, which are 100% natural materials, chopped and pressed, obtained by pressing without the use of binders. The use of pellets for fuel is in accordance with DIN 51731 and the M 713 ecological standards. Pellets have a high calorific value and high density. Transport, storage and use costs are lower, compared to conventional fuels. 1,8-2Kg of pellets have a calorific value equal to 1 m^3 of gas.

Fuel	U. M.	Fuel price (lei/u.m.)	Calorific power (KWh / u.m.)	Efficiency	Price (lei/kWh)
Natural gas	KWh	0.169	1	90	0.132
Electrical energy	KWh	0.580	1	99	0.535
Pellet	kg	0.790	5.1	91	0.153
Wood 20% moisture	kg	0.344	3.6	70	0.097

Good quality pellets have smooth and uniform surface, are the same size and do not crumble. In order to control the quality of the pellets, one method is to put them in water: good quality pellets remain on the surface of the water, poor quality pellets sink into the water.

Advantages of using wood pellets in thermal power plants:

- They are a clean energy source
- Provides high autonomy of the boiler; Depending on the volume of the pellet storage, it can be reached a period of refuelling between 2-3 days up to 30-60 days
- Pellet plant automation also increases autonomy and efficiency, by modifying power according to thermal demand
- Pellets are part of the category of fuels considered as CO_2 neutral
- Smoke emission resulting from combustion is very low
- Re resulting ash is in small quantities (in the case of the use of quality pellets) and can be used as a natural fertilizer
- The operating costs reported at the same power obtained from an condensing gas boiler are approximately identical
- Burning efficiency is higher compared to wood use as fuel
- The pellets storage space is relatively low: 1.2-1.5 m^3
- Pellets are more efficient than firewood because they are higher calorific value; also represents a cheaper energy than that obtained from traditional fossil fuels (coal or oil)

- In case of using poor quality of high moisture pellets, more ash and slag is produced, this decreases the boiler efficiency require more frequent cleaning and maintenance

3. Die for pellet presses

The most important piece of the pellets press is the die. According to the size of the die, the diameter and the depth of the holes, the produced pellets have different dimensions and hardness's. The dies can be used for the production of straw pellets, sawdust, hay, mixed fodder, garbage, beep pulp, peat and other materials.
There are two variants of pellet presses: ring die and flat die. Ring presses with ring die [1] are made in two constructive variants.
In the first embodiment, the die rotates and the pressing rollers are entrained by the friction forces that develop upon contact between them and the extrusion material.
The second method assumes that the ring die is fixed, and the presser rolls are rotating driven by a by a common shaft.
Mainly, the first option is used. The ring-shaped movable die rotates, while the pressing rollers compress the radial material radially through the die holes as in fig. 1.

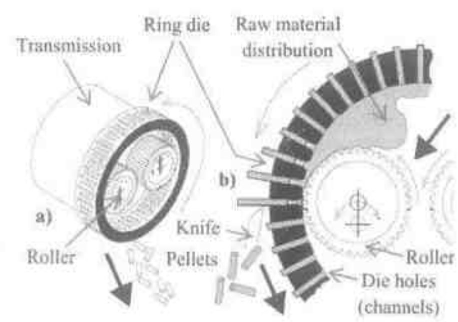

Fig. 1. Rotary ring die chamber with fixed press rollers

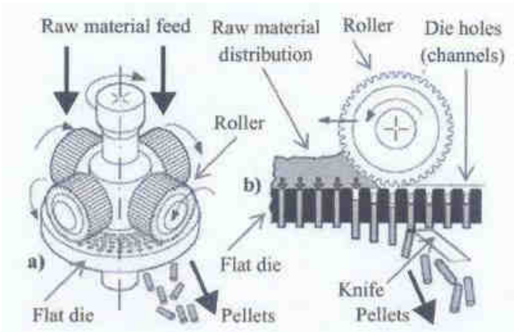

Fig. 2. Flat and fixed die chember with rotating press rollers

Also, in the case of the pellet press with flat die (fig.2) there are two constructive-functional types.
The first variant consists of a stationary die on which the pressing rollers rotate, and the second variant with the stationary press rollers and the rotating die. In this type of pellet press, the raw material is fed upward, falls on the die and on the rollers, thus pressing the raw material by means of the pressing rollers through the die holes.
For the biomass palletisation process, the most important components of the press are the die, the press rolls and the pellet cutting knife. During the pelletizing process, the raw material enters the press chamber and it is equally distributed on the die. On this, a thin layer of high density raw material is formed by rotating the press rollers or the die. The pressure rollers exert a strong pressure on the compressed biomass layer, causing it to penetrate into the die holes. By continuing this process, the biomass is extruded and cut with a knife at the desired size.
A determining characteristic for the formation of quality pellets is the ration between the hole diameter and its depth in the die (the space that biomass is forced to cover during the extrusion process). In wood pelletizing (chip or sawdust), press rations are 3:1 – 5:1.
The ring die has many radially drilled channels.
The annular die has many radially drilled channels. Depending on the selected material, different diameters and channel lengths are selected. Due to the intense friction between the die and rollers, heat is produced which slightly reduces the moisture content of the material (1-2%).
The two main advantages of the pellet ring are low wearing and low energy consumption.
The die components are made of hardened stainless steel in vacuum; the diameter of the holes is 1.8 to 14 mm and the depth of the holes from 55 to 104 mm.

Low-compacting grade feedstocks require longer holes for pressing and vice versa. The temperature of the biomass that reaches into the die holes increases as the depth of the hole increases, thus enhancing the hardening of the pellet. The pelletizing process requires a continuous supply of homogeneous raw material, sufficiently shredded, with a humidity of 8-12%. Another feature of the extrusion process is the peripheral speed of the press rollers. From the practice it has been found that a speed of about 2.5 m/s allows the production of quality pellets. The layer of high density raw material, formed between the die and the press rolls, must have a thickness of 0.5 - 1 mm.

The production process [2] The ground material is fed into the device, (fig. 3), where it is evenly distributed on the die by the dispensers. Two rollers compress the material by pressing it through the radial channels of the die. An adjustable blade then cuts the pellets at a fixed length. Hot pellets are then transported to the cooler.

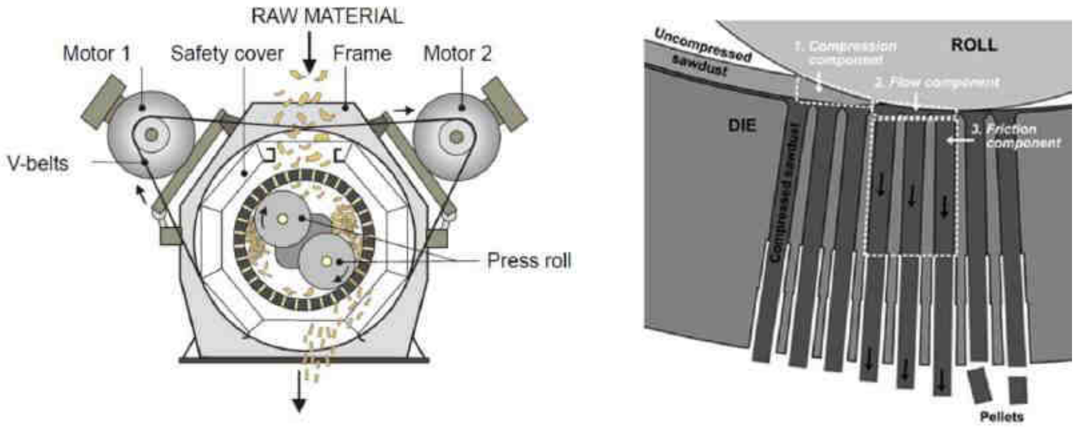

Fig. 3. The process of manufacturing pellets with rotary ring presses and fixed pressing rollers

Fig. 4 illustrates the palletisation process and a die bore. Niels, Douglas, Torben and Claus [3] presented the palletisation process in detail using the circular die. It can be seen how the biomass descends into the pelletizing chamber and is extruded through the cylindrical pressing channels. The die is a cylinder that varies in size between 150-250 mm, with an inner diameter of 800 mm and an outside diameter of 1 m. In the solution they choose, the cylindrical (right) holes have a 60 degree conicity to help the extrusion process and to prevent premature wear of the die. The length of the active part may vary between 30 and 70 mm.

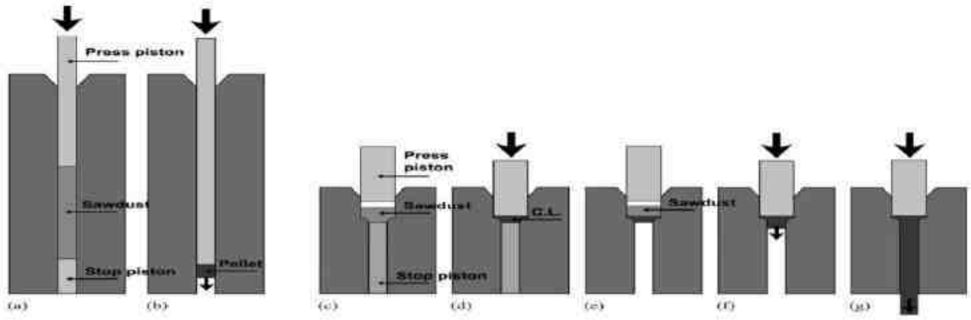

Fig. 4. Two bores and test procedures (a-b) Friction and compression analysis; (c-f) Flow analysis; (g) Continuous pelleting process

The authors present in an intuitive way the procedures for determining compression forces and friction, from die boreholes. They insist more on analysing different sources of biomass, moisture content, and temperatures in the palletisation process. The tests were carried out by introducing pistons, with a force of up to 200 kN, connected to a data acquisition system. A coil system has

been installed around the die to heat it at different temperatures, thus adjusting the bore temperature.
In Fig. 4-a-b is illustrated friction and compression. The bore diameter used is 8 mm; the saw dust was introduced with a force of 15 kN, at a compression speed of 127 mm/min and a holding time of 10 seconds.
After the force was removed, the plunger was extracted and the pellet was pushed at a speed of 127 mm/min until it was out of the canal. After 24 hours of cooling, at a temperature of 20-25 ° C, the pellet resistance was determined.
In FIG. 4 c-f were simulated and determined the flows from the bore of a commercial die, with a diameter of 8 mm and a cone at the beginning of the 2.5 mm deep pressure chamber, made at an angle of 60°. In these determinations sawdust was used. In all determinations the extrusion was done at temperatures of 60, 75, 85, 95, 105, 115, 125, 135, 145 and 160°C.
The results of the determinations led the authors to the conclusion of the need to study the die bores in order to determine the effects of the compression forces, friction and temperature on the pellet quality.

4. Stands for the determination of the technical and functional parameters of pellet presses

Four parameters are tracked on the stands designed to experiment with the active parts of the world-wide pelleting presses (Danish Technological Institute) [3], fig. 5, for each type of biomass:

- The needed force for the extrusion of the biomass into the die with single hole, respectively with multiple holes;
- The static and dynamic friction forces generated at the contact between the active piece of the press (die or roller press, depending on the construction variant) with the high density material and small thickness formed between them in the extrusion process;
- Resistance to compression of the obtained pellets;
- The density of the pellets.

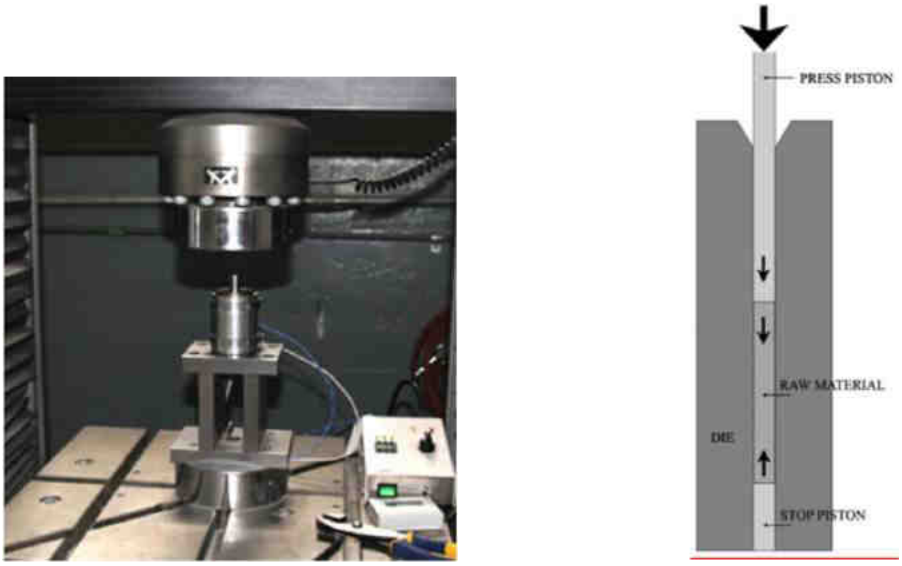

Fig. 5. Stand for determination of extrusion force (single hole die)

The diagram of fig. 6 shows the variation of the parameters: the compressive force and the density of the extruded material along the extrusion bore.

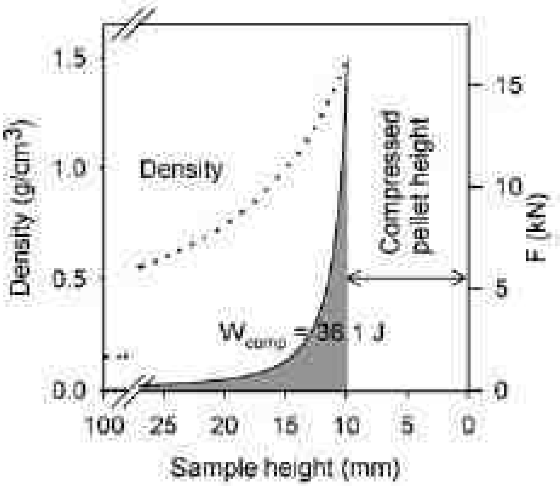

Fig. 6. Variation of the compression force and pellet density along the extrusion bore

The quality of the pellets is appreciated by their behavior under the action of a compression force, fig. 7.

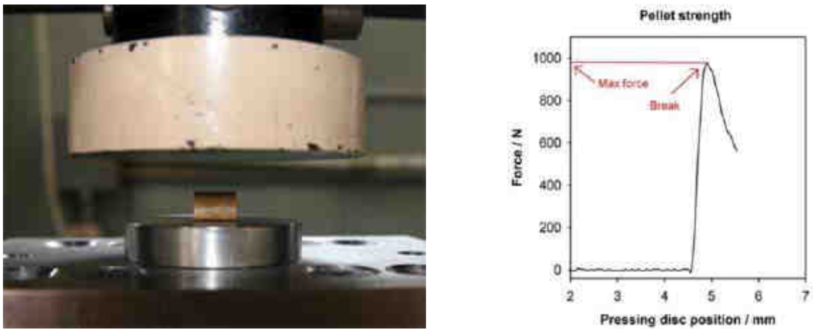

Fig. 7. Determination of pellet quality by compression

The pellet is placed perpendicular to its axis and crushed, resulting in the force-distance curve.
The density of pellets is determined by measurements (length, diameter and weight) and the application of the known calculation formula.
After the analysis of the technical-functional parameters performed on the single press (single hole mold) and the multi-hole pellet press (used in the pelleting process) there is a good correlation shown in fig. 8.

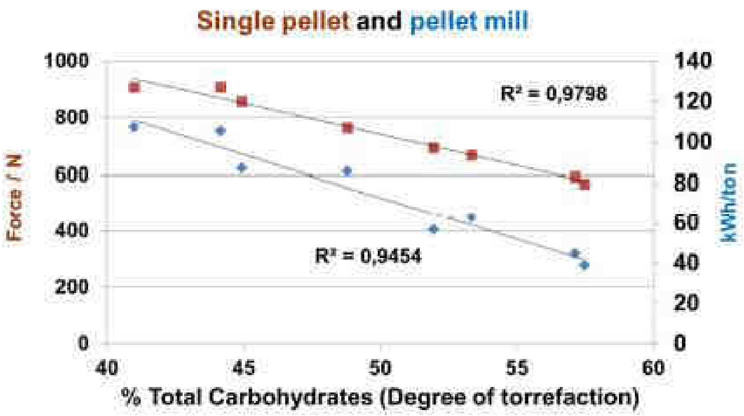

Fig. 8. The correlation between the technical and functional parameters of a single and multiple presses

The stand that was built withing the project, Fig. 9, consists of a rigid resistance frame, a traverse that can be moved on two columns and fixed in the desired working position, a plate solidarized with the hydraulic cylinder on which the single extrusion die is mounted.

Fig. 9. Technological stand for the determination of the die geometry used in biomass pellet making equipment

On the traverse is mounted a force transducer and the pressing piston of the extruded material in the die.
The hole in the die and the pressing piston are perfectly coaxial in order to avoid the occurrence of radial forces, during the extrusion test.
The pressing of the material is done by vertically moving the plate with the die towords the pressing piston.
To highlight the effect of the extrusion temperature on the compression force, the die may be heated with electrical resistors.
The hydraulic power supply of the actuating cylinder is done by an own group.
The technical parameters of the extrusion process (compressive force, friction forces) are determined on a set of single hole molds with different geometric parameters of hole diameter, its shape (circular or truncated press chamber), depth of the hole , mold temperature.
The data subject to experimentation is acquired using a data acquisition system.

5. Conclusions

1. The objective of the project is the development of technical means of research for the optimization of the technical-functional parameters of the biomass pellet production equipment in order to increase the energetic efficiency of the palletisation process;
2. On the stands dedicated to this purpose, made at world level, the following parameters are determined:
- The need for the extrusion of the biomass into the die with the single hole, respectively with multiple holes;
- The static and dynamic friction forces generated at the contact between the active piece of the press (die or roller press, depending on the construction variant) with the high-density material and the small thickness formed between them in the extrusion process;
- Resistance to compression of the pellets obtained;
- Density of pellets;
-Influence of torrefaction in the quality of pellets [4].

3. The stand made within the project meets the technical and functional requirements imposed on the stands of the components of the pelletizing presses.

Acknowledgments

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INNOVATIVE SUPPLY SYSTEM DESIGNED FOR GRAPE SEED SEPARATION EQUIPMENTS FROM WINEMAKING BY-PRODUCTS

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Abstract: *Grape seed separation equipment from winemaking has gained great importance at this time as it can be successfully integrated into the technologies of superior harvesting, technology that according to the new intelligence specializations is in the Smart Industry domain, respectively in the 4.0 Industry and Bioeconomy subdomain. Due to these research directions, and the fact that the winemaking industry occupies an important place in the Romanian and European economy, the development of innovative technologies in this field is opportune and necessary, especially if we take into account the new scientific discoveries in the field of food and phytopharmaceutical breach.*

Keywords*: Innovative supply system, grape seed separation, marc processing, PAM's.*

1. Introduction

In favour of the circular economy approach is mentioned the next arguments: to achieve a sustainable world does not involve to change product quality and consumers purchasing power; doesn't require loss of revenues or extra costs for manufacturers and other economic agents. But the circular economy focuses on areas such as design thinking, systems thinking, product life extension, and recycling, in order to achieve models that are economically and environmentally sustainable, idea supported by most researchers and experts in the field of economy.
Based on the circular economy principles, the study of feedback-rich (non-linear) systems are similar to particularly living systems [1] and its practical applications to economic systems evolved incorporating different features and contributions from a variety of concepts sharing the idea of closed loops. Some of the relevant theoretical influences are cradle to cradle, laws of ecology, looped and performance economy, regenerative design, industrial ecology, biomimicry and blue economy. [2]
The marc capitalization technology used by the wine producers are mainly used to obtain bio-fuels but, due to latest research in Phyto-pharmaceutic field revealed that the fresh mark can be used also as an important source of oxidants and valuable compounds for the human health, and in many other related fields (animal and fish feeding, soil bio-nutrients, etc.). Taking in to consideration that wine industry is present on all continents, the technical and environmental potential and impact has a great impact, for this reason the regenerative systems "is a must", because the resource input are the wine waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops.
The means to achieve circular economy, respectively "long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, recycling, and upcycling" [2], is in contrast to linear economy which has a production model like 'take, make, dispose'. [1].
In 2017 in order to provide guidance to organizations that implement circular economy strategies, the British Standards Institution (BSI) developed and launched the first circular economy standard "BS 8001:2017 Framework for implementing the principles of the circular economy in organizations. Guide". BS 8001:2017 standard, intend to align the far-reaching ambitions of the CE with established business routines at the organizational level. It contains a comprehensive list of CE terms and definitions, describes the core CE principles, and presents a flexible management framework for implementing CE strategies in organizations. Circular economy monitoring and assessment is given, but it missing the consensus yet on a set of central circular economy performance indicators applicable to organizations and individual products.

This fact is generated maybe, because there are not yet implemented this system and the environmental polices strong enough to stimulate and reward the participants, or because the sanctions and fines have no impact on the phenomenon generators enough to stop and mitigate the contaminated sites.
Wine trade between the EU and third countries excels, with exports reaching the level of 6,7 billion euro, in 2010, almost a quarter of European exporters of agricultural products. Economically speaking, European production plays a strategic role, having in to consideration the fact that in 2016, the wine market turnover reached 377 million euro and it is estimated that in 2017 to be 385 million euro, reaching the highest level in recent years. The Romanian market place in the big wine producers in the world is placed on 13-th position, next to Portugal (6,6 mhl), Hungary (2,9 mhl) and Austria (2,4 mhl), and is among the few European countries that have registered an increase compared to 2016. According to KeysFin analyses, after more than 10 years of changes and reorganization, wine sector business has come close to maturity. [3]
If we apply the concept of circular economy in Romania, the innovative technology to capitalize marc is perfect integrable and can create a valuable chain reaction, Fig. 1, and in the main beneficiary is the human being for the food product (wine, grape seed flour and oil) and phytopharmaceutical. [4]

Fig. 1. An example of wine technological process combined with marc capitalization technology respecting the principle of circular economy [4]

2. Innovative technology to capitalize grape marc

Due to research and development activities developed within the project 'Research regarding the developing of innovative technology to recovery of secondary products from viticulture' financed in 2018 the INMA has develop several technologies to recover the vineyard by-products, namely the marc fraction, taking in to consideration the technological aspect of agroecosystem sustainability and ecological aspects of waste recycling. [4, 5]

Usually, the wine technologic yield is an important indicator that represents the ratio between the total grapes mass and must quantity, which usually is influence by grape pomace mechanical properties, from this point on, the by-product capitalization technology must be deployed, in order to achieve a good separation and maximize profits. The values of this indicator it was evaluated at 50 % (wine presses) and 90 % (continuous presses), in some technical papers this indicator variants between 75 ÷ 80 % yield if it is considerate the type and position of the pressing actuation system, the lower value is for vertical hydraulic systems and the upper value for horizontal mechanical or pneumatic presses. [6]

The technology presented in Fig. 2, incorporates a marc complex processing process that can be easily adapted in accordance of the marc quality (marc type: suit or fermented marc). For this reason, the technologic flow incorporates a succession of machines and equipment's dedicated to separate, wash, dry and select the processed material.

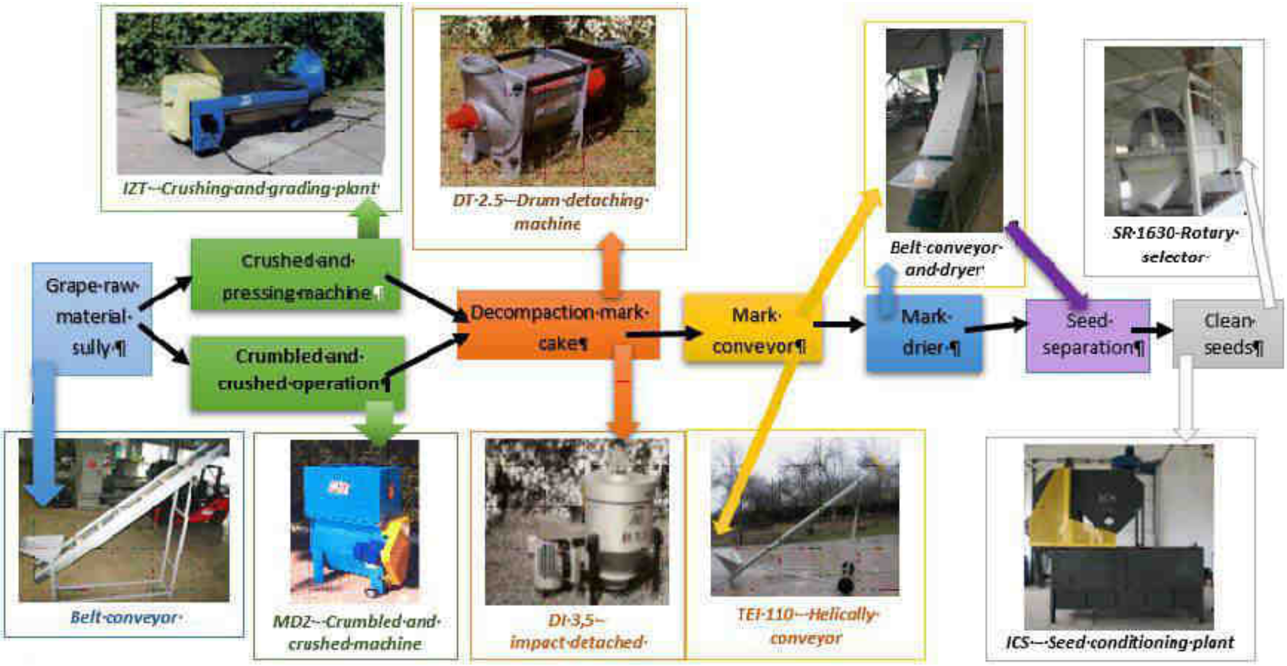

Fig. 2. INMA grape marc capitalization technology [5]

In here presented technological flow are integrated two decompaction equipment's: the DI 3.5 - impact detacher (model with vertical detaching active element positioned parallel with the power source) and DT 2.5 - marc detacher (model with horizontal detaching element positioned in line with the power source). The transportation operation can be successfully used systems that cannot be gripped, allowing the grape pulp and juice to be entirely collected and transported without leakage, from this technologic point of view it can fit the belt conveyor (with or without scraper) and horizontal or oblique spiral conveyors.

The modern transportation systems are fitted with hot/cold air ventilation systems that can provide the proper operating mode, but also to dry the marc in accordance with a certain humidity regime and in this way, the technologic line gauge is diminished. [7]

Depending by the wine technology and the by-product type, respectively sweet (fresh and unfermented) or fermented (resulting in fermentation of the bush). In the case of sweet marc, the diffusion juice must be immediately processed. For obtaining quality grape seed oil and the following procedure is recommended to fulfil: I- seed drying to a maximum temperature of 110 [^{0}C]; II – to reach the conservation humidity of 10 ÷ 12 %; III - assuring sterile conservations conditions to inhibit the growth of lactic bacteria and molds.

Here in presented technologies are made in a logical order to ensure the development of a technological grape seed separation from peels, in accordance with specific processes of secondary material, in order to obtain the finished products grape seeds, peels and cod, which can be later capitalized in order to obtain new products.

3 Innovative supply system designed for grape seed separation equipments

Grape marc capitalization technology can be optimized and shorten if are implemented to innovative solutions on top of SR1630 rotary selector or ICS seed conditioning plant, respective an adjustable capacity hopper powered with PAM's [8] and a separation system of frape seeds from marc [9]. These technical solutions can be implemented also in the mobile or modulated technologies that can be developed nowadays, trends that nowadays are more often encountered, due the fact of equipment interchangeability and technologies adaptation to the processor needs.

3.1. The adjustable capacity hopper powered with PAM's

In practical applications, there are known different companies that manufacture seed/cereal separation and calibration plants with fixed capacity feeding hoppers such as: ROMILL and Eurobagging from the Czech Republic, Murska from Slovenia, Martiney and Staneck from Argentina, etc. Some of them can be also trailed plants and are also equipped with fixed capacity feed hoppers, designed to provide raw material requirements for maximum plant operating capacity but also to be in line with transport norms on public roads.

The drawbacks of these fixed capacity feeding hoppers consist of:

- large gauge and do not fall under the public transport regulations;
- difficult to adapted and mounted on high and low-capacity aggregates;
- decreasing the plant working autonomy if it is adjusted to work at maximum capacity - increasing the hopper feeding time especially when are used front loaders;
- increasing fuel consumption when the hopper is powered by front loaders;
- interruption of the plant continuous workflow especially in the maximum capacity case- respectively, when the processor wants to make the technological process more efficient, or when the plant works in hard field and weather conditions.

The technical problem solved by the technical solution presented in Fig.3 and 4, consists in providing an adjustable capacity hopper provided with fluid artificial muscles, known in speciality literature as PAM's, which can be easy adapted and used in all types of plants (trailed, steady or modular) configurated to process seeds or cereals and also provide a continuous flow in maximum working capacity, so to comply with the legal framework for road transport on public roads and to meet the requirements of grain producers and processors in terms of yield and working conditions of the flattening process.

According to the invention, the adjustable storage hopper provided with artificial fluid muscle, consists of the protective casing *1* made of composite material, which is mounted on the frame not shown in the Fig.3 and 4.

The mobile hopper *2* is provided with a sieve *16* that has a number running slides *17,* on which the rollers *3 are* mounted on the hopper walls *4,* and in this way is generated a sliding motion on vertically direction. The mobile hopper has a certain number of holes through which are passing the stainless-steel cables *5,* that lift the mobile hopper *2*, by means of the fixed rollers *6,* mounted on the fixed hopper *4*.

The cables *5* are coupled to fork element *7* of the rotation levers *8,* which pass through the rotation elements *9*, that are fixed to the support *10,* welded to the fixed hopper *4*. The opposed ends of the levers are provided with the eyelet coupling elements *11*, which assure the connection of the artificial fluid muscles *13* mounted on the side walls of the fixed hopper *4*.

Using the coupling elements *7*, mounted on the fixed hopper *4*, provide the connections with elements *11* of PAM's*,* which are connected to the fluid control and command system *14*. The threaded levers *8* allow the movement of the mobile hopper *2* so that the PAM's raise it to the desired height.

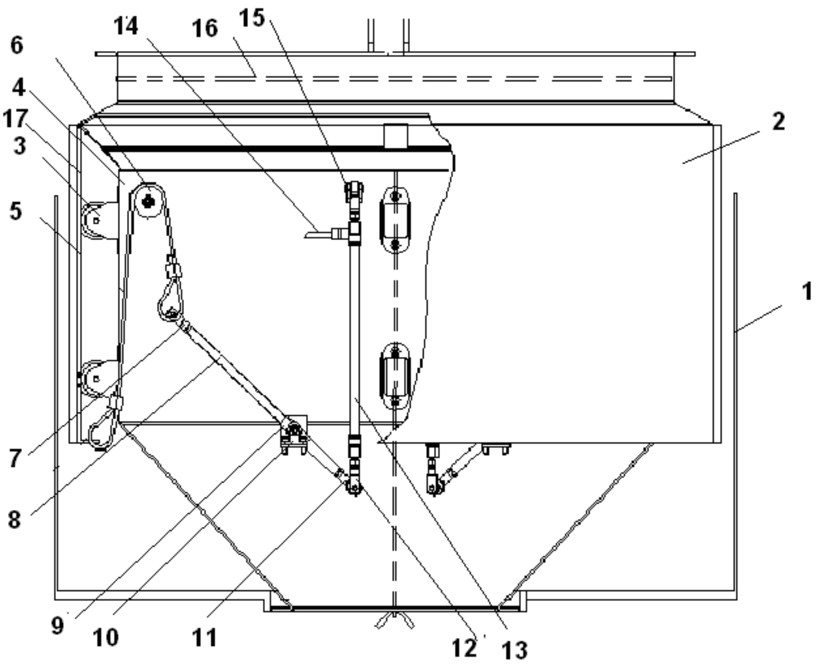

Fig. 3. Adjustable capacity hopper powered with PAM's: position retracted (disconnected from the fluid power system) [8]

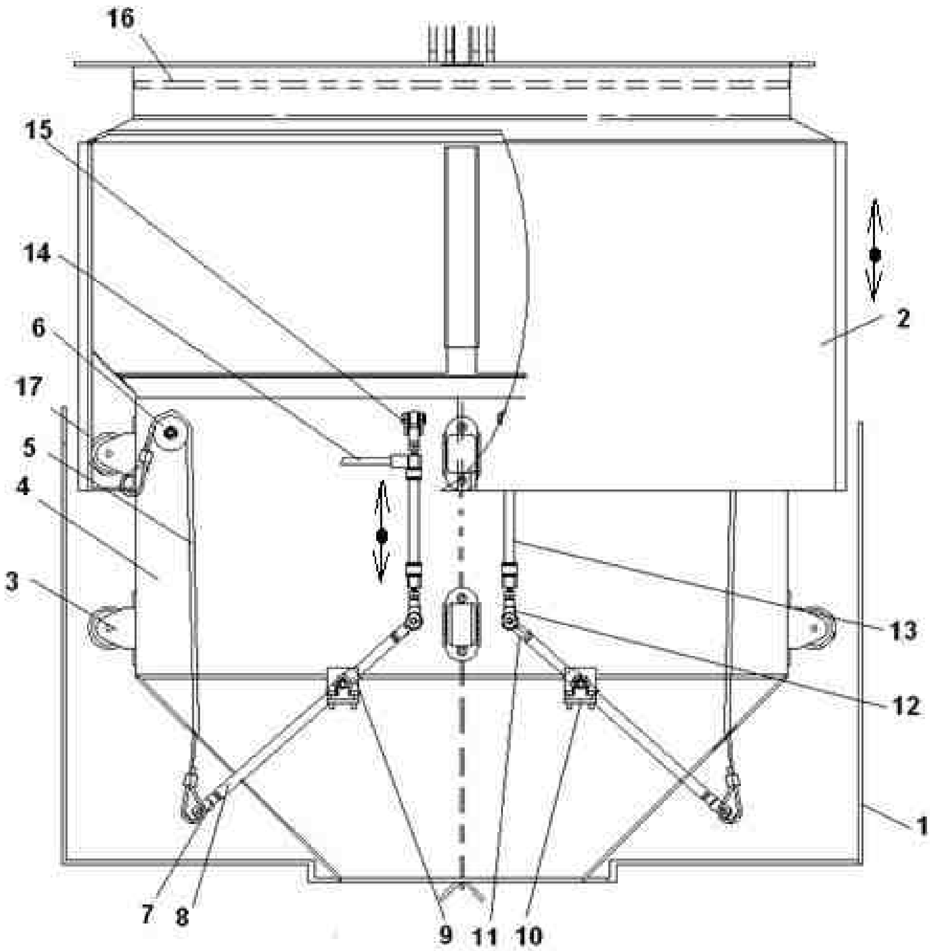

Fig. 4. Adjustable capacity hopper powered with PAM's: position extended - connected to the fluid power system [8]

This system presents the next advantage:

1. easily adapted and powered by fluidic systems, respectively by air compress generator but also by hydraulic groups. Mainly those supply systems can be easily configurated and implemented on an industrial hall, bur also connected at mobile fluidic systems with which the tractors are fitted.
2. increases the working autonomy of cereal/seeds pre-processing plants operating at full capacity, by reducing the hopper feeding time when are used front loaders;
3. lowering fuel/energy consumption when the plant is supplied by front loaders;
4. ensures the storage and processing of harvested grains/seeds directly on field when the plants are supplied directly from agricultural combines;
5. ensures a raw material continuous flow in the plants when it is adjusted to work at maximum capacity, fact that leads to high efficiency of the technological process, especially when the plants work in the field and the changing weather conditions;
6. increase the implementation grade on large powers and gauges aggregates;
7. increase the hopper adaptability to the maximum working capacities of the cereals/seed's processing plants;
8. provide the necessary gauge for the trailed cereals/seed's processing plants to comply with the public transport regulations;
9. increases the machinery field of seed processing due to their adaptability to the requirements of cereal/seed farmers and processors;
10. provide the technologic performance to the highest standards form the fluid actuations systems, respectively 4.0 industrial command and control systems that can be used on smart agriculture industry.

3.2. The separation system of frape seeds from marc

This by-product supplying system designed for marc decompaction has the role to separate the mark fractions (grape peels and seeds) in small pieces that enter in SR1630 rotary selector or ICS seed conditioning plant.

The material undergoes a grinding and decompaction process, subsequently facilitating substantially the working process of seed separations machines.

The current state of the art, are known similar plants produced by companies such as: ALLGAIER Process Technology - USA, Florapower GmbH & Co. KG. KG - Germany, Anyang Best Company Machinery Co., Ltd. - China; Lavrin -Ukraine, ONMAK MAKINA - Turkey, installations that process marc with classic sieve systems.

The disadvantages of these installations are:

- non-uniform raw material feeding; high loading of the active elements;
- high repair costs due to the frequently malfunctions;
- low plant life time;
- low degree of separation due to the high material losses.

System presented in Fig. 5, consists of a fingered rotor *R* located in the feed tank, the rectangular fingers *D1* can be mounted alternately, inclined in two planes rotated at 45 ^{0}, between which two other sets of straight fingers with the round section *D2* are fixed on the vat *C*.

By applying this solution the equipments present the following advantages:

- uniform marc supply of the separation plant; the marc moisture content is evenly distributed;
- decrease mechanical wear of active parts; - increases the grape seeds separation degree;
- reduce maintenance and repair costs of the plant, and also of increase of equipments lifecycle.

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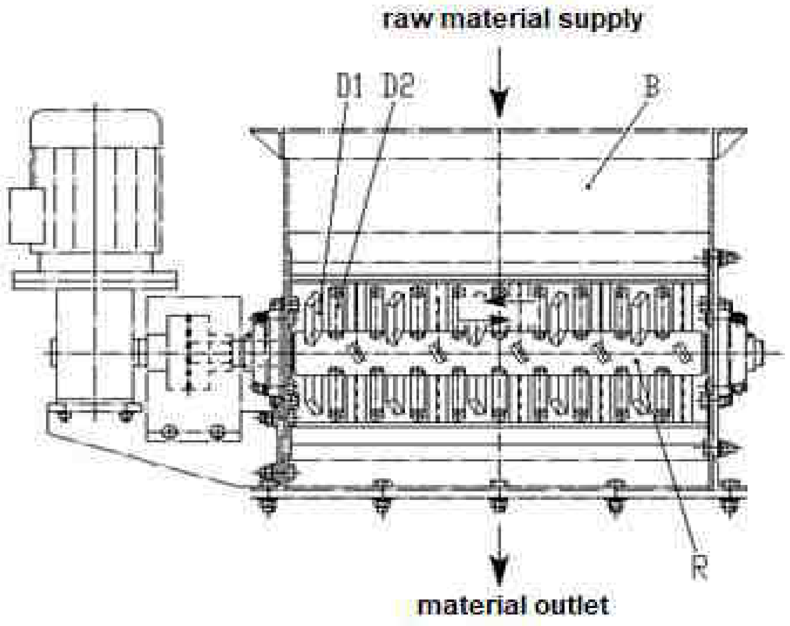

Fig. 5. INMA grape marc capitalization technology [9]

4. Conclusions

In this paperwork is presented one sustainable wine waste management technology, that incorporates different types of equipment's and machines, and some dedicated innovative systems that are perfect integrated in the technologic flow and measure taken to optimise it are adequate in context: of environmental policies; in line with daily grape marc valorisation technologic development, with 4.0 industry and bioeconomy approach from the EU Smart Specialization Strategy.
The INMA innovative technology, can be related also to circular economy approach because respects the arguments:
- achieves a sustainable waste management how does not involve the product quality change and the consumers purchasing power;
- doesn't require loss of revenues or extra costs for manufacturers and other economic agents;
- encourage design thinking, systems thinking, product life extension, and recycling, in order to achieve models that are economically and environmentally sustainable, idea supported by most researchers and experts in the field of economy.
- encourage practical applications to economic systems evolved in incorporating different features and contributions from a variety of concepts sharing the idea of closed loops. (looped and performance economy, regenerative design, industrial ecology, biomimicry and blue economy).

At the end of this paper, are mentioned some of the valuable products that can be obtained from grape marc processing, products that can be found on the market to be commercialized by the most important players are: cosmetic products (face creams, serums and oils, cosmetics, shampoo and conditions, lip-gloss, shaving products, body and massage lotions) and food products (cooking oil, bread and flower, but also the nutritional supplements).

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PAGES FROM THE HISTORY OF FLUID POWER IN ROMANIA

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Abstract: *Fluid Power has a good tradition in Romania, with a history of over 60 years. Over the years there have been several factories or special sections within large industrial plants in which both equipment and hydraulic systems were manufactured.*
It should also be noted that there have been several research & design centres of good technical level among which the most important was the one which today is known as IHP Bucharest.

Keywords: *History, Fluid Power, manufacturing, design and development*

1. Introduction

There are data about Hydraulics published since antiquity, when the first technical books with chapters related to water or air drive were written, such as Archimedes' work on buoyancy of bodies. After the black period of nearly 1,000 years of ante and early Middle Ages with no significant technical and scientific achievements, interesting ideas arose again in the middle period of the Middle Ages. Leonardo da Vinci's work "On Motion and Measurement of Water" is a reference in this respect. A real technical explosion occurred in the 16th and 17th centuries when in countries (or regions of these countries) such as Italy, France, Germany, England or Russia, research has been developed, books have been written and many equipment and machines have been developed, which, in course of time, have entered the history of Fluid Power; so are the writings of Galileo and Newton. Starting with the 18th century, the basic technical and scientific elements of the Hydraulics were created by personalities such as Leonhard Euler, Daniel Bernoulli, Chezy, Darcy, Stokes, Reynolds, Jukovski, Prandtl, and suchlike.
In Romania, the first achievements in the Hydraulics belonged to professors such as D. Pavel, A. Barglazan, I. Anton, George Constantinescu, Dionisie Ghermani, Caius Iacob, D. Dumitrescu, St. Zarea, M.D. Cazacu, E. Carafoli, C. Mateescu, in mid-20th century. However, there still could be no mention of achievements in the field of hydrostatic or pneumatic drives and not even a clear definition of this field.
The first field practitioners emerged in the 1960s and 70s of the 20th century when engineers such as Marin Virgil, Theodor Demetrescu, N. Oprescu, S. Dobrescu, I. Mazilu, A. Popov, G. Radulescu, G. Brebu, L. Sandu, C. Bogoiu, G. Tarlescu, R. Visan, P. Drumea M. Iordanescu, I. Solomon, V. Popa, I. Campean, D. Teneslav, I. Irimia, D. Lazar, C. Arama, R. Moscovici, D.C. Popescu, C. Corodeanu, M. Comes, M. Popescu, S. Medar, G. Trica, have designed and introduced into production the first hydraulic and pneumatic equipment. At that time, the first specialized factories appeared, such as those in Sibiu, Plopeni, Bucharest, Focsani, Ramnicu Valcea, Bistrita, Sinaia, Cluj-Napoca, Stei, Braila, Galati. Nowadays the field has been and still is kept up by several production units located in Bucharest, Iasi, Ramnicu Valcea, Sibiu, Brasov, and several research centers such as INOE 2000-IHP Bucharest (M. Blejan, I. Lepadatu, T.C. Popescu, N. Ionita, C. Cristescu, G. Matache, R. Radoi, C. Dumitrescu, L. Dumitrescu, I. Balan, R. Sauciuc) and the research centers of the technical universities in Iasi (C. Chirita, D. Calarasu, A. Hanganu), Cluj-Napoca (L. Deacu, I. Pop, L. Vaida, D. Opruta, L. Marcu, D. Banyai), Bucharest (N. Vasiliu, C. Calinoiu, M. Avram, D. Prodan, A. Olaru, P. Patrut, I. David, N. Tonciu, N. Alexandrescu), Timisoara (I. Bordeasu, E. Dobanda, V. Balasoiu, M.O. Popoviciu), Galati , Brasov and Constanta.

2. Research and design centres

Hydraulic drives have reached great bloom in Romania through the emergence of specialized design and research centers and also through the establishment of factories or departments within large enterprises, which produced hydraulic equipment and systems.

During the period 1950-1965 many research and design units of national interest, called “Institutes“, have emerged in Romania; within them there were created fluid power departments, called "design workshops". In this sense, the most famous ones were those from IPROMET (Dipl.eng. Tarlescu), IPROLAM (PhD.eng. B. Pitigoi, Dipl.eng. Gh. Vladescu), IMUAB (PhD.eng. Popov, PhD.eng. I.Mazilu, S. Medar, D. Hancu), ICPAT Brasov (R. Moscovici, B. Tavidian, T. Cocis). The most famous and also the most important unit of its kind was the research and design workshop for hydraulics and pneumatics created in the years 1958-1962 at the ITCM institute, known later as ICTCM. The organizational finalization was accomplished with the arrival of the engineer Marin Virgil along with the young engineers Theodor Demetrescu and S. Dobrescu from the Pump Manufacturer (later known as Aversa). The first headquarters of this team was in the Machine Tools Institute (IMUAB) area, until they moved to the headquarters in the South Market. During this period, for several years, until 1971, the hydraulic workshop also had a headquarters in the Arsenal area for microproduction and laboratories. After 1970 the main task of this team was to develop the nomenclature of the products that were assimilated by the specialized factories (HESPER, Balanta Sibiu, HERVIL Rm. Valcea, etc.), or large specialized sections (Plopeni, Braila, Focsani, Bistrita, etc.) of some industrial complexes. To better meet this task, the design workshop was organized between 1979 and 1991 in specialized teams according to the manufacturing profile of a partner plant. Thus there arose Focsani Hydraulics Team initially led by C. Barhala, then led by Gabriel Radulescu, Sibiu Hydraulics Team led by Radu Visan, Valcea Hydraulics Team led by Petrin Drumea, the (2) Hesper teams led by Lucian Sandu and Corneliu Corodeanu, the Team of Pneumatics whose leader was Dan Popescu, with V. Tutunaru and Ileana Oprisescu as principal design researchers; it collaborated with Balanta Sibiu and Mecanica Bistrita. Following the regrouping of the hydraulic plants within the Precision Mechanics Center, it was also decided to move the hydraulics and pneumatics workshop from ICTCM to CCSITMFS, in June 1980, and to transform it into a sector and then into a subsidiary of the new institute, without changing profile, tasks or leadership. With the moving of the team to the new building on Cutitul de Argint Street, in 1983, the staff grew to over 300 people, out of which about 200 people were involved in the research & design activity, which led to a great increase of the field, which soon surpassed the number of 35,000 staff involved. Since 1995 the subsidiary has detached itself from the Precision Mechanics Institute and has turned into ROMFLUID Trading Company with a research profile, with Radu Visan as general manager and Petrin Drumea as technical director. In 1996 the research sector of ROMFLUID has separated itself and, together with an Optoelectronics Center on the Magurele Platform and a Research Center in Cluj-Napoca, made INOE 2000. The hydraulics and pneumatics team has become the Hydraulics and Pneumatics Research Institute (IHP), with the status of a subsidiary of INOE 2000. The Director of IHP since its founding has been Petrin Drumea (from 1996 to 2014), and from 2004 to 2011 Gabriel Radulescu has been technical director. Starting with 2014, the directorate of IHP has been taken over by Catalin Dumitrescu. In these years (after 1992) the structure of the institute has changed by giving up the plant-dedicated teams structure, and switching to 3 large departments which cover the basic directions of research in the field, namely: Hydraulics and general hydraulic systems; Pneumatics and renewable energies; Mechatronics, electronics, hydrotronics. The heads of these departments are Ion Lepadatu, Gabriela Matache and respectively Radu Radoi. Apart from the research and design activities, the Institute has undertaken editing of the specialized magazine “Hidraulica” (Managing editor P. Drumea, Editor-in-chief G. Matache), coordination of the International annual Symposium HERVEX and coordination of the professional association FLUIDAS. IHP has also undertaken organizing training courses in accordance with the requirements of the European Association CETOP.

3. Hydraulic or pneumatic equipment manufacturers

The first production of hydraulic equipment can be considered the manufacturing of gear pumps by the pump factory in Bucharest, also known as Aversa, under technical coordination of Dipl. eng. Ganea.

After 1960 the manufacturing of various equipment specific to the production of tractors and trucks began at I.M. Sinaia, or even in Brasov. At some point, part of manufacturing of Sinaia was transferred to Breaza and other localities from the Brasov area.

An extremely important step was made by introducing into fabrication axial piston hydraulic pumps and motors at I.M.Plopeni (I. Irimia, D. Teneslav, G. Bucurescu, I. Daisa, G. Rotaru, I. Juncu), under a Brueninghaus license (today at Bosch-Rexroth), gear pumps and hydraulic cylinders. The experience gained by the specialists here in assimilating gear pumps standard Plessey has enabled rapid integration of these new equipment, with great influence in the industrial development of the country.

A new step in the development of hydraulics was the beginning of the manufacturing of 200-bar hydraulic equipment (designed in Romania by the team led by Th. Demetrescu and then by Radu Visan) at I. Balanta Sibiu, with the creation of the new plant Balanta2, later known as Hidrosib. Right during the manufacturing phase of the 300-bar family of appliances a license was purchased from Germany from Bosch for pressure valves and hydraulic directional valves of 300 bar. The manufacturing was coordinated technically and organizationally by a series of engineers, among which we mention Solomon, Ocos, Mandea, Lazar (transferred from Plopeni), Popa, Necula, Campean, Pascu. Currently the plant decreased in number of employees from 2000 to 35. About the same time and in the same place, namely in Sibiu, but at Independenta, pneumatic air preparation equipment (filters, regulators and lubricators) was introduced into production. Today there is no pneumatics manufacturing.

The company ISEH Focsani, turned to ROMSEH, has introduced into production the first stack style directional valves, under the coordination of engineers A. Bourceanu, L. Veber, Pricop, starting from the designs drafted in IHP under coordination of engineers C. Barhala, G. Radulescu and P. Drumea. The plant soon developed its production with monoblock stack valves and proportional stack valves. Although this manufacturing has been successful, effective production has quickly ceased. In those years (1985-1990), hydraulic throttles and regulators were also introduced in the manufacturing, and also stands for hydraulic equipment, according to own designs or designs elaborated by IHP. Nowadays, there is no kind of hydraulics manufacturing in our country.

For many years (starting from 1965) pneumatic equipment has been manufactured in Sibiu by the two large factories Independenta (air preparation units - FRL) and Balanta (directional control valves and regular valves), but starting from 1972 manufacturing of pneumatic equipment has been transferred to I.M. Bistrita by Mr. Dan Popescu from IHP and by the specialists of the plant led by Mr. I. Fiscutean. Nowadays, there is no such manufacturing in the country.

Of great interest was the appearance in the group of hydraulic manufacturers of the plant in Ramnicu Valcea (G. Popa, O. Fota, Gh. Rizoiu, C. Dinescu, G. Surlin, Cichirdan), which, based on the designs of S. Medar, G. Trica from ICSIT TITAN, P. Drumea, M. Stefan, I. Balan, N. Oprescu, N. Ionita from IHP, have assimilated into series manufacturing families of hydraulic filters, pneumatic-hydraulic accumulators, proportional devices and servovalves, hydraulic cylinders and lubricating equipment. A family of high-pressure (700 bar) equipment and devices has also been introduced into fabrication by the specialized team of IHP located in Ramnicu Valcea, led by I. Galea and coordinated from IHP by P. Drumea. Today the plant is taken over by an Indian manufacturer and is restricted to manufacturing of hydraulic cylinders.

An interesting case is the plant HESPER, former Steaua Rosie, in Bucharest, which in the 1970s, under the directorate of Mr. Bratulescu, introduced in manufacturing hydraulic power steering and slow orbital engines. The real step towards the big hydraulics was made when the gear pumps were assimilated in the manufacturing; such equipment has been developed especially since 1993, under the coordination of the Ph.D. engineer Mircea Pricop. Today, the plant, privately owned, with

Romanian capital (business owner Mircea Pricop), produces and exports intensively gear pumps, and it is the most powerful Romanian company in the field of hydraulics.
The factories in Galati (hydraulic cylinders), Braila (slow-type motors, hydromotors and hydraulic systems and cylinders), Sinaia, Breaza, Stei, Sibiu (Independenta), Fagaras (pneumatic equipment) have reduced their production capacity close to zero.

4. Field support activities

The event called “HERVEX” was born in 1993 due to the desire of the management of the hydraulic equipment production company (IEH Ramnicu Valcea, which later became HERVIL) to make a different type of marketing through a complex exhibition of company achievements. In this respect, the company director, Dipl.eng. O. Fota, together with the main collaborators, Dipl.eng. C. Dinescu, Dipl.eng. Gh. Surlin and Dipl.eng. Gh. Rizoiu, have asked the colleagues at the Hydraulics and Pneumatics Institute in Bucharest (Dipl.eng. R. Visan, Dipl.eng. G. Radulescu, Dipl.eng. P. Drumea, Dipl.eng. I. Lepadatu, Dipl.eng. St. Breazu) with which they have been collaborating since the plant was set up, to add a technical and scientific touch to the exhibition formula. If in the first year this cooperation was manifested through general discourses and presentations, starting with the second year besides the exhibition a second direction of the event materialized, namely a technical and scientific symposium. Also, a third partner joined the first two partners (HERVIL and IHP); thus, the partnership included the Chamber of Commerce and Industry Valcea (CCIVL), which, as time went on, has taken over a large part of the organizational activities through the involvement of the then (and current) President, Dipl.eng. V. Cismaru. It was very important the transfer of Dipl.eng. Gh. Rizoiu from HERVIL to CCIVL as thus the organizational level increased, considering the fairly rapid increase in the size of the event, and the Chamber of Commerce has become, together with the Institute in Bucharest, a pillar of the organizational process. After the first three years, HERVEX has become quite known nationwide, and in the following years it became known internationally, too, both through its exhibition direction and through its technical-scientific direction. During this period, the technical universities in Bucharest, Iasi, Cluj-Napoca and Timisoara joined the three original partners by including in the organizers' team some personalities like Prof. P. Svasta, Prof. Al. Marin, Prof. E. Murad, Prof. C. Chirita, Prof. L. Vaida, Prof. D. Opruta and Prof. I. Bordeasu. The spectacular leap was achieved by including PIA Aachen, Germany (through Dr. Ing. Elmar Dorgeloh) and the University in Wroclaw, Poland (through professors Chrostovski, Domagala and Kędzia), in the group of organizers. Thus, the number of annual exhibitors has grown to 55 companies, and the number of participants to over 400 people. A lot of participants that we could not record officially added to this number. Of course, the involvement of the FLUIDAS Professional Association as an organizer and the support from ANCS have expanded the area of European knowing and recognition of HERVEX, let only consider the fact that it has been included in the international catalogue of events of CETOP (the European specialized Association). During this period the organizers found an extremely welcoming and cooperative host in Calimanesti-Caciulata through the hotel complex Cozia - Oltul - Caciulata, and especially through the person of the economic director, Mr. Necsoiu. Initially, the event was also supported and encouraged by local officials both in the Calimanesti town hall and in the Valcea County Council; the managers of these authorities even used to attend the opening ceremonies of the event. Over time, their involvement has diminished to the situation of recent years when we have not had with us any person in the board of the local authorities, even if HERVEX became interesting and emblematic for the county. As at some point the number of participants and the level of national interest decreased, several years ago, two steps were taken to bring us back to the standards that the world became used to when it came to HERVEX. The first step was to switch from the annual basis to the biannual basis of HERVEX organizing. The second step was to include, as main organizer next to IHP and CCIVL, the KOMAG Institute in Katowice, Poland, thus the event taking place alternately one year in Valcea and the next year in Poland. Although things went really well for four years, the Polish institute has recently undergone transformations that prevented it from continuing this agreement. With the decline in hydraulic and pneumatic manufacturing, the exhibition section has dramatically decreased; it has been compensated for a while by the symposium section, which has been maintained at a good level both quantitatively and qualitatively. In this respect it is worth mentioning the presence of outstanding representatives of the university research centers in Aachen, Dresden and Darmstadt - Germany, of research centers in Milano and Torino - Italy, Poitiers and Angouleme - France, Wrocław, Katowice and Cracow - Poland. Throughout this period HERVEX has preserved hydraulics and pneumatics as its main areas, in spite of all the problems created by the dramatic reduction of production and even use. To keep the symposium at a high technical-scientific level the organizers have opened in the last few years also directions like the environment and renewable energies hoping to add new co-organizers to replace those who are not as close to us as they used to be in previous years. The organizers also decided that only two or three specialized companies should be presented per each event issues; the chosen companies were those able to expose their industrial and development offer.

Foundation of the Professional Association FLUIDAS has represented an extremely important achievement during the rather unclear period regarding the situation of the domain in the years following 1990. Domestic manufacturers were totally confused about the development of the field, and foreign manufacturers did not have enough data on needs and areas with development potential. At that time, there were countless attempts to coagulate manufacturers and distributors of hydro-pneumatic equipment in an association, without achieving the desired results. Only in the years 1995-1996, under the coordination of IHP and with sustained support of CCI Valcea, Hydramold Iasi, HESPER Bucharest and some young companies in Brasov, Constanta and Bucharest, the founding of a professional association, with a well-defined status and a firm organization, was finally successful. In addition to the over 40 companies that adhered to FLUIDAS there was also created a section of specialists in the field, regardless of whether they were working in production, education or research. The first president was Mr. P. Drumea from IHP, and had as main collaborators Mr. Rizoiu (Valcea) and Mr. C-tin Chirita (Iasi). Shortly (1997-1998), FUIDAS became a member of the European Professional Association CETOP, attending all meetings of European interest, until recently. The association's problems arose when almost half of its members have entered into insolvency (or bankruptcy), and no new-entries of the industrial landscape have been co-opted.

Another element of interest for the field was the appearance of the specialized magazine HIDRAULICA. Slowly, it was turned into a scientific journal with international spread, and this reason has made it to move away from hydraulic and pneumatic manufacturers and distributors. However, there is still a great interest in it, the magazine being quite appreciated internationally, especially as it was directed mainly at the field of applied research, including primarily scientific papers about pieces of equipment that are the subject of manufacturing. Another important element is the team of specialists who review the works and do not allow insignificant material to be published.

5. Conclusions

5.1 Hydraulics and pneumatics represent a field of great interest.
5.2 Domestic production has decreased over the last years and has not managed to recover.
5.3 There is a great interest in the design and development of hydraulic and pneumatic drive systems.
5.4 In the past few years, an increasingly intense maintenance direction has been developing.
5.5 There are still resources in the field of research and design in hydraulics and pneumatics.

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MECHATRONICS, CYBER-MIXMECHATRONICS AND IT&C BASED ON THE DEVELOPMENT OF INDUSTRY 4.0 IN ROMANIA

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Abstract: *The scientific work focuses in the synthesis on the substantial importance of Mechatronics and Cyber-MixMechatronics in the development of Industry 4.0 in Romania through fundamental concepts and solutions for integration and implementation in the structures of intelligent industrial architectural components and assemblies. The scientific paper presents comparatively the stage of Industry 4.0 in Europe and Romania and especially the European and national policies of this new Global and Synergic Industry. There are mentioned the development stages of Industry 4.0, intelligent components and industries and more for the digitization of all industrial structures of industrial enterprises for intelligent and cybernetic manufacturing. Mechatronic and cyber-mixmechatronics concepts and solutions are addressed to simulate, develop and support Industry 4.0 in Romania.*

Keywords*: Industry 4.0 (Fourth Industrial Revolution); industrial digitization; mechatronics and cyber-mixmechatronics; intelligent concepts and solutions; mechatronic and cyber-mixmechronic systems; Integrated system of intelligent systems; digital trust; IoT Cyber-Physical Systems; IoT Cyber-MixMechatronic Systems; collaborative digital applications, etc.*

1. Introduction

At european union level, new concepts have been created to stimulate, develop and support industry 4.0 as a basis for economic competitiveness development of the member countries, as key lessons for european and national policies.Stimulating industry 4.0 is for the eu economy.At present and in the future, advanced technologies fuel the so-called "fourth industrial revolution" with the strategic goal of transforming eu industries and creating a massive growth of the european economy through the greatest digital opportunity for existing industry and enterprise not by creating new industries.
This means adapting advanced digital technologies to existing European and national enterprises, which is now the greatest challenge and paradigm to achieve the best positive results.
Development of Industry 4.0 is the key to the development of the European Union.
Based on recent European studies on industry development through the Fourth Industrial Revolution called Industry 4.0, it was stated with reasons of hope that 76% of respondents see digital technologies as an opportunity, while 64% of companies investing in digital technologies have already generated positive results.
Support for Industry 4.0 in Europe is achieved through national policies of member countries.
In this respect, in response to these challenges and paradigm solutions, most EU governments have adopted, as a matter of priority, the policies of the large-scale Industry 4.0 to increase productivity and competitiveness and to improve high-tech skills of the workforce.
As a positive example, the key components of the national policies of Industry 4.0 to Spain, the UK, France, Italy, Germany, the Czech Republic, Sweden and the Netherlands can be nominated through a substantial (public and private) financial targeting approach and target audience (industry and production base, SMEs, manufacturers, large companies, universities, research centers, academic and industrial research, service sector, trade unions, etc.).
As a positive example, the key components of the national policies of Industry 4.0 to Spain, the UK, France, Italy, Germany, the Czech Republic, Sweden and the Netherlands can be nominated through a substantial (public and private) financial targeting approach and target audience (industry and production base, SMEs, manufacturers, large companies, universities, research centers, academic and industrial research, service sector, trade unions, etc.).
The key features of National Industry 4.0 policies are global and synergistic.

These are integrated into Industry 4.0's global and synergistic policy frameworks, which are part of a general and strategic framework reflecting the industry's 4.0 priority status in Europe.
In particular, they are much broader frameworks or strategies, which prioritize the vision and general approach of research, innovation and industry policies.
Each developed European country, based on the new European concept of Industry 4.0, develops its related national policies, as follows:
• the French industry: ”Industrie du Future (IdF)” is linked to the new Industrial France (NFI), where significant underinvestment and problems in developing competitive digital industries have been the driving force behind policy;
• Italian industry: through ”Cluster Factory Inteligent Italian (CFI)”), drew up against the Italian Innovation Roadmap, a wider strategy on Italy's socio-economic challenges such as climate change, resource scarcity, demographic developments , etc.
• the Dutch industry: identifies very tangible reasons for launching initiatives;
the Netherlands industries: through the relatively low labor-related employment share, has led to the creation of a smart industry;
• the Netherlands industries: through the relatively low labor-related employment share, has led to the creation of a smart industry;
• industries of other European countries through a political initiative with a direct result of a general national framework, strategy and / or agenda;
• the German industry has created Industry 4.0 through ten major future projects under the High-Tech 2020 Strategy Action Plan.
• the Spanish industry has developed a digital part of the Industrial Sector Consolidation Agenda, which has gradually transformed into Connect Industry 4.0.
• the British industry has advocated a policy strategy for the establishment of technology centers in different industries;
• the Romanian industry is based on the National Development Strategy of Romania 2015-2020 and 2020-2030, the National Competitiveness Program 2015-2020;
and the Mecatron Group Initiative, to MMACA, to develop the Industry Development Strategy 4.0.
Industry 4.0 applies strategic focus and industry / technology focus:
In the first stage, sector / technology focus within Industry 4.0 includes a distributed local implementation structure such as Transport, IoT, Artificial Intelligence, Block Data, PC Hardware, Digital Trust, Intelligent Cities, IoT Cyber-Physical Systems , IoT Cyber-Mechatronics and Cyber-MixMechatronics systems, digital platforms, collaborative applications, sectoral implementation in aerospace, automotive, chemical, nuclear, pharmaceutical, electronics, mechatronics, etc.
In the second stage, strategic focusing within Industry 4.0 includes an overall architectural structure, industry and enterprise-specific, in strategic implementation.

2. Strategic policies of the Industry 4.0

In summary, the strategic policies for Industry 4.0 are well defined and look great, overlapping with the objectives and targets pursued, notably consolidation of the country and new industrial competitiveness, modernization and better assurance of the sustainable growth of the intelligent production sector.
Most European countries, especially Germany, are focusing on gaining greater productivity and increased efficiency.
Thus, providing of the future generation of technologies (such as Italy and the UK), the development of new industrial process improvement products and services (such as Germany and Italy) that give support to SMEs for innovation and commercialization (such as the UK, France and Spain), are among the most prominent objectives.
In Europe, Industry 4.0 policies have common goals, but all have elements that give each policy a small influence, as follows:
• **French initiatives**, presents a market-based approach to the companies participating in the program;

• **Spanish initiatives** present a cost-based approach based on the line of action and the type of company that varies between a 25% to 70% coverage cost; The French IdF combines a wide range of financing, instruments (eg, loans and tax incentives with private investment in R & D);

• **Swedish initiatives** (Sweden P2030) present a strong leadership and funding approach by industry that ensures the long-term impact and sustainability of industry;

• **British initiatives** focus on providing technology and expertise on an industrial scale, for companies, to eliminate risk in innovation through technology centers.

Focusing and impact area involves research on Industry 4.0, giving priority to speeding up deployment and application of Industry 4.0 technologies focusing on the development of new technologies that address manufacturing innovation challenges such as the Internet of Things (IoT), Cyber-Physical Systems (CPS) / Cyber-MixMechatronics Systems (CMMS).

It is noted that models are lacking and Industry 4.0 initiatives tend to be relatively open in terms of the application of specific technologies or sectoral domains in terms of increasing the sustainability of production as a common impact area in terms of offering information and support for implementation, and better business and opportunity exploitation, greater flexibility in production volume, efficiency, costs and customer satisfaction as the main expected effects.

The exemples of funding sources for Industry 4.0 contain a structure of public sources, private sources and public-private sources, as follows:

• **Industry 4.0 in Germany**, public-private sources, ratio 2:1 ÷ 5:1;

• **Industry for future, in France**, public sources (10 bil. Euro) and private sources, ratio 5:1;

• **Spanish industry**, manufacturing of high value (CATAPULT) Spain, public sources (367 bil. Euro) in multiannual financing and private sources, ratio: 17:1.

The results of Industry 4.0 in Europe have tangible results and qualitative and quantitative results as a result of national policies for Industry 4.0 in Europe (eg France, the Netherlands, Sweden and the United Kingdom), as follows:

• **In France**, through IDF, more than 800 loans for enterprises and 3400 of diagnosis were achieved;

• **In Sweden**, through P2030, were financed 30 projects with the participation of over 150 enterprises;

• **In Germany**, through I 4.0 initiative, has highlighted outstanding qualitative results such as the segregation of small industries, the transformation of research into practical applications, and the creation of platform reference architectures with more than 150 members;

• **In the UK**, through HVMC, were initiatives with clear digitization, monitoring and evaluation cycles, with the value of innovation work above 123% of the initial target (2013-2015)

• etc.

In Romania, there are initiatives to address Industry 4.0, in stages, in a complementarity with the initiatives of European countries, as follows:

- **developing the Strategy for Industry 4.0 in the period 2019-2023 and 2023-2027 and in the future;**
- **Integration of the Industry Strategy 4.0** within the National Strategies and Programs elaborated for the years 2019-2023 and 2023-2027 and in the future;
- **Development of Strategic Industry Programs and Plans 4.0** (by industry / pilot enterprises), (eg Intelligent Production Program 2030, National University School of Digitized Production, etc.);
- **Implementing the Industry Strategy 4.0** for the 2019-2023 and 2023-2027 periods and in the future;
- **Implementation** of Strategic Industry 4.0 Programs and Plans;
- **Implementation** of Industry 4.0 Initiatives **and** related and complementary areas;
- development of technologies and infrastructures specific to Industry 4.0; and so on.

3. Approach to the Industry Strategy 4.0, through the Mechatron Group

Industrial production related to Industry 4.0 will develop in symbiosis with the modern technique of mechatronics, cyber-mixmechatronics, information and communication.
The technical basis for achieving this goal is the general and complex problem of the digitization of the industry with the integration of intelligent mechatronics, cyber-mixmechatronics, informational and communication systems and the acquisition of related and adequate competences of human resources.
Thus, in their entirety, they make it possible for Industry 4.0, a smart, self-organized production where people (operators), machines, installations, logistics and the product (as output value in the value chain) communicate and cooperate with each other, directly together.
Interconnection / integration will make it possible to jump from supervising a small production segment into self-organization of a whole chain to an enterprise level.
The network will need to include all phases of a product: from idea, through design and production processes, including logistics, product and service usage to recycling.
This fourth industrial revolution is fundamentally different from its predecessors. It would be impossible to define it without using the terms "cyber-physical systems / cyber-mixmechatronics systems" or "cloud computing".
It is a revolution of networks, platforms, people and digital technology.
Industry 4.0 focuses on end-to-end digitization of all physical assets and processes as well as integration into digital ecosystems with partners in the value chain.
The great industrial revolution depends on small technological revolutions in various areas:
Applying information and communications technology to digitize information and integrate systems from design to product development, manufacturing and use.
New software technologies for modeling, simulation, virtualization and digital manufacturing.
Develop Cyber-Physical Systems and Cyber-MixMechatronics Systems to monitor and control physical processes.
The evolution of 3D printers and additive manufacturing to simplify manufacturing.
Decision support for human operators, the emergence of intelligent tools and assistance using augmented reality. New forms of human-machine interaction. Many of these technologies have been available for a few years, and others are not yet ready for use on a large scale.
Based on the above mentioned, the MECATRON GROUP, consisting of the National Institute for Research Development for Mechatronics and Measurement Technique - INCDMTM, the Innovative Strategic Cluster for the Mechatronics and Cyber-Mix Mechatronics Intelligent Field of Specialization "MECATHREC", the Employing Association of the Fine Mechanics, Optics and Mechatronics in Romania - APROMECA Cluster Management Entity, Relay Center for Technology Transfer and Consultancy - CRTTC of INCDMTM, Mechatronics Industry Competitiveness Pole - INMECHATRON and Training and Evaluation Centers for Intelligent Mechatronics have been designed and developed since 2010 , concepts, syntheses, principles, models, intelligent architectures, modular constructions and mechatronic products and Cyber-MixMecatronics for Industry 4.0, currently many of which are already technologically transferred and implemented in Industry (eg Automobile Industry - SC Automobile Renault-Dacia S.A Piteşti, in the Medical Industry - Laser Selection Sintering Technology; in the Aerospace Industry - Metering Systems by Telemetry of Positioning and Relative Distances between Microsatellites; in Intelligent Agricultural Industry - Robots in Drone Integrated Systems; etc.), economy and society.
MECATRON GROUP together with national consortia, consortium having entities such as the National Research Institute, Advanced Research Universities, innovative SME’s, etc. and structures at European level that include research entities such as Universities, Research Institute, Research Firms and SME’s. They have designed, developed and proposed in various national and international research programs, large and complex research projects for various national and international programs, including Horizon 2020.
The contribution of Intelligent Mechatronics and Cyber-MixMechatronics concepts and constructions to Industry 4.0 is made to a substantial extent on the systems and system parts of

intelligent manufacturing products and processes and less the industrial enterprise mix.
In order to develop and support Industry 4.0, the Romanian conception is based on two structural steps, namely: digitization and cybernetization of the components of the architectural ensemble of industry (Industrial Enterprise, Firm, SME's) and digitization of the architectural enterprise ensemble (from input sizes to output sizes).

4. Examples of original concepts and original solutions for Industry digitalization, based on the development and integration of Mechatronics and Cyber Mechatronics as XXI century sciences

Original concepts and of intelligent mechatronics systems and cyber mechatronics integrative

- Smart mechatronics system and cyber-mixmechatronics integrative of control (fig. 1)

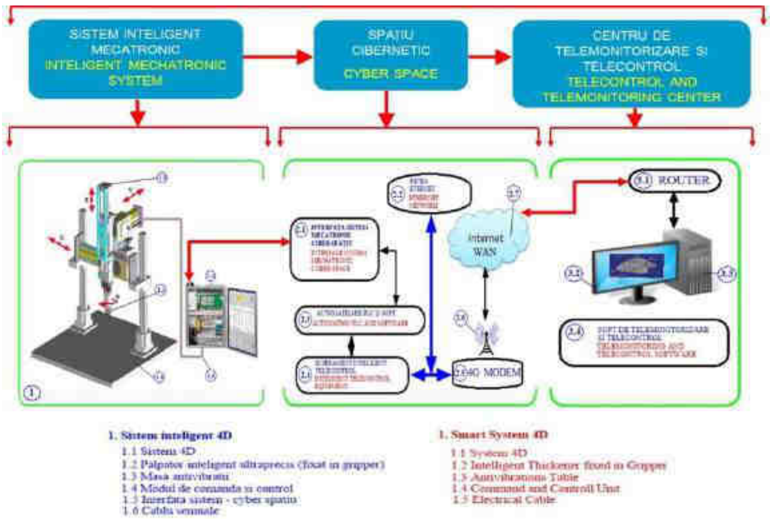

Fig. 1. Smart mechatronics system and cyber-mixmechatronics integrative of control

- Smart mechatronics and cyber-mixmechatronics integrative system for verification and tightness measurement for cast parts in automotive industry (fig. 2).

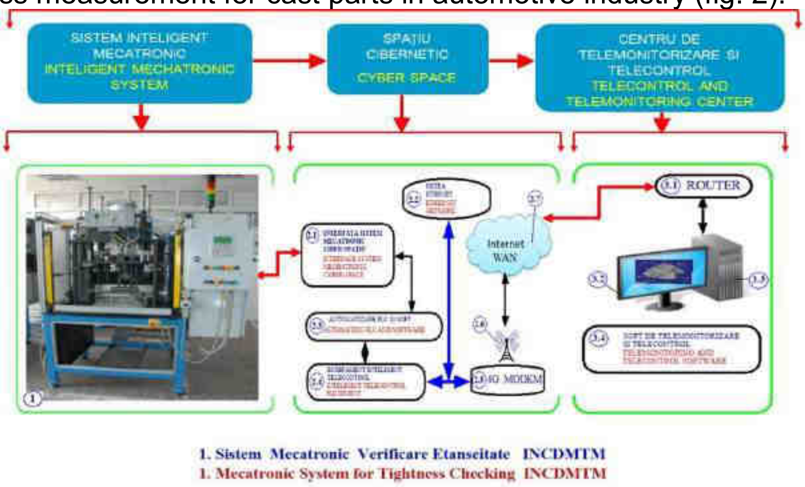

Fig. 2. Smart mechatronics and cyber-mixmechatronics integrative system for verification and measurement

- Smart mechatronics system and cyber-mixmechatronics architectural system of sensors (multiaplicative in industry) (fig. 3)

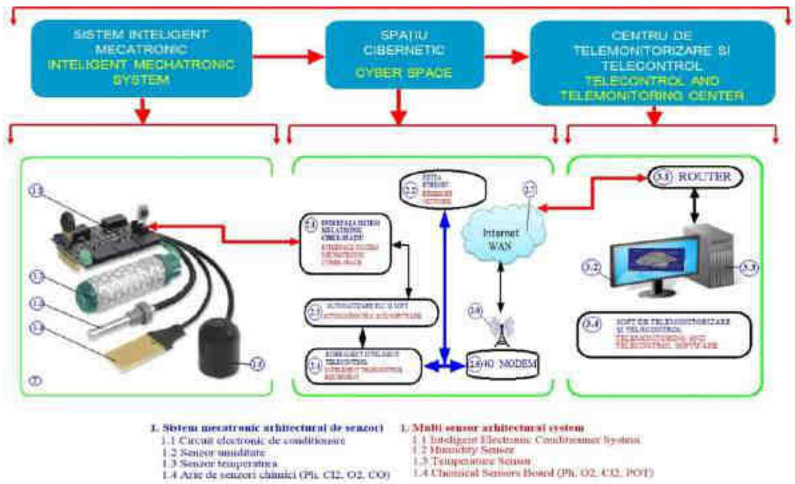

Fig. 3. Smart mechatronics system and cyber-mixmechatronics architectural system of sensors

➢ Smart mechatronics system and cyber-mixmechatronics integrative system for welding (industrial multiaplicative) (fig. 4)

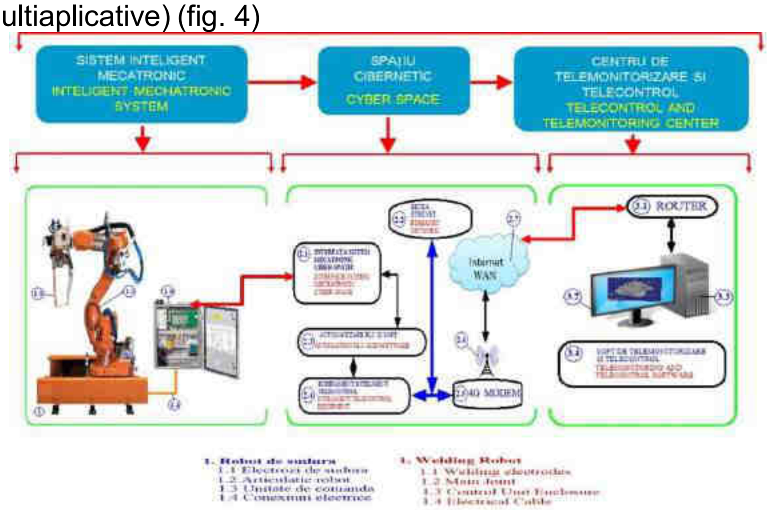

Fig. 4. Smart mechatronics system and cyber-mixmechatronics integrative system for welding

➢ Intelligent mechatronics and cyber-mixmechatronics integrative system for packing / assembling (mailbox), (multiplicative) (fig. 5)

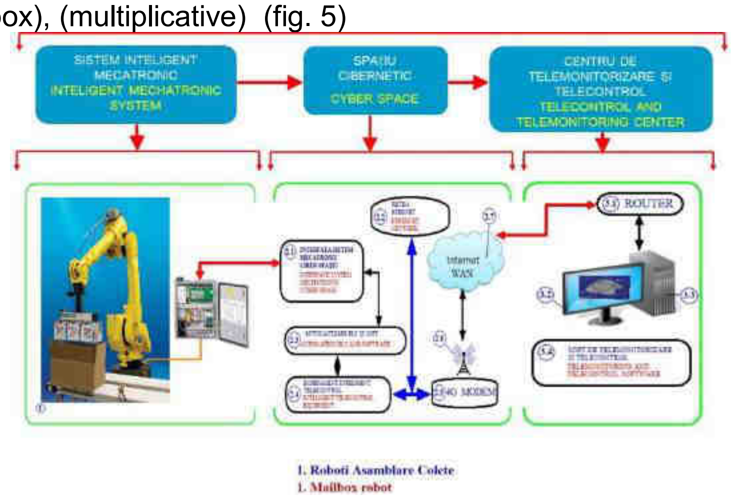

Fig. 5. Intelligent mechatronics and cyber-mixmechatronics integrative system for packing / assembling

- Smart mechatronics system and cyber-mixmechatronics integrative system for assistant machine tools (multiaplicative) (fig. 6)

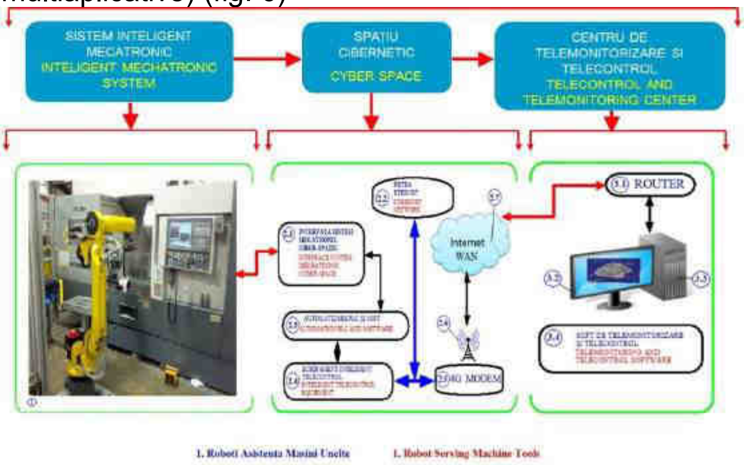

Fig.6. Smart mechatronics system and cyber-mixmechatronics integrative system for assistant machine tools

- Smart mechatronics system and cyber-mixmechatronics integrative system for car painting (multiaplicative) (fig. 7)

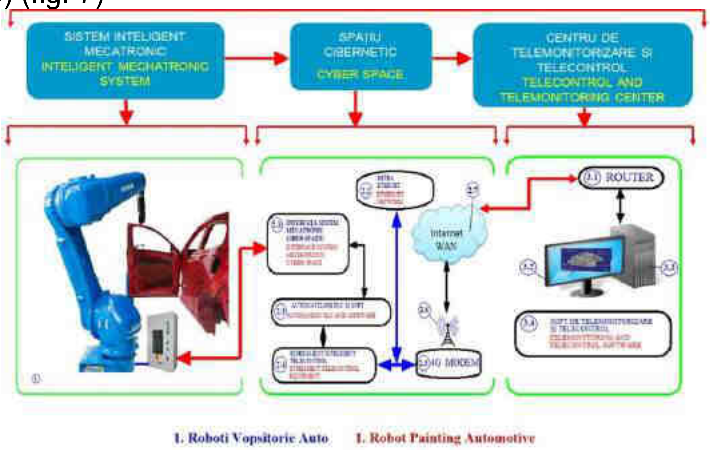

Fig. 7. Smart mechatronics system and cyber-mixmechatronics integrative system for car painting

- Smart mechatronics system and cyber-mixmechatronics integrative system for dimensional control (multiaplicative) in industry (fig. 8)

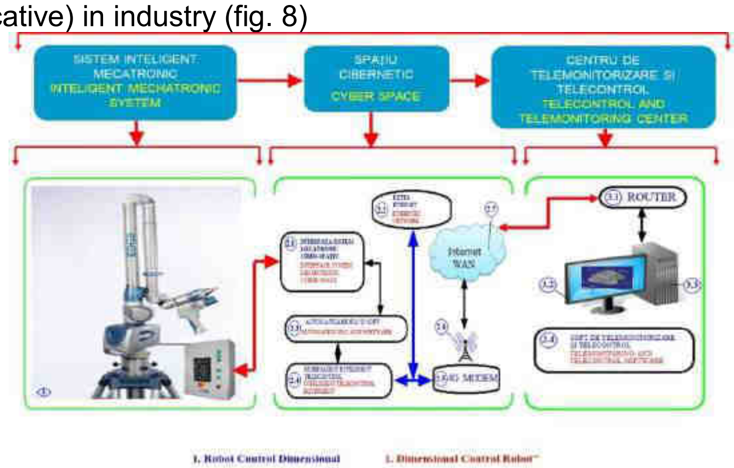

Fig. 8. Smart mechatronics system and cyber-mixmechatronics integrative system for dimensional control

- Smart mechatronics system and cyber-mixmechatronics integrative for ultraprecise positioning (multiaplicative) (fig. 9)

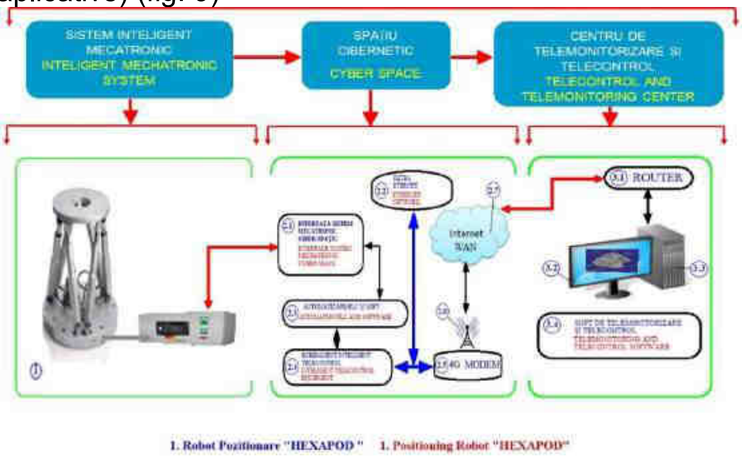

Fig. 9. Smart mechatronics system and cyber-mixmechatronics integrative for ultraprecise positioning

- Smart mechatronics system and cyber-mixmechatronics integrative for medicine (in surgery), (multiaplicative) (fig. 10)

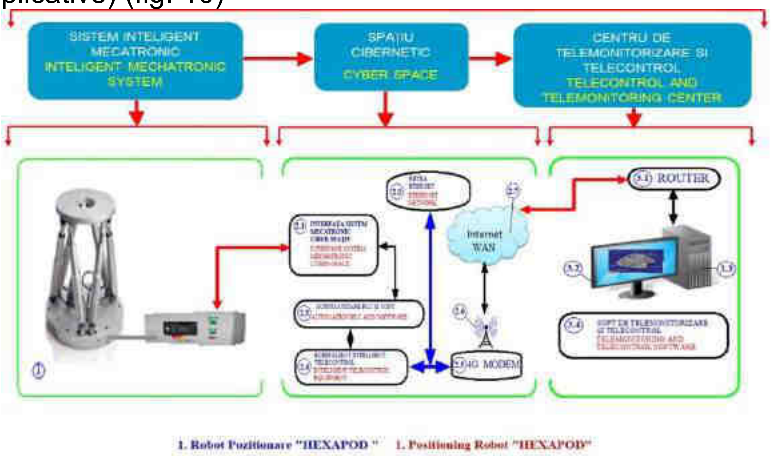

Fig. 10. Smart mechatronics system and cyber-mixmechatronics integrative for medicine (in surgery)

- Smart mechatronics system and cyber-mixmechatronics integrative (Drone type) for extinguishing electric fires (fig. 11)

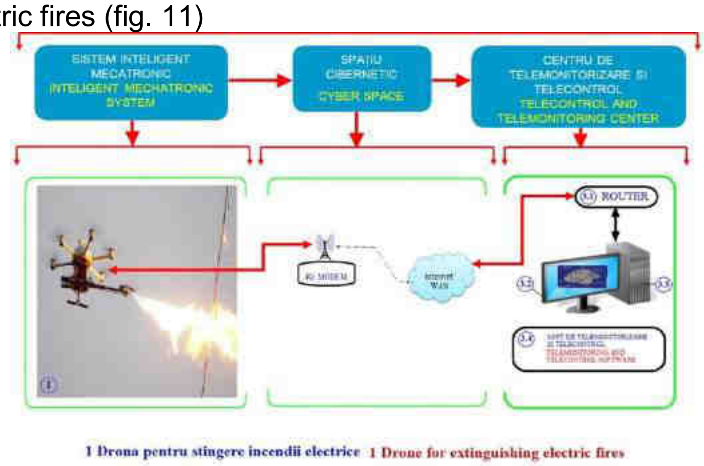

Fig. 11. Smart mechatronics system and cyber-mixmechatronics integrative (Drone type) for extinguishing electric fires

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➢ Smart mechatronics system and cyber-mixmechatronics integrative for agriculture (spraying), (fig. 12)

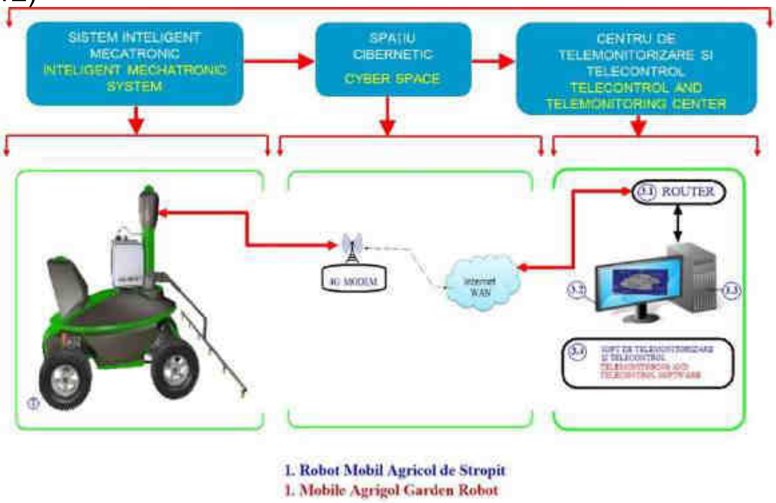

Fig. 12. Smart mechatronics system and cyber-mixmechatronics integrative for agriculture (spraying)

➢ Smart mechatronics system and cyber-mixmechatronics integrative, "Smart multi-tasking drones" type (fig. 13)

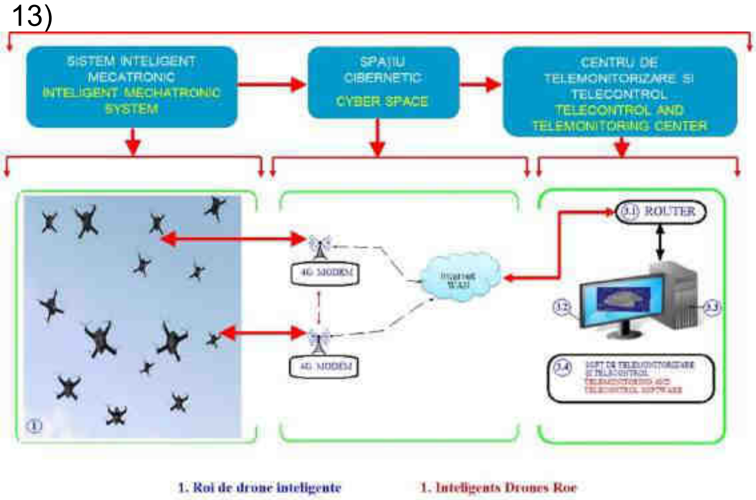

Fig. 13. Smart mechatronics system and cyber-mixmechatronics integrative, "Smart multi-tasking drones" type

➢ Smart mechatronics system and cyber-mixmechatronics integrative for renewable energy (fig. 14)

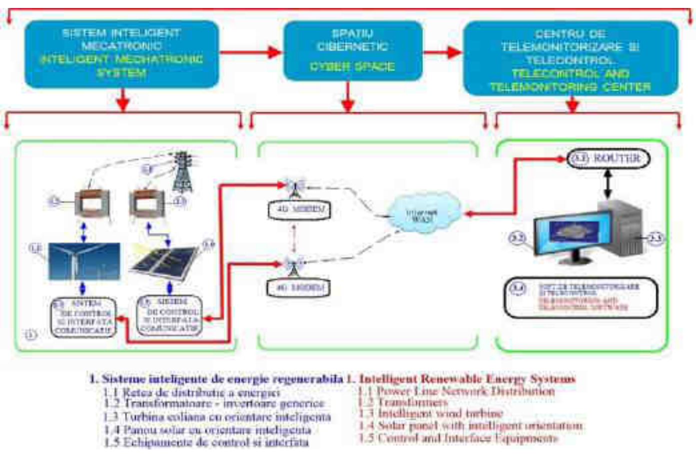

Fig. 14. Smart mechatronics system and cyber-mixmechatronics integrative for renewable energy

- Smart mechatronics system and cyber-mixmechatronics integrative for terrestrial telescope network (fig. 15)

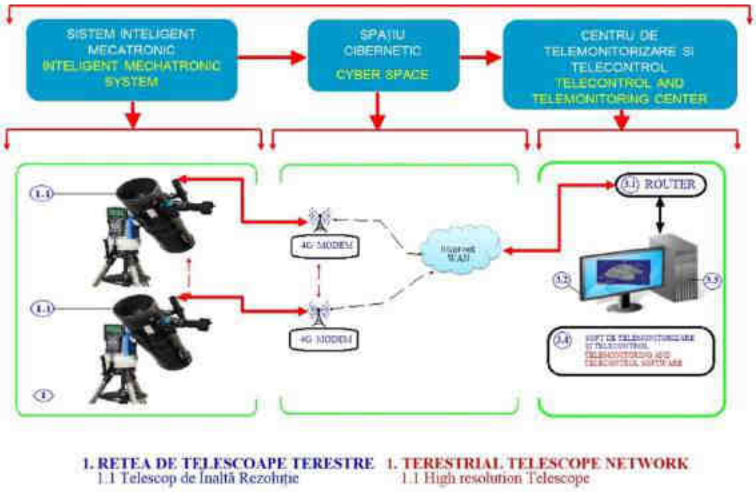

Fig. 15. Smart mechatronics system and cyber-mixmechatronics integrative for terrestrial telescope network

- Smart mechatronics system and cyber-mixmechatronics integrative for automatic waste sorting (fig. 16)

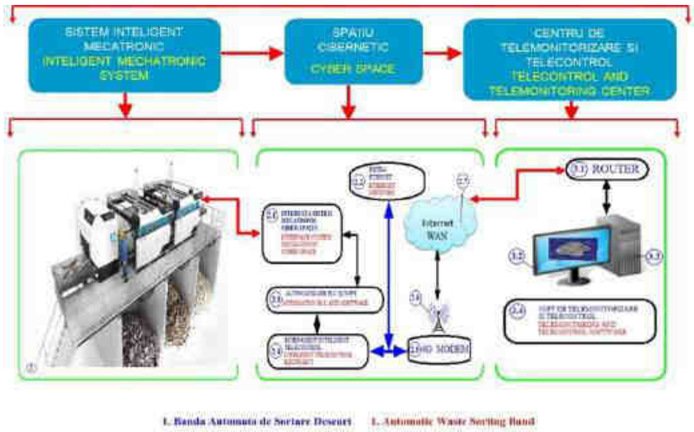

Fig. 16. Smart mechatronics system and cyber-mixmechatronics integrative for automatic waste sorting

- Smart mechatronics system and cyber-mixmechatronics integrative for network of micronanosatellites (fig. 17)

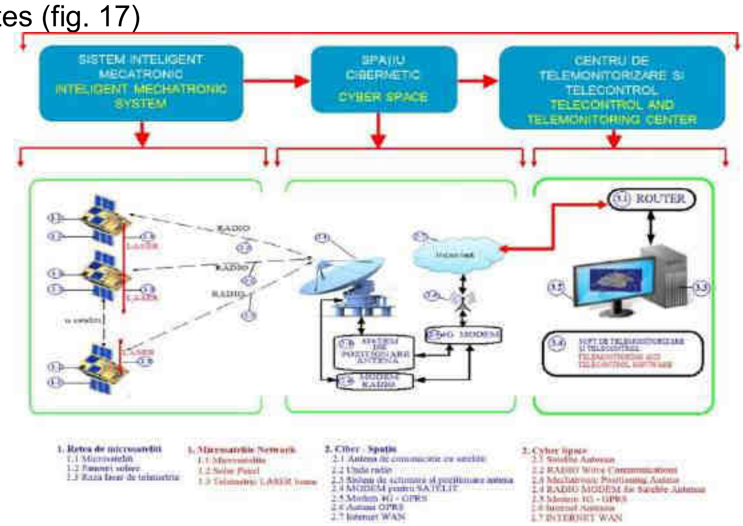

Fig. 17. Smart mechatronics system and cyber-mixmechatronics integrative for network of micronanosatellites

- **Concepts of activities in Industry 4.0**
- ”Circle” of activities in Industry 4.0 (fig. 18)

Fig.18. ”Circle” of activities in Industry 4.0

- ”Cube” of activities in Industry 4.0 (fig. 19)

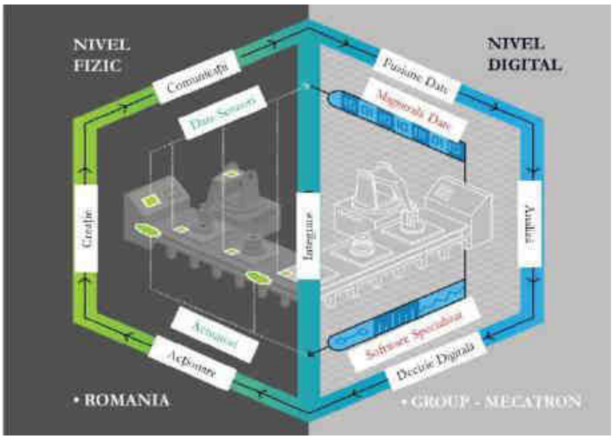

Fig.19. ”Cube” of activities in Industry 4.0

- ”The architecture” of Industry 4.0 (fig. 20)

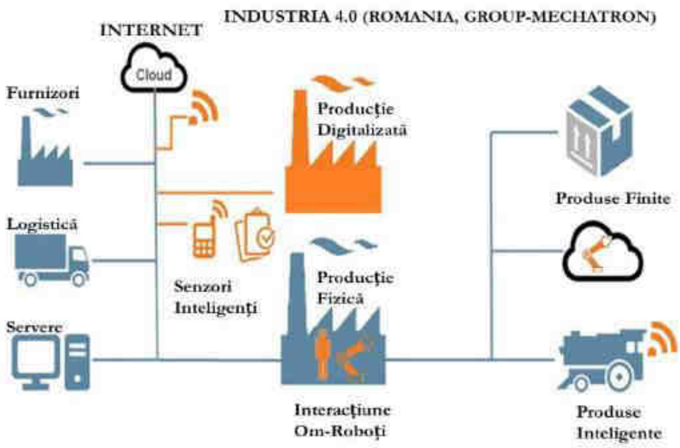

Fig.20. ”The architecture” of Industry 4.0

- Innovative model for Digitizing an enterprise (fig. 21)

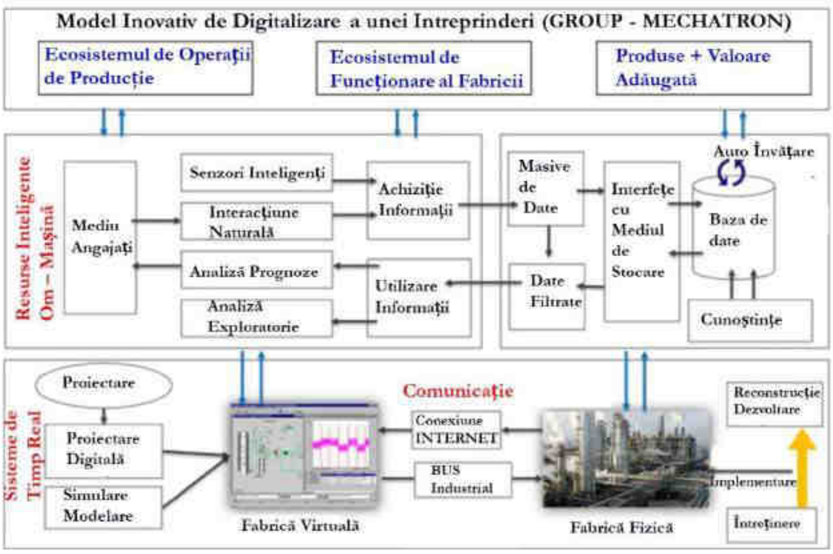

Fig. 21. Innovative model for Digitizing an enterprise

➢ Simplified structure Digitizing Enterprise (fig. 22)

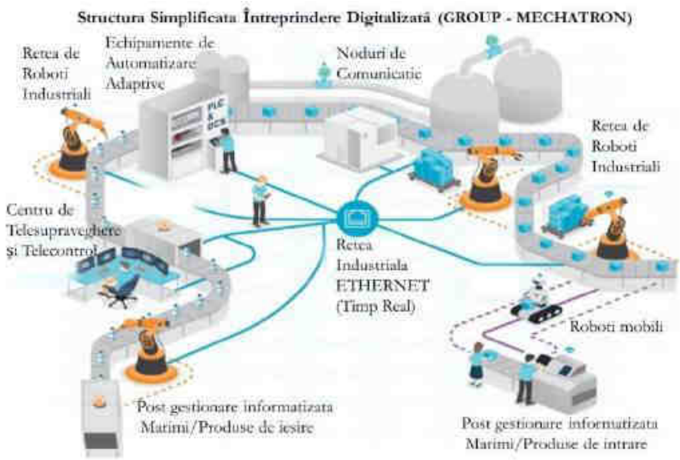

Fig. 22. Simplified structure Digitizing Enterprise

➢ Simplified scheme Automotive Digitized Factory (fig. 23)

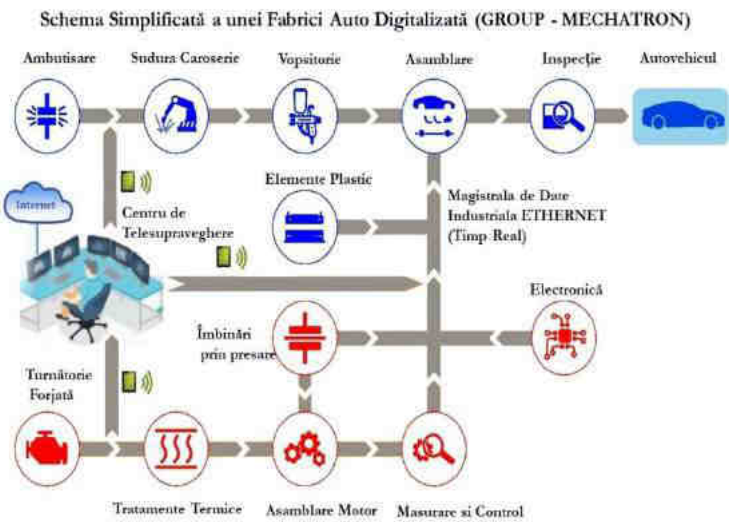

Fig. 23. Simplified scheme Automotive Digitized Factory

➢ Simplified scheme Energetic Digitized Factory (fig. 24)

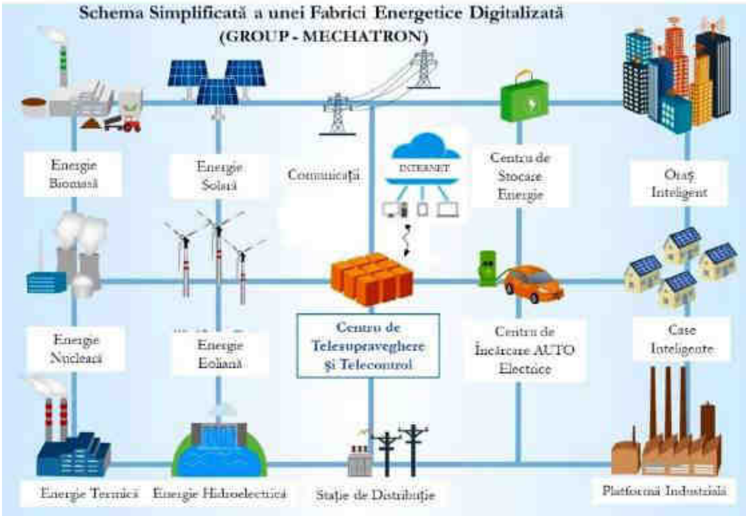

Fig. 24. Simplified scheme Energetic Digitized Factory

➢ Simplified scheme Digitized Cheese Factory (fig. 25)

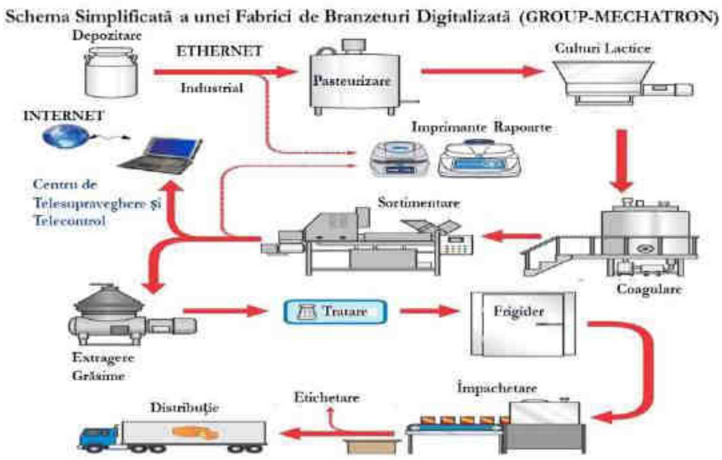

Fig. 25. Simplified scheme Digitized Cheese Factory

5. The advantages of Industry 4.0

• **time:** Each employee becomes more efficient, productive and qualitative;
• **minimal cost:** through very precise data in the right and necessary context;
• **Flexibility:** by creating flexible systems ready for change and for new opportunities;
• **integration:** digital manufacturing involves the simultaneous development of the product and the production process.

The Advantages of Romania in the perspective of Industry 4.0

Romania is in a favorable position for Industry 4.0, as follows:

- **Represents** the best destinations for investments in new production facilities, by returning industrial production to Europe;
- **has** the well developed automotive industy, with a wide chain of suppliers in the field;
- **has** the fastest internet connection from Europe;
- **there** are in România, many specialized firms in TIC, many research institutes, with domains in Mechatronics and Cyber-Mix-Mechatronics and staff with professional skils;
- **etc.**

6. Conclusions

The scientific paper shows that industrial digitization will have both a horizontal and a vertical impact on the value chain, which implies that on the one hand companies need to integrate and digitize their vertical data flow much better to the development of products and purchases to the processing and logistics of transport, and on the other hand, presupposes a horizontal collaboration with key suppliers, customers and other partners in the value chain.
Companies, businesses and industry in general in Industry 4.0 should be involved in the development and deployment of complex digital solutions, and all committed staff have total confidence that industrial digitization is the most appropriate and necessary choice for the future.
The scientific work also synthesizes the beginnings of industrial digitization by introducing intelligent concepts and solutions proposed by the author for mechatronic and cyber-mixmechronic integrated systems that are or are to be implemented in different industrial sectors (automobiles, aerospace, agriculture, medicine, etc.) from Romania.

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A CASE STUDY RELATED TO COUNTERFEITING A PATENTED PRODUCT

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Abstract: *The current paper shows a case study based on the judicial expertise in a conflict of interest related to the infringement of a patented product, a connection piece which ensures the transition from the pipes of polyethylene to those of metal, for the networks of natural gas. For an accurate description of the case, the authors illustrate the technical and judicial problems that led to disputes, and they refer to the way in which the expertise was completed and the case solved.*

Keywords*: Intellectual property disputes, patented products, expertise, transition piece*

1. Introduction

The design and completion of the systems of supply with natural gas is regulated by specific technical norms. At the end of the connection of polyethylene, the following transition pieces are used for

- DN greater than or equal to 63 mm, heads of connection without protection anode (reiser), where the polyethylene/steel transition is achieved above the soil, at the level of the vertical end of the connection;
- DN greater than 75 mm, heads of connection with a specific type of insulation or equal and protection anode, which have certified and technically developed components.

Figure 1 shows the head of a connection without the protection anode, which has the following components: 1-polyethylene pipe; 2-sealing; 3—metallic wire; 4—protective pipe (steel); 5—pipe of polyethylene; 6—transition piece polyethylene-steel.

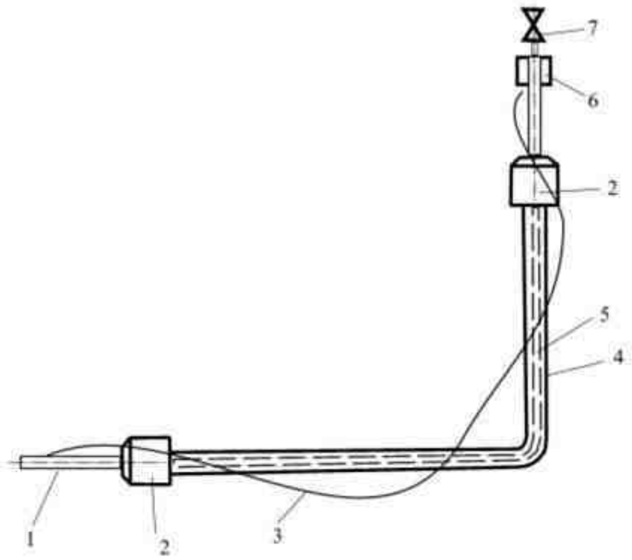

Fig. 1. Head of connection

2. The technical problem

A group made of four inventors, which included a certified one, conceived and patented a transition piece 6, called by the authors PAT1 (Figure 2).

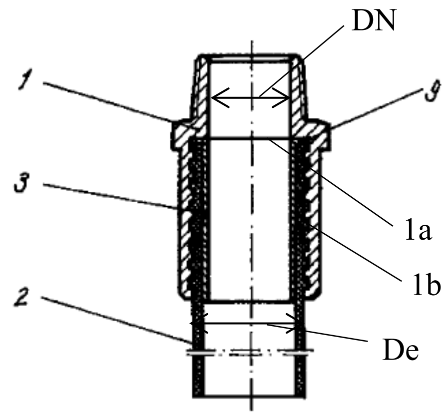

Fig. 2. Transition piece (PAT1)

The connection piece PAT1 presented in Figure 2 consists of a crimping between the metallic nipple 1 and the polyethylene pipe 2, using an intermediate piece 3 made of copper. When the invention is applied, the polyethylene pipe 2 is welded to the underground main pipe, which is also made of polyethylene. Nipple 1, made of steel, is equipped in its inner side with bore with two diameters DN/De and a shoulder 1a. On the De diameter part, there are applied a number of radial channels marked with 1b.
The technology of completion of the connection between the polyethylene pipe 2 and the metallic nipple is completed in accordance with the schematic in Figure 3.

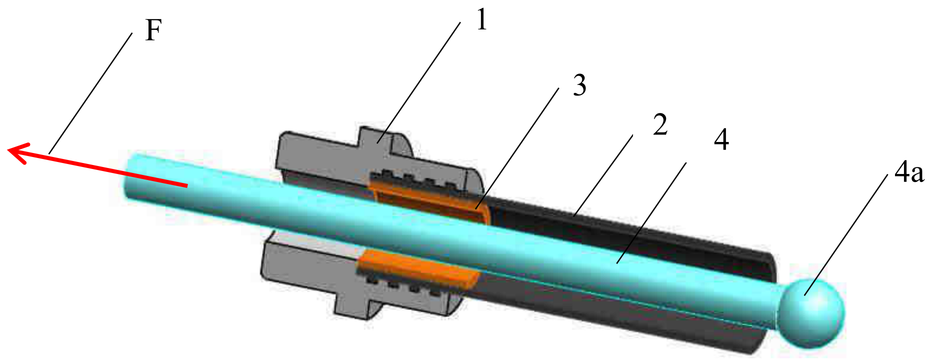

Fig. 3. The procedure of crimping

At an end of the polyethylene pipe 2 there is introduced the intermediate piece 3, which is then introduced, together with pipe 2, in nipple 1.
Rod 4 is introduced through the polyethylene pipe and it is connected to a hydraulic system of traction, which exerts force F. The spherical part 4a of the rod crosses the intermediate piece 3, it deforms it and ensures that the polyethylene pipe fits in the radial channels 1b, making thus possible the polyethylene-steel connection.

After a while, three of the inventors that completed connection PAT1 patent a new transition piece, called by the authors PAT2 (Figure 4).
The connection PAT2 consists of a nipple 1, equipped with circular grooves in which the polyethylene pipe 2 is crimpled with an intermediate piece 3, made of copper. On the outer side of nipple 1, there is mounted a metallic pipe 4, and the drainage tube 5 is mounted onto it. The potential leakage of gas in the area close to the connection enters the drainage tube 5, through area f between the pipe 4 and the pipe 2, and exits it through hole d.

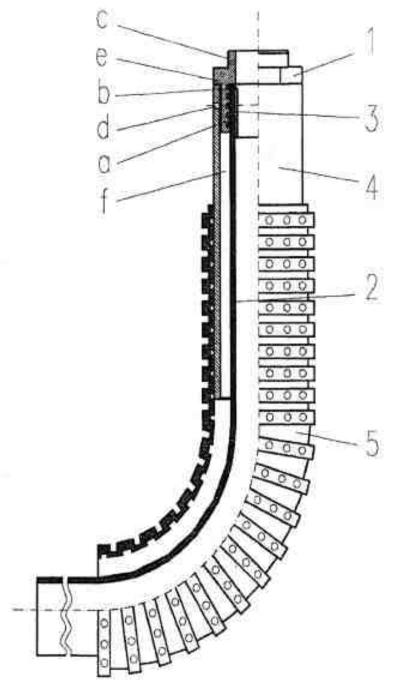

Fig. 4. Connection for the gas networks (PAT2)

3. The judicial problem

The four inventors that obtained patent PAT1 (Figure 2) used in common the invention for a while, as partners of a company A. Due to misunderstanding, one of the inventors, the owner of the patent, sets his own company B which produces and sells the patented product, which is similar to the one produced by company A, but, as a result of not paying the fees for holding the patent, he loses his rights of patent ownership. The other three associates conceive and patent a new transition piece (PAT2), which includes the technique of the former patent, which they improve, by adding a drainage tube, whose role is to tap any potential gas leakage (Figure 4). After obtaining patent PAT2 for the improved connection, company A contacts the gas supplier, who decides to accept, beginning with that moment, only the use of the connections with a drainage tube, in accordance with PAT2. Company B adjusts to the circumstance and produces the improved connection, in accordance with PAT2. As owner of the new patent, company B complains to the Prosecutor’s Office of the county’s High Court of Justice and asks that the production of the improved connection by company B be forbidden.
In order to solve the dispute, the court relies on technical experts, who are asked to answer the following objectives:

A. If there are differences between the description of the invention, the claims and the drawings of the two patents PAT1 and PAT2 in the documents regarding the invention, and if the answer is affirmative, the expert is required to specify their nature.

B. If company B produces and sells the product under the name “Transition piece for gases” based on patent PAT1, or on patent PAT2.
C. If the products made by company B, “Transition piece for gases”, and those made by company A, “Connection pieces for gas networks”, products gathered by the prosecution, are identical, and if they are not, the experts are required to specify the nature of their difference.
D. If PAT2 could have been completed based on the procedure and the device claimed in PAT1.
E. If the product "Transition connection for gases” made by company B based on PAT1 can be a component of the product "Connection for gas networks” made by company A in accordance with PAT2, or vice versa.
F. If the technical solution of evacuation of the accidental gases from the area of connection, by equipping the end of the connection with a drainage tube, appears in the claims of both patents, and if it is an element that differentiates them;
G. If the claims of the patents owned by the two parties do not refer to the technical solution mentioned in E, the expert will specify whether the equipment of the connection piece with a drainage tube such the one mentioned by the party whose patent does not include this claim is the object of counterfeiting.

4. Completion of the expertise

4.1 The comparative analysis of the two patents

In order for the expert to identify the differences between the two products, there have been analysed the description, claims and drawings of patents PAT1 and PAT2. To highlight the conceptual difference between them, there are shown parallelly (Table 1) the representative figures and the claims of the analysed patents. According to Art. 34 of the law, "the extent of the protection granted by the patent is determined by the content of the claims to be interpreted in relation to the description and the drawings of the invention”.

Table 1: Analysis of the claims regarding the explanatory drawings

PAT1- 4 inventors (owner: 1 inventor)	PAT2 – 3 inventors (owner: company A)
Selected representative drawing: Figure 2	Selected representative drawing: Figure 4
Number of claims: 5. Claims 1, 2 and 3 refer to the transition piece PE-Steel, in two variants of completion, and the other ones refer to the procedure and the completion of the device. **R1. Independent (main) claim:** Transition piece, **characterized by the fact that** it is equipped with a connection nipple (1) equipped with a number of circular grooves 1b and a polyethylene pipe 2, which is crimpled to the nipple by means of an intermediate piece 3. **R2. Dependent claim:** Transition connection, according to claim 1, **characterized by the fact that** the number of the grooves 1a is between 6 and 8 for DN=1 inches.	Number of claims: 2. **R1. Independent (main) claim:** Connection for the networks of gas including a nipple 1, a pipe of polyethylene 2, an intermediate piece 3, a protection pipe 4 and a drainage tube 5, **characterized by the fact that** nipple (1) is equipped in its inner side with a number of channels on which pipe 2 is sertized by means of a cylindrical ring 3, while it is equipped in its outer side with a shoulder for the protection pipe 4 and a part c with thread, which is a well-known solution in terms of tap mounting. **R2. Dependent claim:** The connection for the gas networks, in accordance with claim 1, **characterized by the fact that** the protection pipe 4 is equipped at the end of the superior end with exhaust holes d, while at the inferior end, it is covered with a drainage perforated tube 5, which collects the accidental leakage of the gases.

The selection of the element components that are identical from a functional and conceptual point of view:

nipple (1) vs. nipple (1)

the polyethylene pipe (2) vs. the polyethylene pipe (2)

the intermediate piece (3) vs. the cylindrical ring (3)

circular grooves (1a) vs. radial channels (a)

4.2 Answer to the questions

Answer to question A

Between PAT1 and PAT2 there are differences: The technical solution revealed in PAT2 improves the one in PAT1, by adding the following elements:

- protection pipe 4 (reference which has to be stipulated, based on "The norm act for the design and completion of the natural gas supply systems" I6-PE 2000; I6-PE 97)
- the perforated drainage tube, known in itself, and whose role does not change within the current invention, its role within the invention being that of ensuring the drainage of any potential leakage of gases.

Answer to question B

The product of company B was made based on PAT1, but the "drainage tube", provided in the dependent claim of patent PAT2, was added to it.

Answer to question C

The products do not differ qualitatively and conceptually.

Answer to question D

Both products can be completed using the same procedure and device. It is hard to imagine a different technological process suited to this product. For the device of application of the axial force, other technical solutions can be found.

Answer to question E

Yes, as the transition connection PE-Steel is conceptually identical in the case of both patents, and the sizes are imposed by the diameter of the pipe (DN), by means of technical measures.

Answer to question F

No, this solution appears only in the patent PAT2 and this is the element that sets the difference between the two patents.

Answer to question G

Based on the research completed, the expert finds that the equipment of the connection PAT1 with a perforated drainage tube 5, known in itself, and whose role does not change, does not constitute counterfeiting.

Moreover, taking into account the fact that PAT1 preceded PAT2, and the identity of the two solutions of crimping, the examiners should not have accepted the claim (R1) for the patent PAT2, and the inventors, knowing the solution presented in PAT1, avoided on purpose (ill-meaningly) the reference to PAT1 in the documents cited in the state-of-the-art section in the description of PAT2.

To the same extent, claim (R2) of the patent PAT2, which sets the difference between the two patents, is claim dependent on claim (R1). If R1 was granted in an erroneous manner, this can be cancelled by a court action. Under this circumstance, the dissolution of the main claim involves the dissolution of the dependent claim, which takes over the provisions of the main claim.

5. Conclusions

In what follows the authors show the important conclusions that can be gleaned from this case:

A. The complaining part, company A, committed the following mistakes:
   - In the documentation of PAT2, it should have made reference to PAT1, and it should have insisted more on the difference between the two patents, in order for it to obtain an independent claim regarding the use of the protection pipe and of the drainage tube;
   - It did not understand the role of the claims in the extension of the protection;
   - It did not rely on an expert when it completed the documentation for PAT2.

B. The company B and the owner of PAT1 did not defend themselves appropriately, as they committed the following mistakes:
   - They did not hold in force PAT1; the owner could have prohibited company A to use it, or they could have used it to negotiate its use in exchange for PAT2;
   - They did not study the documentation PAT2 after its publication, and they did not react against the patentation based on the lack of novelty of the crimping, revealed in PAT1.

C. Based on the expertise, the court did not have reasons to forbid company B to produce the transition piece equipped with drainage tube, as shown in the dependent claim of PAT2.

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TRENDS IN THE DEVELOPMENT OF HYDRAULIC DRIVES

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Abstract: *The article represents an attempt by the authors to define the development trends of the field in the following years. The authors indicate the main directions, drawn from the scientific content of the specialized symposiums and from the news presented by the renowned companies with concerns and production in hydraulic drives. Trends considered are not the only ones and probably some are not the most important, but at some point, they have been a worthwhile event. These trends are extremely important for the Romanian hydraulic research and education.*

Keywords*: Hydraulics, hydraulic drives, directions of development, trends*

1. Introduction

During history, the Hydraulic has always been spoken, each time it was clear to the reader that it is about water. Under this name (Hydraulics) there has been talk and talk over the last years about the hydrostatic actions, which have only begun to be used on a large scale after 1930, when the serious series of gear pumps and especially the piston pumps axial. Other approaches refer to “Fluid Power” and wider refers to the use of the term "fluid engineering".
It is very important to know the stages of hydraulic development over time in order to determine and then use the development trends of the field for the future. It is essential for the specialists from this field of engineering to have a main direction of activity, consistent with the major direction that others are going on, without removing the possibility of developing new ideas, possibly creating new directions of research or equipment.
Hydraulic drives have important advantages. This is the main reason they find a wide spread in the construction of the equipment; the most important of which are:

- the easy achievement of large forces and powers with simple and small gauge mechanisms, as well as the easy command of these large energies with the help of hydraulic equipment and permanent control over the forces acting in the system;

- the possibility of placing the hydraulic drive motors in convenient positions, as well as the control elements;

- high power amplification and good frequency response;

- the possibility of continuous variations on a wide range of linear or radial speeds during the operation of the machines;easy reversal of motion, without high dynamic effects or demands, with relatively simple devices, which allows a substantial reduction of reversal time and high reversing frequencies;

- l ow wear of the equipment due to the fact that the liquid used also serves as a lubricant; it also has the role of cooling agent, giving away the heat from hydraulic equipment to passing through a heat exchanger.

The advantages listed here have been discovered over the years, both on the basis of the practical results obtained and on the basis of the theoretical studies on the important directions of research and analysis.
All these directions, as well as many others to be done, have imposed and require that engineers and technologies of creation and exploitation work in interdisciplinary teams with respect to hydraulic, electrical and electronic engineering, automatic and sensory control, computer hardware and software, mechanical engineering and materials science, etc.. The current feature of products involves innovative character, complexity and individuality, friendly exploitation but also the realization in economic conditions that allow entry and maintenance on the market.
The main applications of hydraulic devices are found in the field of machine tools, agricultural machines, machines and terrain equipment, mining and metallurgical complexes, but also in applications of turbine power machines and hydraulic pumps, naval propellers etc. Other high applications techniques are those in spacecraft and airplane systems. It is obviously that all those working in the field have to be aware of the major concerns in the entire thematic area of the hydraulic shareholders. In this sense, from the notion of ideas, some, which have been considered once, as main trends, we can now consider, in some of them, stages in the development of the field. For example, we can consider some ideas that have passed from the phase to the stage.

2. Stages of hydraulic development

2.1 Converting complex technical systems into hydraulic in order to achieve great forces in the process of operation.

Being a start when counting movements without counting consumption, the period lasted for many years and we have to accept that it is still going on today. If in the early period the hydraulic on the water was discussed in this new stage, the use as the main working fluid of the mineral oil obtained by the processing of crude oil was outlined. Reducing weight and gauge at the same time as increasing forces and driving moments was an important but not decisive concern.

The introduction of hydraulic power in the sectors of complex machinery and equipment from the iron and steel industry, mining and especially machine tools has made the need for hydraulic equipment to grow and extent the number of manufacturers in various countries of the world. A real boom was the appliance of hydraulic systems on mobile machinery and tractors, agricultural machinery, construction equipment and transport vehicles.

2.2 Diversification of hydrostatic equipment.

Very important was the period of occurrence of axial piston pumps, pallet pumps, radial piston pumps, distribution and adjustment devices. Interestingly, although hydraulic cylinders have appeared for a long time at this stage, manufacturing has focused on standardizing sizes and performance along with functional diversification.

This diversification of the equipment nomenclature, correlated with the increase of the production, has made the hydraulic drive extremely widespread. The rapid development of the hydraulic (hydrostatic) equipment industry has led to a wide variety of solutions and especially to shapes and sizes.

The situation was interesting and useful until the necessity of maintaining or replacing appliances. At that time, it was known, for a long time, that each producer had his own projects, which even though they resembled the others as a function did not resemble dimensions and as such were not interchangeable. This incompatibility has led to the emergence of national standardization organizations, such as the Deutsches Institut für Normung eV, the ANSI (American National Standards Institute) or, in Romania, the Romanian Standardization Institute. This step was not enough, and as a result, ISO (International Organization for Standardization) and CETOP emerged. All countries affiliated to these international organizations comply with the required norms, even if they are accepted that the standards are indicative and not binding. Obligation is given by recipients who buy only equipment according to international standards.

In Romania, standards have been aligned with ISO standards since 1968 when national manufacturers have become mandatory. From the development of equipment specific to some subdomains, both in function and size, a fabrication of both nomenclature and dimensions to allow for interchangeability and interoperability was made. In this way, the distribution, adjustment and safety equipment have not only become the functional equivalent, but also easy to replace in installations, irrespective of the company of origin. A major role was played by the European organization CETOP, which, by setting international standards, has supported the standardization and typing of hydraulic equipment, symbolizing the equipment's side-setting at European level and as a consequence also at a global level. This standardization has not reduced the nomenclature of appliances, and even allowed an orderly diversification of manufacturing.

2.3 Achieving adjustable flow pumps.

The stage is more qualitative not historically significant, but especially of quantity and production. Surely the stage is important through its consequences that have led to a reduction in energy losses.

Variable flow pumps can be adjusted manually or with automatic systems. The manual adjustment is done by simple mechanical mechanisms such as a worm screw connected to the hydraulic component and ending with a handwheel. The manual adjustment is imprecise, has a slow response and obviously does not allow any automatic control in case of load variation. This elementary system must not be confused with the mechanical adjustment encountered when the variable cylinder of the radial piston and blade pumps is required, because in these types of pumps the initial manual adjustment sets the flow from zero according to the maximum pressure of connected circuit.

Anyway, it will be obvious that the components of the control systems have almost the same principle of flow or pressure regulation, while simple details, such as the different stiffness of the springs, influence their application

Another problem is choosing the most appropriate term, between "control" and "compensator" [7]. Even though the first is appropriate for each situation, most of these components actually compensate for the variation of a parameter by changing another parameter: for example, the decrease in flow in a constant power regulator is offset by the increase in pressure; however, we notice that a flow stop controller (flow regulator) does not compensate very much. As a consequence, the flow is constant even at variable pressure. Therefore, the word "compensator" should be used with appropriate caution in those applications where there is a real balance between real pressure and flow.

2.4 Realization of servovalves and proportional hydraulic valves in series production.

Electro-hydraulic equipment used for pressure and flow control are divided into two categories: proportional hydraulic devices and servo valves.

Servo valves were the first control equipment used in electro-hydraulic proportional systems in the early 1940s (1943). Servo valves are currently reliable equipment and have a robust construction due to the major improvements they have made over time. However, their production costs are very high and require special working fluid filtration conditions due to very small games but also to their mechanical complexity. Consequently, this type of high-performance electro-hydraulic equipment is suitable for use in complex machines where dynamic performance or special precision is required. Major research has been done to study the static and dynamic behaviors of the basic components of the devices, namely hydraulic resistors. As a result, increased work pressure, reduced hydrodynamic forces, improved dynamic behavior of appliances. Other aspects are related to the improvement of command actuators and the reduction of moving masses (pistons).

The proportional hydraulic valves since 1960 can be regarded as a technological compromise between servo valves and ON / OFF electro-hydraulic devices. These are somewhat similar to electromagnet-controlled drawer dispensers and provide good performance in terms of regulation, steering and control, with electronic control modules.

Unlike the ON / OFF distributors, their electromagnet controls the positioning of the drawer in a proportional way, which means that the distributor passage openings are opened depending on the size of the control current

2.5 Using mathematical modeling and simulation for the development and optimization of hydraulic automation or drive systems.

In hydraulic drives, as in fact in all technical fields, mathematical modeling represents an action of the representation of physical phenomena based on a set of mathematical formulas developed in physics and fluid mechanics. The mathematical model can answer our questions about the static and dynamic behavior of the analyzed system. These explanations lead us to the idea that there must be a complex system, a well-defined installation, for which mathematical equations can be written to represent as accurately as possible the reality of the final product. Mathematical modeling employs simplified mathematical equations of real physical systems, motion and control processes of hydraulic systems. The use of modeling has naturally been intertwined with numerical simulation, since it is often too expensive to investigate the hydraulic systems at the final physical level. And then the analysis of reduced functional models and, moreover, much more is made.

According to VDI 3633, the simulation concept can be defined as follows: "Simulation is the rebuilding of a system with its dynamic processes into an experimental model to acquire transferable knowledge on reality". This working method allowed specialists to reduce the costs as a result of the experimental validation of areas with major operational importance during the development process. In this way, a special optimization of the simulated and simulated system was obtained, but also allowed a higher development of the analyzed functional constructions.

2.6 Including hydraulics and pneumatics as basic elements in mechatronics.

The name "mecatronica" was first used by Tetsuro Mori, senior engineer of the Japanese company Yaskawa in 1969. Professor Okyay Kaynak believes that mechatronics is a synergistic integration of mechanical engineering with electronics and intelligent computerized command in the design and execution of products and processes. He considers that a mechatronic system has two main components the control system and the command system. Interestingly, the author introduces sensors and actuators in addition to the mechanical component. In the control component introduces a perception subsystem, an execution system and a cognition subsystem. Conventional microprocessors, artificial neural networks, fuzzy logic, and probabilistic computation are the main elements used in the information processing and decision-making subsystem.

From the very beginning it was found that the mechanical basis of the mecatronic complex is very well represented by the hydraulic and pneumatic drive equipment. Given their qualities and applications, it is appreciated that the extreme good for electronics, sensory and informatics are hydraulic systems, but especially pneumatic

2.7 Development of operating systems, from very small to very large, driven by specialized software

This phase, started for several decades, coincided with the development of the use of hydraulics in almost all technical fields. The stage had two essential components, namely the development of multi-dimensional manufacturing simultaneously with the miniaturization of the equipment. There is no confusion between miniaturization of equipment and use in a system of equipment of the appropriate dimensional dimensions. If the first direction relates to the development of resistance calculations and the use of good quality material for component manufacturing, the second direction is to obtain the hydraulic system (flow and pressure), based on the calculations as close as possible to the technical requirements of the complex, hydrophilic equipment. Even in the early phases of hydraulic and pneumatic use, it has become necessary to combine with command electronics, often in an extremely compact unit, so switching to the use of computers and specialized software has made it natural without any problems.

3. Trends

Current trends are pursued in a number of directions, most important of which are related to reducing energy losses, increasing functional performance and reducing production costs by using new technologies and materials.

3.1 Reducing energy losses by developing solutions whereby the hydraulic energy produced is very close to the energy consumed in each phase of the car's operating cycle.

One of the major problems of the hydraulic system is the large energy losses at the installation-system level.

Overall yields ranging between 30% and 80%, meaning that only about half of the electrical or mechanical energy used is already a major problem, which will soon lead to a dramatic drop in the use of hydraulics. The solutions seem to be using current equipment in installations based on rigorous calculations, but also designing new equipment, such as digital hydration, which will significantly reduce energy losses.

3.2 Increasing the performance of hydraulic equipment by using new technologies and intelligent materials.

In the new situation, the reduction of gauges and masses will be passed as an essential requirement of the research and design processes.

3.3 Finding working fluids and sealing elements that can be used in systems with high fluctuations in speed, temperature or extreme climatic conditions.

This "older" trend in amplification is based on the action of replacing mineral oil in hydraulic systems with vegetable oil-based liquids that are more environmentally friendly (biodegradability of nearly 80% compared to mineral that has this characteristic 20%). As the basic material is used, for example, rape oil, which from a chemical point of view is a natural ester oil consisting of alcohol, glycerin and carbonic acids. These oils have superior lubricating properties, high viscosity stability at temperature variation and flashing point. Disadvantageous in them is low aging stability, hydrolytic maladivity and low temperature behavior.

When choosing the working fluid, the following factors must be taken into account:
- Temperature range of the environment and the temperature gradient within the specific limits;
- The maximum temperature that may occur during operation;
- Working pressure;
- Time required to operate the plant without changing the fluid;
- Limits allowed for pollution;
- Difficulties in changing the fluid from the installation, and not only from the tank;
- The type of materials in the installation component with which it must be compatible, in particular the sealing elements;
- Price and procurement difficulties.

3.4 Introduction of hydraulic or pneumatic systems in clean, renewable energy production equipment for both power and control functions and automation.

In recent years, there has been a marked increase in the development of renewable energy technologies. In all variants of "green" energy production, hydraulic or pneumatic drives are increasingly found, and in many situations, they are determining the quality and quantity of technology and production. In this regard, we present some areas where hydraulic and pneumatic systems and equipment must intervene. In the case of wind or wind power generation, wind turbine blade tuning or turbine power transfer or wind turbine positioning are or will be hydrophilized. When using photovoltaic panels, it is possible to orient them to the sun by means of automated hydraulic systems. In the case of obtaining energy from the wave energy, the energy transfer from the wave to the shore equipment will be done with the help of the hydraulic drive. Even with the use of biomass to obtain thermal or electrical energy, the pneumatic equipment is increasingly used.

3.5 Digitalization of hydraulic systems

If we take into account the basic ideas of international specialty conferences, digitization in hydraulically-operated industrial plants is becoming increasingly important. However, there are still many things unclear both as a definition and as a way of solving.

Digitization is used in all phases of research, design, production and maintenance of hydraulic equipment and systems, but also in structuring them. Mathematical modeling and numerical simulation are closely related to computers without which we cannot discuss serious achievements nowadays. t is very important that conducting computers with systems that are equipped with hydraulic systems or standard servo-hydraulic systems will lead to the inclusion in the installation of analogue-digital or analogue digital converting equipment. In the meantime, the analogue drive will only be maintained in sections of the system requiring very high speeds and precisions that can be developed as independent on the respective areas, but the overall drive will be digital with the computer or other similar equipment.

3.6 Switching to the manufacture of digital hydraulic equipment and systems

Since the last few decades have gone into an intensive campaign to reduce energy losses as the safest method of reducing energy consumption, it has had to go along with the other systems (especially electric) and the hydraulic system to look for bringing of the energy consumed near the amount of energy used. A solution to this problem also seems to be digital hydration. Digital Hydraulics means the hydraulic system in which at least one hydraulic element has digital functioning (behavior). So, the digital hydraulic does not represent the standard hydraulic, which is applied to some electronic functions of transforming the analogical (continuously) functional parameters into numerical parameters. As a result, there is a clear distinction between the digitization of hydraulic systems and the use of digital hydraulics. Theoretically, digital hydration has either parallel distribution or commutation distribution. We must note that there have already been technological, technological applications in which digital hydration is used. If at the equipment level there are clear, practical achievements at the level of systems (installations) are still researched

3.7 Increased reliability of hydraulic equipment and systems through careful control of heating, vibration and friction.

Hydraulic equipment and systems have become in many situations a basis for the operation of complex automation with high automation. It is important that besides proper operation, in accordance with the technical requirements of the general assembly, there is also a well-studied part and achieved by the safety in operation, thus functioning without failures. In the case of hydraulics, the malfunction is not only of destructive type but also of the type of output within the prescribed limits of the functional parameters.

In this respect it is necessary to use the most efficient transducers, placed in the places that allow highlighting the variations of parameters which may affect the good functioning or can lead to rapid deterioration of the hydro-pneumatic drive system. Excessive heating or vibration is a deviation from proper operation and are treated as failures that will affect the proper operation of the machine as a whole. As relative assemblies there are frictions that lead to wear, which in turn lead to changes in operating parameters outside the prescribed limits, so when defects occur. In all these situations, it is necessary to have the possibility to prevent the malfunctions by including at the design stage some sensor-based methods and / or equipment that will detect in real time the first symptoms of system output from normal operating parameters.

3.8 Integration of Hydraulics and Pneumatics into the Industry Concept 4.0

Industry 4.0 was born in Germany and represents, besides the name of a Government Research Council, the name of a strategic technical project, as well as the name of a research platform. Expression 4.0 means that it would be the initiation of the fourth industrial revolution and that it is based on software products. Whether or not we are an industrial revolution will be blazing for the future, but as we are discussing a revolution in digital networks, platforms and technology where man is totally involved, that is clear today. There are similar initiatives in the world, but with different names. In the USA there is an Industrial Internet Consortium (IIC), in Japan there is an Industrial Value-Chain Initiative (IVI), in France there is Future Industry.
An important role is played by the Industrial Internet of Things (IIOT) that describes the "fusion" of computational power with mechatronic systems and their interconnection over the Internet. In the field of hydraulic equipment manufacturing, the underlying issue is the commissioning process, which is mostly done manually and which even in machinery insertion is done manually, which ultimately leads to increased manufacturing time and easement errors that affect the quality of the final product. The process of putting into operation during the third industrial revolution involves limitations in the areas of communication, information, coherence, the existence of a relatively large number of manual activities, and too many individual actions that reduce profitability and flexibility. Most of these deficiencies are addressed within the Industry 4.0 concept.

4. Conclusions

The article wanted to present the domains and sub-domains of interest to the researchers of the three units of which the authors belong, even if for other specialists there are other or other sub-domains of interest in perspective. These trends, transformed into research directions, serve to efficiently use the existing scientific potential at this time.

The new trends in automation and robotics, with increasing strengths and moments, and reduced gauges and masses, drive strong changes in drive hydraulics by using the latest applications of electronics, intelligent material science, manufacturing and treatment-related technologies in the field of explosion and increasingly sophisticated software and software.

Research over the coming years will have to address system-level problems, use all the novelties in design, the use of new materials, and new technology-efficient technologies.

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