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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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