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# FLUID POWER, INDUSTRY 4.0 AND CIRCULAR ECONOMY

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***Abstract:*** *This article seeks to define some modern concepts regarding the economic and industrial development and make some general assessments on the framing of hydraulic drives in these approaches. The main connection of sustainable development with the circular economy and the 4th industrial revolution is highlighted, with arguments as close as possible to the engineering acceptation of social development. The material takes the basic elements of the definition of the three directions of analysis and makes brief remarks regarding some possible ways of aligning our area of activity with the current global trends.*

***Keywords****: Sustainable development; circular economy; Industry 4.0; scientific research; development*

## 1. Introduction

In recent years, scientists have noticed some wrong directions that mankind, in its chaotic and, above all, mercantile development of the 20th century and the beginning of the 21st century, is going in. It is a good thing that there is a massive increase in production and consumption with no regard to costs, but isn't it true that lack of control leads to more serious problems and with irreparable consequences on medium and long term? The first serious warning occurred in 1970 and 1972 in Sweden and continued especially through the work of the World Commission for Environment and Development led by Gro Brundtland. In course of time, it has been accepted that sustainable development is the development that seeks to meet the needs of the present, without compromising the possibility of future generations to meet their own needs. In 1974 Lester R. Brown showed that there is a tendency to deplete natural energy resources, raw materials and even food, that mankind consumes renewable resources at a rate higher than their regenerative capacity and there can be noticed a physical deterioration and an accentuated pollution of some vital factors such as water, air and soil. One of the answers is the emergence of the circular economy model which involves first and foremost the idea of reducing waste and recycling materials, possibly subassemblies. It is necessary to give up the habit of throwing away the products that have reached the end of their lifespan and move to re-introducing them into the economy as assemblies or parts. An essential role in the change of mind is played by sustainable scientific research (and technical-scientific development) which must address the problems at global level, possibly only at a regional level, but in a way that will lead to smart growth. The spectacular increase of the scientific and technological level of the production has led a new form of development, known in our country as Industry 4.0. This industrial revolution also started from the fact that for several decades the manufacturing was transferred to Asia, so today the question of Europe's re-industrialization is posed for sustainable development. The problem of the technical-economic development of the countries is not just Europe's problem; it is felt in many countries of the world where it got all kinds of names, of which we mention IIC in USA, Industrial Value-Chain Initiative in Japan, Industrie de futur in France, and also a similar initiative in China.

## 2. Circular economy

In 1976 Walter Stahel and Genevieve Reday au elaborated for the European Commission a report called "The Potential for Substituting Manpower for Energy" in which they sketched the first model of circular economy through which the connection is made between design, manufacture, consumption of products and waste management process when these products exceed their lifespan. This signal was one of the first warnings regarding the need to give up the economic model of waste disposal in exchange for a system promoting the reuse, repair, reconditioning and

recycling of seemingly outdated materials and products and the need to turn waste into raw material. This new concept helps the economy use fewer new materials and raw materials and create a new closed loop system through which existing products to be reused. While for technical and industrial products things are almost clear, for food, textiles, pharmaceuticals, etc. there is no repair, reconditioning, reuse, but there is the variant of recycling and extraction of special elements such as metals from household or biological waste. Many times, the question arises why so many complications are needed for something that seems unimportant. To give the correct answer we need to see that the global population grows, that the waste of materials also grows, while the essential raw materials are limited and already many countries no longer have them at their discretion. Early since 2015 the European Commission has adopted an action plan with 54 measures for the transition to the circular economy, through which to proceed to the correct management of waste.

There are a few things that should become principles of life for mankind, such as the idea that waste is raw material and not garbage, or energy should be obtained mainly from renewable sources, or to understand that it is important to use long-lifespan objects and reject disposable ones. In order to go in the direction of "zero waste" we must act from the design stage. In the field of hydraulic drives for a long time there are elements that can be included in the working methodologies of the concept of Circular Economy. In this regard, the maintenance, remanufacturing and metallizing practices can be analyzed.

Maintenance is defined as a combination of all technical, administrative and managerial actions that are taken during the life cycle of an equipment in order to maintain or restore its ability to perform the desired function (acc. to the European standard EN 13306). On this line, maintenance includes measurement activities, operation control, testing, fault detection, repair, adjustment, replacement of elements or subassemblies and service. It is obvious that repair or service activities are part of a complex action called maintenance and they can be included as part of the circular economy as well, given that they already exist in industrial practice and with ancient and widespread applications in hydraulic drives.

For example, as a result of the wear of the mobile equipment of the directional control valves, of the impurities of the oil or of other accidental causes, during the service life of the device the following failures were found by Italian specialists [1] and specialists of our institute; they, in principle, can be prevented by maintenance, can be repaired, parts can be remanufactured and only finally, when there are no resources, one shall obtain the residual waste (Table 1).

**Table 1**

| Ref. no. | Failure | Cause | How to fix it |
|---|---|---|---|
| 1 | The directional control valve with electric control does not switch | - Electromagnet is out of order | - Check the functionality of the slide valve movement by pressing the operation button of the magnetic core<br>- Check the coil voltage<br>- Replace the coil or the entire electromagnet, as suited<br>- Replace the push rod if it is battered |
| | | - Slide valve is stuck | - Remove the slide valve from the body, wash both parts with oil, blow with air, lubricate the surfaces in contact and reassemble, and then test |
| | | - The spring does not return to the starting position when the command is terminated | - Replace the broken or battered spring |

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|---|---|---|---|
| 2 | The directional control valve or the pilot valve has large internal oil leaks | - Highly normal wear and tear due to exceeding the service life | - Replace the directional control valve |
| | | - Accidental wear as a result of abrasive particles penetrating the directional control valve because of improper filtration | - Replace the oil, clean the installation, install new filter cartridges and then replace the hydraulic directional valve |
| 3 | Shocks (water hammer) on the system | - Throttling (timing) plate is out of order | - Disassemble the throttling plate and check the stroke of the one-way valve and the qualities of the spring - Replace the spring or the entire throttling plate |
| 4 | External oil losses | - O-rings, sealing cuffs are out of order | - Disassemble the directional control valve, the component parts, and replace the static and dynamic seals |
| 5 | Manual controls are not kept in the indexed position | - Springs are not strong enough, circular index notches have rounded edges | - Disassemble the manual control cover, ascertain the appearance of the spring, increase the prestressing force, or replace the piece and execute a new one with index notches |

Maintenance ensures the continuity of production for as long as possible without interruptions that can cause a significant decrease in productivity, with the natural consequence of reducing the consumption of raw materials. In the case of complex equipment such as rotary hydraulic pumps and motors, when major failures occur, they are repaired and put back into use by replacing the totally compromised parts. This process of refurbishment, known and used for a long time, is a part of circular economy. The big difference between refurbishment and traditional reconditioning is that through refurbishment a complete disassembly of the complex hydraulic equipment takes place, a total check is made and all subassemblies and parts with problems are replaced [2]. Even the replaced components do not become garbage, but enter into a process of analysis and then restoration to the level of acceptability, in order to be reused in other situations of equipment failure.

There is a technology which, for a long time has been included among the hydraulic equipment repair technologies, especially hydraulic cylinders and hydraulic directional control valves. It is a simple technology, defined at the level of Wikipedia as a process through which coating is made with the necessary materials to some components such as rods or distribution slide valves undergoing significant wear and serious consequences. Metallizing - the technology in question - is suitable for medium and large dimension pieces, being ideal in covering their surfaces with zinc, aluminium, chromium, tungsten and other metals. Thickness of the coating layers which cover pieces for anticorrosive purposes, or restore the rubbed and worn layers, usually varies between 50-200 μm, but there are also much thicker coatings. Coating by metallizing is done according to international standards, ensuring a much longer life to the processed parts, compared to other processes similar as to their purpose.

Metallizing is not advantageous if one desires to process small parts (of the order of several millimeters).

Finally, Circular Economy can be visualized as in figure 1.


**Fig. 1.**

*Source: [3]*

Circular economy is a model of production and consumption that involves all stages, from design to consumption and then to recycling, resulting in only a small amount of waste comparable to raw material and initial materials.

## 3. Industry 4.0

The idea of Industry 4.0 is recent and was presented for the first time in 2011 at the exhibition in Hanover by a group of specialists from Germany (Henning Kagermann, Wolf-Dieter Lukas and Wolfgang Wahlster). While the label concepts of industrial revolutions were assigned to some stages of development of the world economy after their course was completed, the concept of Industry 4.0 has appeared and come into focus ever since the emergence of some components that we can categorize as small technological revolutions, such as the application of information and telecommunications technology, or new software technologies for modeling and simulation, or the development of cyber-physical systems for controlling physical processes and even the involvement of 3D printers in manufacturing. If the advances of the previous revolutions were taken readily and at an acceptable pace by most countries, transition to Industry 4.0 is fast and can be

performed only by the countries that have prepared their economy for such progress. For the first revolution, when the switch from the exploitation of animals to the use of water and steam in the engines of complex machines took place, mankind adapted quickly. The second industrial revolution allowed people to create physical connections through rail networks and connections of ideas through the telegraph, but also to improve the manufacturing process on modernized production lines through the special contribution of electricity. This technological revolution has been quite easily assimilated by most countries of the world and has been a great progress in the development of mankind.
At the end of the 20th century, the third industrial revolution took place, the digital one, which is quite difficult to be assimilated by mankind, already establishing noteworthy differences between countries.
The fourth industrial revolution, according to many specialists, is ongoing, and given the extremely high technical and scientific level special training is required for all countries.

An intuitive presentation of the course of these revolutions is shown in Fig. 2, taken from [4].

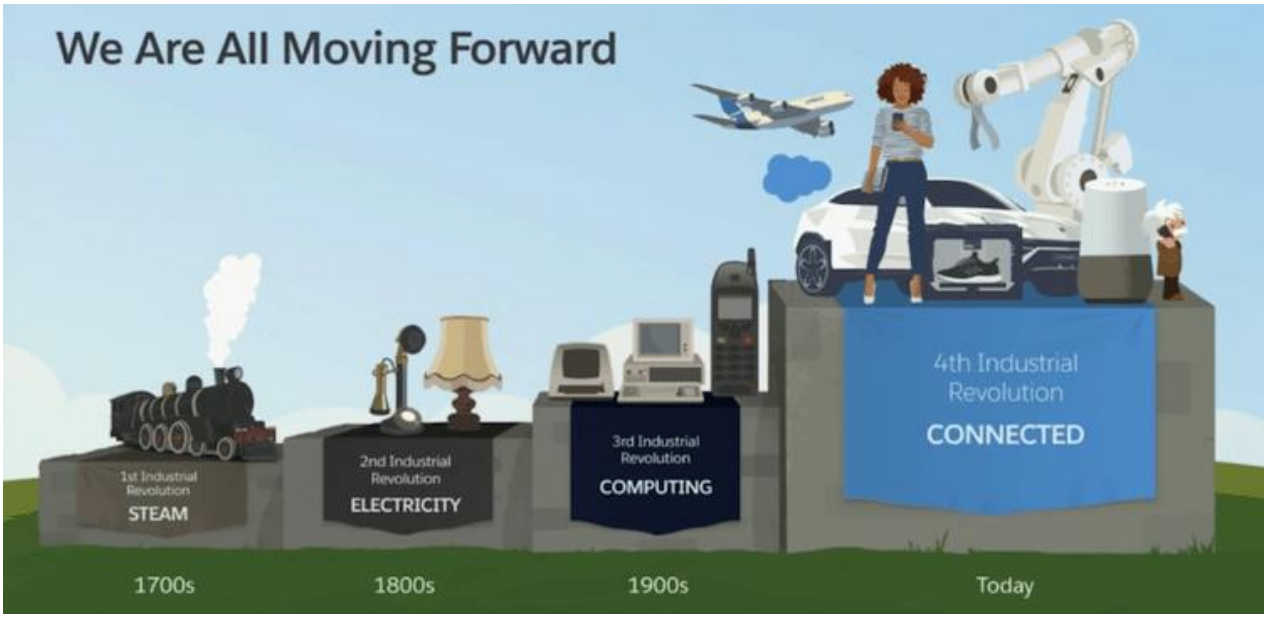


**Fig. 2.**

A country where notions like cyber-physical systems, the Internet of Things (IoT), the industrial Internet of Things (IIOT), cloud computing, etc. are not known well enough and mastered will have major problems in the process of framing in the progress implied by the new revolution Industry 4.0. The key to the success of this revolution seems to be the digitization process that applies in all industries and in all fields. In order for the economy of a country or a company to move on the road to Industry 4.0 it is absolutely mandatory for employees to be trained in understanding and applying the idea of digitization. The factory of the future becomes an intelligent factory that creates a convergence between the Internet and computerization, laying data and connectivity at the foundation of development. It is becoming increasingly clear that at this stage people and organizations alike need to transform and adapt to new technologies. The production will be full of interactions and connections, easy to fit into this industry of the future, but difficult to achieve given the problems that arise as a result of the many reorganizations and disruptions of resources and organizations. Another question that is often asked, besides the one that requires defining the concept in plain words, is the one that seeks the benefits of this industrial revolution. The first advantages are related to improved efficiency and increased productivity, both relating to

automation and increased professional performance of employees, and both raising the quality of products and services [5].
The problem that arises, unexpectedly, is that there are some disadvantages, too, among which there are some drawbacks related to the staff that see their creativity limited by technology, see the increase of the level of unemployment, and also sees the necessity and the difficulty of raising the level of initial and lifelong training. Although the technological level is in full growth, there can be noted an unexpected increase of the initial costs, an increase in efforts related to security of IoT, but especially an increase in the implementation time. In the paper of the specialists from Aachen [6] there is an interesting solution for structuring the manufacturing of a linear electro hydraulic actuator within the concept of Industry 4.0.
When analyzing the ways in which factories approach Industry 4.0, besides several expected possibilities, such as flexible production, manufacturing oriented to the consumer's demands, or increasing the role of data usage in manufacturing, there is also the need for a design capable of meeting the requirements of the circular economy with regard to recycling of raw materials.

## 4. Research and development

From what has been presented so far, it turns out that the support for Romania's involvement in the new global development trends is sustainable research and development which should use a cross-disciplinary systemic approach to processes and products, combining applied technical research with environmental research and social research.
This new research model engages besides specialized units such as universities and institutes also SMEs with specific research and development activities. Europe as a whole is trying to transform its standard economy into an economy based on innovation, through which to ensure competitiveness with the other economies in the world and to move to the sustainable development solution which takes into account the environment and resources. In March 2000 in Lisbon a target of 3% of GDP for research was set for European countries; this target has never been reached in Romania; on the contrary, it has decreased year by year. This has led to an alarming decline in the number of scientific research specialists, at the same time with an increase of their age. The attempts to develop the degree of innovation by increasing the number of patents did not produced the expected results, and the causes can easily be found in the absence of the real and steady forms of involvement of the researchers, but also in the complicated and expensive bureaucracy of studying and developing applications. Too many people without patents have become patent experts, advisors and school creators. Many ideas that emerged during this period were inefficient as neither the Technological Transfer Centers, nor the islands of excellence, nor other solutions initiated without a serious analysis carried out by specialists in the field proved to be useful or at least economical. Because applied research conducted by companies is possible where there are large, financially powerful companies it is clear that the best solution for Romania will be to maintain dedicated research units able to collaborate with SMEs. It is estimated that a large number of young people who will enter the research will work in areas that today do not exist and they will become a great added value in the management of new technologies. The natural conclusion is that the initial training, education and continuous professional development will become essential, as they will provide the basis for future development.

## 5. Conclusions

Industry 4.0 and Circular Economy represent two modern development trends, resulting from a serious, multidisciplinary analysis regarding the future of human society in general and Europe’s future in particular. The two research directions are essential for our future; they are not the fancies of guys posing as specialists, but represent probably the most important elements of perspective research, with direct and unfortunately very fast impact on life on the planet. These two areas are part of the general idea of sustainable development and come upon us with or without our will. Our country is involved in both topics and has managed to overcome the theoretical phase, moving to

the implementation of many of the basic principles of these directions, without deconcentrating at the level of companies and specialists the elements that are generally discussed at global and national level.

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**References**

[1] ASSOFLUID. *Hydraulics in Industrial and Mobile Applications*. Brugherio (Milano), Grafiche Parole Nuove s.r.l. Publishing House, 2007.
[2] Prodan, Dan, and Sorin Marinescu. *Refabricarea si modernizarea masinilor-unelte: sisteme hidraulice / Remanufacturing and modernization of machine tools: hydraulic systems*. Bucharest, Technical Publishing House, 2005.
[3] https://www.europarl.europa.eu/news/ro/headlines/economy/20151201STO05603/economia-circulara-definitie-importanta-si-beneficii. Accessed October 8, 2019.
[4] https://www.salesforce.com/blog/2018/12/what-is-the-fourth-industrial-revolution-4IR.html. Accessed October 10, 2019.
[5] Marin, V., et al. *Sisteme hidraulice de actionare si reglare automata. Probleme practice. Proiectare, executie, exploatare / Practical problems. Design, execution, operation*. Bucharest, Technical Publishing House, 1981.
[6] Alt, Raphael, Hubertus Murrenhoff, and Katharina Schmitz. “A survey of „Industry 4.0” in the field of Fluid Power- challenges and opportunities by the example of field device integration.” Paper presented at the 11th International Fluid Power Conference, Aachen, Germany, March 19-21, 2018.