The Role of Industrial and Service Robots in Manufacturing Processes

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Abstract: One of the characteristics of today's world economic trends is market expansion, i. e. the need for constant modification of existing products through application of new technologies, which should ensure competitiveness in turbulent market conditions. The role of industrial and service robots is essential in such conditions of manufacturing processes. An industrial and service robot is an essential constituent element of the new manufacturing lines, which are designed on a high degree of automation with the characteristics of flexibility, where it is very difficult to observe the robot and its effect outside the whole manufacturing line. The inclusion of industrial and service robots in existing production facilities increases significantly the performance of existing equipment, ensuring its efficiency. This reduces or postpones the need for new or larger investments, since certain situations have shown that the acquisition of robots is much more economical than purchasing new machines. The application of robotic systems in manufacturing processes, whether it is a fully automated process or highly automated manufacturing line (the so-called fixed automation or a possible flexible manufacturing cell), is observed through: materials handling and supporting machines, process operations, assembly tasks, and tasks of products inspection. The paper describes the dissemination of industrial and service robots in the world in the period 2009 to 2014, through the application in specific operations in the manufacturing process.

Keywords: An industrial robot, a service robot, a manufacturing process, automation.

1. INTRODUCTION

As it is known, the level of development of a society is determined by the technology, which represents a set of material and intellectual goods. The prerequisite for satisfying the needs and a success of technology is the combination of: scientific knowledge, production procedures, general technical organization, engineering experience, equipment expediency, as well as other craft and human skills. The success of technology involves improving technical solutions in the field of automation and modernization of technological processes and the application of intelligent systems in a variety of industries, which include all manufacturing processes that have to be made flexible, as well as metal-processing industry. Nowadays, there are many applications of both industrial and service robots in all manufacturing processes of various industries. Their application is motivated by technical and economic reasons, some of which are [1, 2, 6, 9, 10]: the increase in quality of finished products (machining, etc.), the reduction of discards (in assembling processes), increasing the level of uniformity-constancy of quality (in all processes related to the repeatability of robot actions), the increase in the level of work safety (in aggressive, flammable, explosive and other areas, including a high degree of protection of the robot itself), reducing the necessary manpower for routine and repeatable processes, reducing costs of production and maintenance in general, the fulfilment of demands imposed by competition and increasingly stringent quality standards. Apart from technical advantages, brought by the use of industrial and service robots, it should be noted that the rationality of introducing robots in specific manufacturing processes is conditioned primarily by production quantity and nature of the operations that the robot (or more robots) performs. For example, the increase in the quantity of production results in the fall of the cost of robots introduction, so the invested funds for installation of industrial and service robots are often returned for a very short period of time [18]. The application of robotic systems in production processes, whether it is a fully automated process or highly automated manufacturing line (the so-called fixed automation or a possible flexible manufacturing cell), is observed through: materials handling and machines supporting, process operations, assembly tasks, and tasks of products inspection. Service robots application is one of the most significant developments in the automation of transport operations in the manufacturing processes, at the assembly lines, storages, and so on.

2. INSTALLATION OF INDUSTRIAL AND SERVICE ROBOTS IN MANUFACTURING PROCESSES

In 1995, the United Nations Economic Commission for Europe (UNECE) and the International Federation of Robotics (IFR) adopted a preliminary classification system of industrial and service robots by category and

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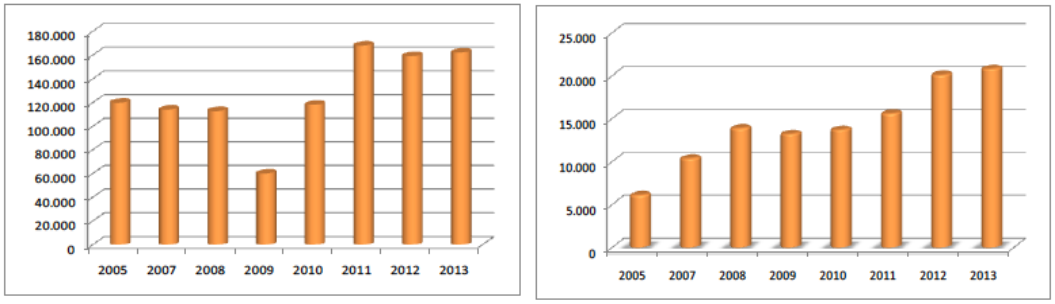
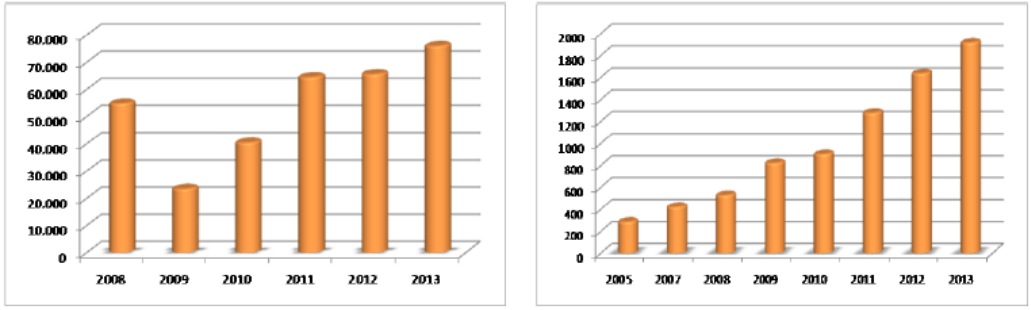
ways of interacting with them. Figure **1** shows the application of service robots in the world from 2005 to 2013. The statistical data shown in the diagrams have been obtained from the International Federation of Robotics (IFR), the data of the United Nations Economic Commission for Europe (UNECE), the Organization for Economic Cooperation and Development (OECD), as well as literature [1, 3-8].

Figure **1a** shows the representation of industrial robots on the basis of which we can conclude that the application of industrial robots in the last three years is around 160.000 units in all production processes in the industry. However, when it comes to service robots for professional use, we can conclude from the Figure **1b** that their application increases from year to year, and that it increased from around 5.000 units in 2005 to about 20.000 units. Based on these findings, we can say that the 21st century is a century of service robots, although we cannot ignore the application of industrial robots, since their implementation is eight times that of professional service robots. Figure **2a** shows the representation of industrial robots in flexible manufacturing production processes of auto parts, motor parts, metal processing industry and machinery industry, from which we can conclude that only 43.75% of the total number of applied industrial robots in 2013 is used. The representation of service robots for logistics is shown in Figure **2b** from which we can conclude that it increased since 2005, from around 200 units to 18.200 units of service robots in 2013. This points to the fact that the number of service robots units increased for about nine times in seven years. This leads us to the conclusion that there has been an intensive work in recent years on the development and application of service robots for logistics, since the automation and modernization of production processes leads to their use in non-production processes as well. There are many reasons for this trend of representation of both industrial and service robots. One of the main reasons is the development of sensor and information technology that are implemented in robotic technologies. There are many other conditions for the trend of constant increase, some of them being: constant automation and modernization of production processes, the protection of workers from hard labour, protection of workers from work in unsuitable areas, achieving high quality, higher productivity, low labour costs, etc.



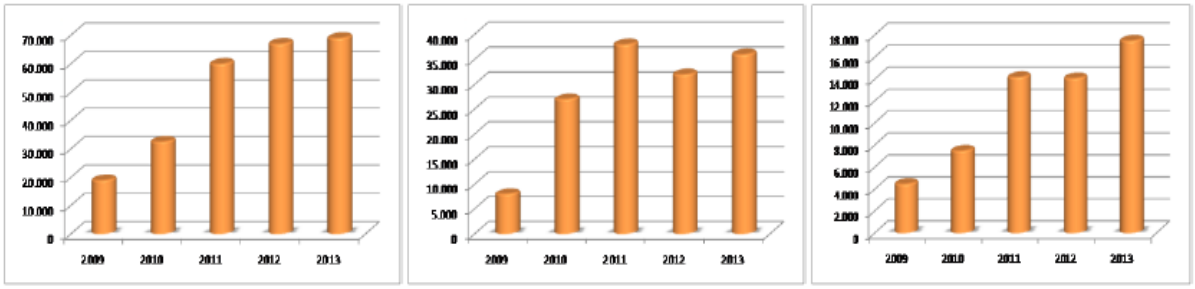
a - industrial robots *b – service robots*

Figure 1: Annual supply of industrial and service robots for the period of 2005-2013 in all production and non-production processes.



a- industrial robots *b- service robots in logistic*

Figure 2: Annual supply of industrial robots in flexible manufacturing processes (a production of auto parts and motor parts, metal processing industry and production of machines) and service robots in logistics (transport operations) between 2008 and 2013.



a - automotive industry *b - electric/electronic industry* *c- metal industry*

Figure 3: Annual supply of industrial robots in automotive, electrical/ electronics and metal industry in the period 2009-2013.

3. APPLICATION OF INDUSTRIAL ROBOTS IN MANUFACTURING PROCESSES

When it comes to the application of industrial robots, it is impossible nowadays to imagine any manufacturing process without an industrial robot installed in it. When it comes to the metal-working industry, industrial robots are used in the following tasks: transport of materials, machine support, the use of robots in casting, the use of robots in the forging, the use of robots in the process operations (turning, drilling, milling, grinding, etc.), the use of robots in the process of joining (welding, soldering, bonding), the use of robots in the process of cutting sheet metal, the use of robots in the paint process, the use of robots in coating, the use of robots in the process of palletising, packaging and sorting, the use in the assembly process, the process of storage and picking, as well as other activities that are not mentioned here. Service robots for logistics are mainly used in manufacturing processes for transport of material or semi-finished product to the machine or from machine to machine, or in the case of finished product, a transport to storage or for picking. If we analyse production processes of various industries where industrial robots are applied, we come to the conclusion they are most represented in the following three industries: automotive, electrical/ electronics industry, as well as in the metal industry (which includes: metal products, basic metal and industrial machinery).

Based on Figure **3**, we conclude that the application of industrial robots is the largest in the manufacturing processes of the automotive industry, then production processes of electrical/electronic industry, and manufacturing processes of metal industry. The representation of industrial robots is logical, because in the automotive industry, they are applied in the following production processes: the process of welding parts and carosserie of cars and trucks, the assembly process, the process of painting, control process, etc. The production process of welding should have the highest representation of industrial robots for the reason that it is a fully automated production process, as this process is harmful to the health of welders and often avoided. Figure **4** shows the representation of industrial robots in the welding process in the automobile industry.

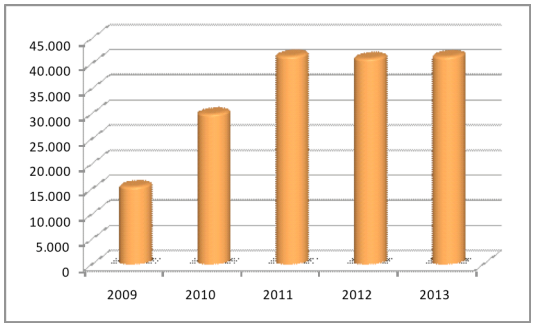


Figure 4: The application of industrial robots in welding processes in the world in the period 2009-2013.

Based on Figure **4** and Figure **5**, we can conclude that about 40.000 robot units is used annually in manufacturing processes of welding in the world from 2011 to 2013. The first in the world is China with around 8.000 units in the same period, the second country is Japan, and it is followed by Germany, North America and the Republic of Korea. It can be concluded that, until 2011, Japan held the first place when it comes to application of robots in the welding process, and that China took over the first place in 2011 and still holds it to this day. The reason for this trend of industrial robots application in welding process is a rapid development of automobile industry in China, where robots are most applied in the welding process in carosserie production. It is expected that China will continue increasing the application of industrial robots.

Figure **6** shows the applications of industrial robots in three different production processes. Figure **6a**

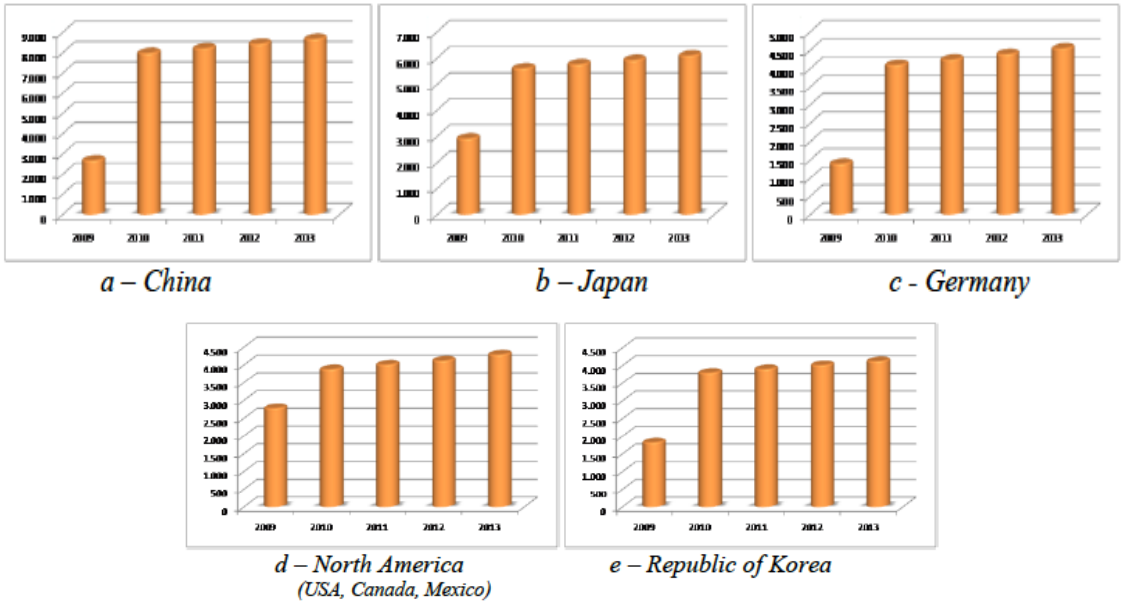


Figure 5: The industrial robots application in welding processes in the world in the countries with the highest number of robot units installed in the period 2009-2013.

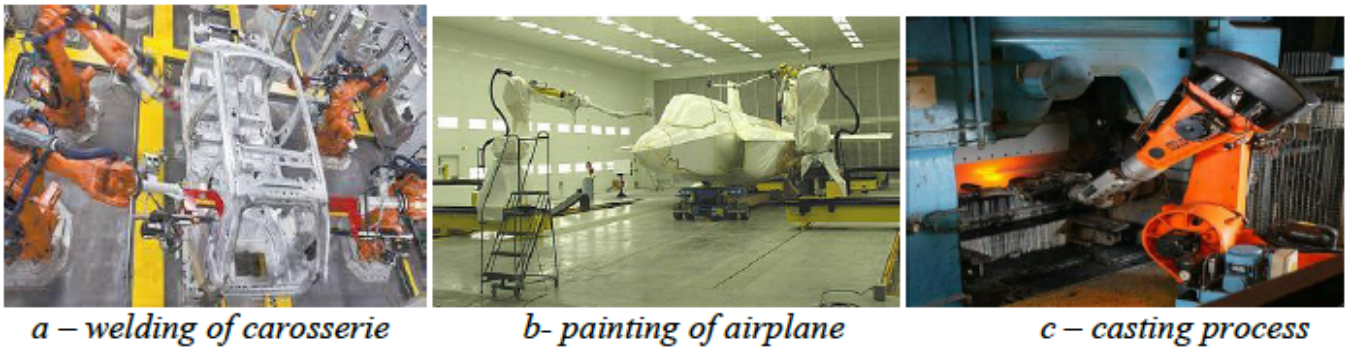


Figure 6: Application of industrial robots in the process of welding, painting and casting.

shows the application of industrial robots in the welding process where they are used the most in the automotive industry, as we noted in the diagrams in Figure **5**. The second picture **6b** shows the application of industrial robots in the painting process in the aerospace industry, and the application in the painting process in the automotive industry is identical. The third example of industrial robots application is in the casting, where the temperatures are high Figure **6c**.

Figure **7** shows the application of industrial robots in different production processes Figure **7a**. presents the application of industrial robots in assembly systems in the automotive industry, where *Kuka* industrial robots are applied to perform assembly operations of elements moving on the assembly line. Figure **7b** illustrates an industrial robot supporting two machine tools that are part of flexible manufacturing. These operations require a high flexibility of robots (taking a work piece from the pallet, high speed and positioning accuracy, as well as load capacity). When a robot supports several machine tools, the processing sequence is programmed by a computer.

Service robots for logistics are mainly used in manufacturing processes for transport of material or semi-finished product to the machine or from machine to machine, or in the case of finished product, a transport to storage or for picking. Introduction of service robots (AGV) in production systems is one of the most significant qualitative developments in the automation of transport operations in the production processes, at the assembly lines, as well as storages. Given the large number of service robots applications (AGV), they represent a wide range of different techno-exploitation solutions. Service robots (AGV) are primarily used for the realization of the internal transport process, so the necessity for small space for

a - assembly system *b – supporting several machines*

Figure 7: The application of industrial robots in: a- an assembly system, b- supporting several machines with small parts in machining process.

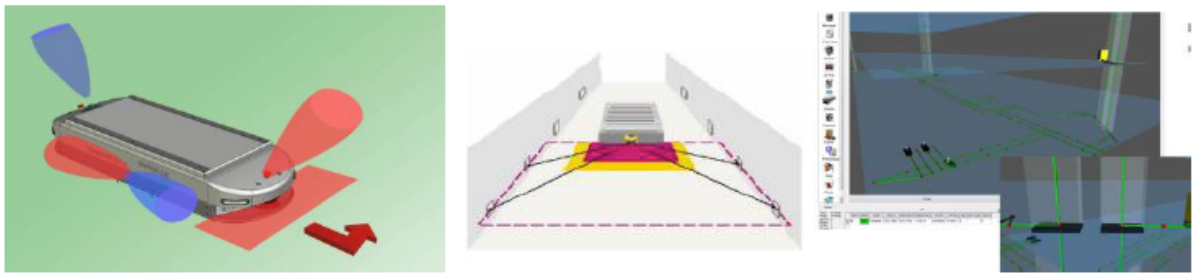


Figure 8: A service robot for logistics equipped with sensors for communication and a tracking software [17].

the movement is of great influence. The AGV's service robots are equipped with laser, light and sound sensors, which help in the realization of safe transportation, as shown in Figure **8**.

For the sake of safety at work, service robots for logistics are equipped with both sensors which have a warning zone to indicate that an obstacle is on the way so they respond with a sound, and a safety zone where the service robot stops in case the obstacle is not removed, as shown in Figure **8**.

Service robots (transport vehicles) are autonomous units that are primarily intended for the transport of loads at a time when it is necessary to integrate with any other process (receiving loads from a conveyor belt), or in conditions of significantly limited space. Figure **9** shows some examples of service robots applications in the transportation process. Due to their autonomy, service robots (AGV) with the possibility of integration in production and assembly lines in some way represent mobile work posts which, according to the technology and speed of work in certain areas, deliver or ship items of work appropriately. Automated vehicles largely depend on the digital data related to tasks performance and the look of the environment in which they work, which is very difficult for small companies to provide. To navigate in the open unlimited space, wireless service robots (AGV systems) must know their position at all times and to be able to determine the path to the end point.

Figure 9: Service robots application (AVG) in a transport during a production process.

4. CONCLUSION

The increase in production quantity and the quality of production assortment is achieved by ever increasing modernization and automation of manufacturing processes. Not a single automation of flexible manufacturing processes can be imagined without the introduction of industrial and service robots. Furthermore, the need for constant modification of existing products is achieved through the usage of new technologies, which include robotics technology as well. Based on Figure **1** and Figure **2**, we conclude that the application of industrial and service robots increases from year to year, but the application of industrial robots at the annual level is thirty times greater than the application of service robots. This statement is justified because we can say that industrial robots are engaged in almost all stages of the manufacturing process, which is not the case with the service robots, although their application is not insignificant in the production process. The introduction of service robots AGV (automatic guided vehicles) in production processes is one of the most important qualitative shifts in the automation transport operations in production, on assembly lines, as well as storages. Given the large number of application possibilities of service robots in logistics, they represent a wide range of various techno-exploitation solutions. Service robots AGV are primarily used for the realization of the internal transport process. Service robots for logistics in the production processes have a very large estimate of the significance factor when it comes to reducing physical labour. At the end, we can say that the number of industrial and service robots in flexible manufacturing processes will increase every year, because this conclusion is imposed by monitoring application of industrial and service robots in the period 2008 to 2013. On the other hand, the second conclusion is imposed by the market that seeks faster and cheaper products manufacturing with less human physical labour.

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