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THE APPLICATION OF INDUSTRY 4.0 IN PRODUCTION PROCESSES OF THE AUTOMOTIVE INDUSTRY

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RESEARCH ARTICLE

ABSTRACT: The use of new technologies to connect people, equipment and machines, i.e. Industry 4.0 is a key player in the manufacturing processes of all industries, as well as in the automotive industry. The Industry 4.0 application in the automotive industrial environment brings smart automation in the automotive element manufacturing process, as well as the car assembly process. The automotive industry is ranked first in the Insuatria 4.0 application in manufacturing processes, and the reason is the global market where every automotive company wants to be a leader. So far, the automotive manufacturing processes have been automated for decades and have been quite automated, but rigid automation has been required. To establish full connectivity to the manufacturing process, there was a lack of wireless connectivity and communication, or production networks where information carriers communicate with each other and exchange data and data. Real-time information, making automation more flexible, improving productivity as well as quality itself. Manufacturers are given the opportunity to quickly adapt the production of other products, which has not been the case so far. The paper presents trends in the use of second-generation service and industrial robots, as well as the use of smart sensors to increase the quality of production and assembly. Industry 4.0's application in the automotive industry has been growing day by day until production processes become completely intelligent.

KEY WORDS: Industry 4.0, automotive, manufacturing, assembly, smart sensor

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PRIMENA INDUSTRIJE 4.0 U PROIZVODNIM PROCESIMA AUTOMOBILSKE INDUSTRIJE

REZIME: Korišćenje novih tehnologija za povezivanje ljudi, opreme i mašina, odnosno industrije 4.0, ključni je igrač u proizvodnim procesima svih industrija, kao i u automobilskoj industriji. Primena Industrije 4.0 u automobilskom industrijskom okruženju donosi pametnu automatizaciju u procesu proizvodnje automobilskih elemenata, kao i u procesu sklapanja automobila. Automobilska industrija je na prvom mjestu u aplikaciji Insuatria 4.0 u proizvodnim procesima, a razlog je globalno tržište na kojem svaka automobilska kompanija želi da bude lider. Do sada su procesi proizvodnje automobila automatizovani decenijama i bili su prilično automatizovani, ali je bila potrebna stroga automatizacija. Da bi se uspostavila potpuna povezanost sa proizvodnim procesom, nedostajalo je bežično povezivanje i komunikacija, ili proizvodnih mreža u kojima nosioci informacija međusobno komuniciraju i razmenjuju podatke i podatke. Informacije u realnom vremenu, čineći automatizaciju fleksibilnijom, poboljšavaju produktivnost kao i sam kvalitet. Proizvođačima se daje mogućnost da brzo prilagode proizvodnju drugih proizvoda, što do sada nije bio slučaj. U radu su prikazani trendovi u korišćenju servisnih i industrijskih robota druge generacije, kao i upotreba pametnih senzora za povećanje kvaliteta proizvodnje i montaže. Primena Industrije 4.0 u automobilskoj industriji raste iz dana u dan sve dok proizvodni procesi ne postanu potpuno inteligentni.

KLJUČNE REČI: Industrija 4.0, automobilska industrija, proizvodnja, montaža, pametni senzor

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INTRODUCTION

Although well known, the automation and modernization of production processes in the industry began in the 60s of the last century, when industrial robots were included in automation and modernization. Automation was well accepted at the time, but from today's point of view we have to admit that automation was rigid and not enough flexible. The reason for the inflexibility lies in the fact that in order to manufacture another product, especially in the automotive industry where rapid changes are required, the same production process required reprogramming of every industrial robot with its grips, change tools, etc., thus causing long production delay and an additional production costs [1-5]. In the last 20 years there has been a rapid development of new technologies such as robotic technology, digital technology, sensor technology, information technology, etc., which are being implemented in the production processes. We are currently at the beginning of the fourth industrial revolution because many of the industrial development strategies of the technologically advanced countries advocate the transformation of industrial production through the implementation of advanced technologies. Industry 4.0 creates radical new approaches in the production process itself, through the communication between the devices in the production process and the implementation of a large number of sensors that provide data based on which decision-making process is made, thus giving great benefits to the automotive industry. The Industry 4.0 platform has one common objective to balancesupply and demand in a very affordable way by providing a wide range of products to the customer, with both parties interacting. The integration of digital technologies with other advanced technologies will transform manufacturing processes in industrial production because the price of these technologies is continuously declining in the market and they are becoming more widespread in production processes. The second reason is that ICT technologies are implemented with other technologies and enable digital transformation of production process [6-10]. When it comes to transforming production processes in the automotive industry, it is impossible to imagine the process without the inclusion of robotics, and networked digital, sensor and information technology. The second-generation of industrial robots has been developed, which must be intelligent and autonomous, thus increasing the reliability of the production process, reducing the time of the finished product, and providing precision and adaptability that exceeds human capabilities. Their implementation will increase the assembly process itself.

1. INDUSTRY 4.0 – DIGITAL PRODUCTION IS IN THE PRODUCTION PROCESSES

In the last 20 years there has been wide development and implementation of digital technology in companies, from the supply of materials to the delivery of finished products. Most innovative applications are implemented in the automotive industry production processes. We are currently at the beginning of the fourth industrial revolution because many of the industrial development strategies of the technologically advanced countries advocate the transformation of industrial production through the implementation of advanced technologies, especially digital technologies (Figure 1).

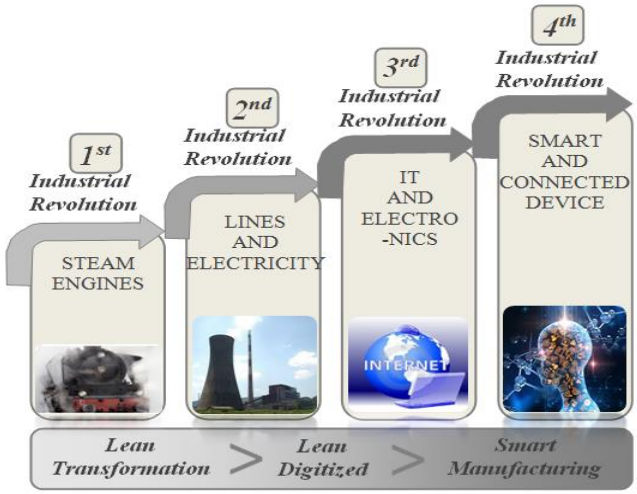

Figure 1 The evolution of industrial revolutions in the world

Germany first announced its ‘’High-Tech Strategy 2020’’ program in 2011 in Hannover under the name Industry 4.0. In 2012, the USA Advanced Manufacturing Partnership Steering Board specified recommendations for positioning USA for the long-term leadership in advanced technology. Similarly, in 2013, the UK Government Office for Science highlighted the strategy ‘’The Future of Manufacturing - A new era of opportunity and challenge for the UK", while China’s objective is to become technologically most advanced country with a strategy called ‘’Made in China 2025’’. The Swedish Government's strategy for new industrialization is to strengthen companies' capacity for change and competitiveness through automation and digitalization. The market is driven by the global economy, and competition is the highest in the automotive industry. Automotive companies are competing how to reduce labor costs and remain competitive in the market. In order to be the leader they need to increase productivity, and provide top quality, i.e. to produce vehicle with less cost. The competitive advantage over others can be achieved through the application of new Industry 4.0 innovations that offer the solution. Digital technology has made a large contribution within Industry 4.0 as shown in Figure 2.The contribution of digital technology within Industry 4.0 is reflected in the large amount of data and analytics we can use to make the right decisions when it comes to the production process. We are able to digitize and integrate vertical and horizontal value chains in companies, which will give the automotive industry a new chance to transform the current linear production method into a network with full connectivity and available information at all times in all segments of the production process, from the input of raw material to the information on each finished product in use.

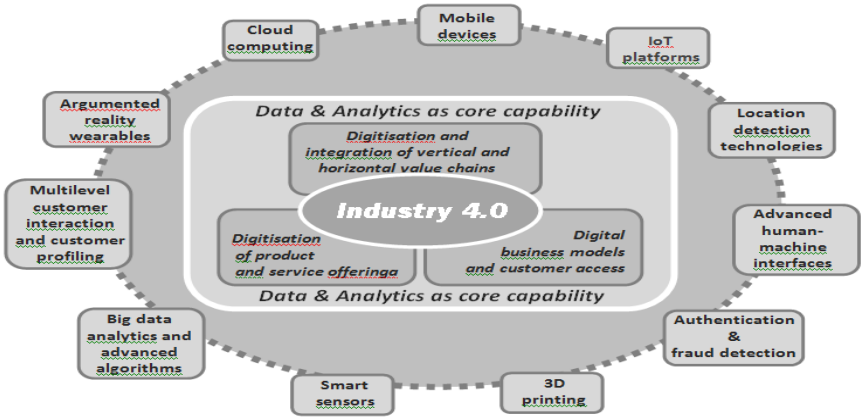

Figure 2 The contribution of digital technology within Industry 4.0

We have the ability to use digital business models as well as customer access, all of which enabled by: smart sensors, 3D printing, IoT platforms, Mobile devices, Location detection technologies, Advanced human-machine interfaces, Authentication & fraud detection, Multilevel customer interaction and customer profiling, Augmented reality wearables, Cloud Computing, Big Data analytics and advanced algorithms, as shown in Figure 2. Through the Industry 4.0 application in production processes, the technologies shown in Figure 2 lead to connectivity and smart communication between machines and workers in the production process. They enable us to increase productivity and quality, as well as adjust to the new levels [11].

2. THE APPLICATION OF THE INDUSTRY 4.0 IN THE AUTOMOTIVE INDUSTRY

Ever since their invention, the industrial robots have found the greatest application in the production processes of the automotive industry. To this day, industrial robots have been continuously installed in the automation of automotive production processes, and the trend is increasing each year. Figure 3 shows the trend of industrial robot application in the world and the application in the automotive industry in the past ten years [9, 13-18]. The statistical data are taken from the International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD). The trend of industrial robot application in the production process is growing worldwide. In the last ten years the situation has changed from 60.000 robot units used in 2009 to the value of about 448.000 robot units applied in 2019. We can conclude that this is a linearly increasing trend, as shown in Figure 3a. The growing trend is predicted to continue in the coming period, so that about 630.000 robot units are expected in 2021. The highest percentage of industrial robots are applied in the automotive industry, as shown in the Figure 3b.

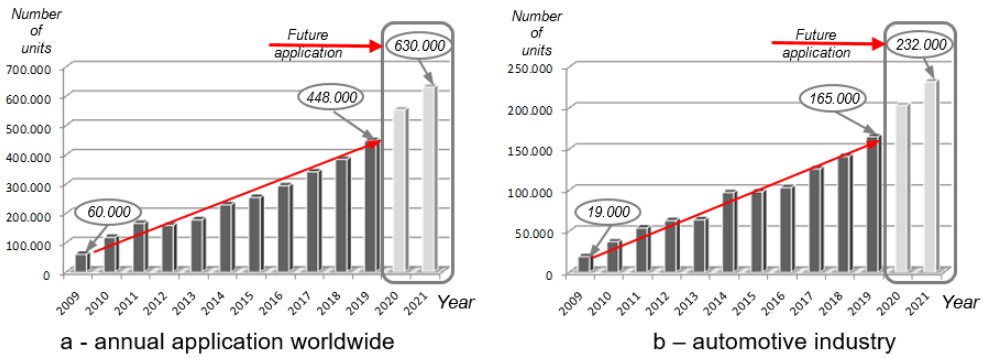

Figure 3 Annual application of industrial robots in production processes in the world and in the automotive industry for the period 2009-2019 and estimated application for 2020 and 2021

In 2009, about 19.000 robot units were used in the automotive industry. The trend of application in the automotive industry continued to increase each year, so that in 2019 the application in this industry amounted to about 165.000 robot units. It is estimated that automotive industry will implement about 232.000 robot units in 2021. The trend of robot applications will continue to increase in the future owing to the application of Industry 4.0 in production processes, which would be impossible without the participation of both industrial and service robots. The development of new technologies such as digital technologies, sensor technologies, information and communicationtechnologies contribute to the development of robotic technology. The collaborative robots in the robotic industry are currently a main research topic in the world, with the aim of creating environment in which workers can safely work together with robots that would assist humans in performing their daily routines without risk. It should be noted that collaborative robots are not intended to completely replace workers, but rather to work together with the workers and to remove the enclosures that currently encircle first-generation industrial robots in the production processes. Worker can perform various complex operations and analytical tasks, whereas the collaborative robot is easy to operate, performs monotonous repetitive operations, can handle dangerous substances, as well as lift heavy objects. The differences between workers and robots are shown in Figure 4 [19, 20].

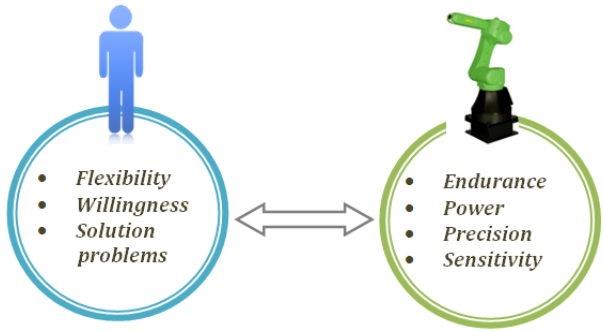

Figure 4 Advantages that should be considered for worker and industrial robot when deciding to install a robot Vehicles Directive

The advantages of collaborative robots over workers and first-generation industrial robots are the following: lifting loads greater than 20 kg, handling hazardous materials (hazardous chemicals that affect workers' health, high temperature items, etc.) and reducing occupational injuries. The flexibility of deploying collaborative robots is that they reduce the working area to perform tasks and do not need enclosures. The collaborative robot has great sensitivity because it has advanced sensors such as integral force and torque sensors, as well as visual sensors that provide safe workspace and protection zones, secure collision detection, secure tool detection, safe force monitoring, etc. The collaborative robot can be easily programmed to perform various tasks which gives it more flexibility. The collaborative robot automatic working cycle is flexible so that it can easily adapt the robot's characteristics to individual tasks. Collaborative robots guarantee the safety of the workers in workplaces where functional safety must be ensured, i.e. there must be a safety zone. A safety zone can be ensured by monitoring the speed of the robot, depending on the distance of the worker from the robot itself, as shown in Figure 5 [20]. The collaborative robot with sensors is designed to directly interact with workers within a common defined workspace. One such DSC (DualCheck Safety) system was developed by the company FANUC, as shown in Figure 5 [21-23].

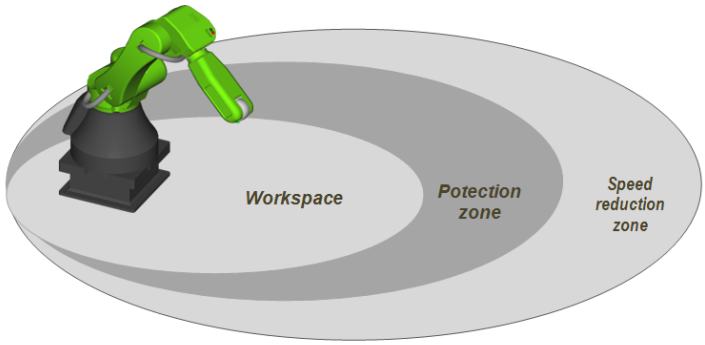

Figure 5 Collaborative robot security system DSC (DSC - Dual Security System) by company FANUC

The laser sensor-based DSC system monitors additional security and controls the robot accordingly as follows. When the worker is not in the three zones indicated, the robot is operating at the full design speed of its work task. When a worker enters a speed reduction zone, the sensor gives information to the PLC, which gives the command to reduce the speed of performing operations. If the worker resumes movement and enters the protection zone, speed of operation continues to decrease and ''Contact stop'' is activated. If the worker enters the workspace, the robot switches to collaborative mode, the operating speed is reduced, and the ''Contact stop'' is still enabled. When a worker touches a robot, gripper, or work piece, the robot stops performing tasks (stops working). When the worker moves away, the robot resumes operation at a rate that is dependent on the zone in which the worker is located. Besides the increase in the application of Industry 4.0 and robots in the automotive industry production processes, in addition to welding and body painting processes of vehicles where robots are most used, the use of robots will also increase in the assembly processes alongside with workers, as shown in Figure 6 [12].The application of Industry 4.0 and industrial and service robots in the automotive industry is vital to the

quality of the finished product - the vehicle. In the near future, many solutions are predicted to provide: a guaranteed assembly process with increased quality, the processes will become adaptable to the assembly input positions which will increase the safety and quality of individual operators, the results of assembly stations will be guaranteed, as well as horizontal and vertical integration between research, development, production, services with feedback and closed loop.

Figure 6 The application of Industry 4.0 and collaborative robots in theautomotive industry assembly process

With the application of Industry 4.0 to the automotive production processes, the classic linear production process will be replaced by an online production process [19-24]. Likewise, new services are based on a real-time data and data analytics, leading to improved production process performance and machine optimization in the production process, as well as predictive maintenance. The application of Industry 4.0 in the production processes of the automotive industry will continue to grow, mainly in the assembly process, assuming that the assembly process must be performed by a combination of humans and collaborative robots.

3. CONCLUSIONS

The convergence of new technologies, including robotics, 3D printing, artificial intelligence, and the Internet of Things, which drive the Cloud Computing and Big Date concept, i.e. Industry 4.0 is transforming the way companies do business. The best example is automotive companies where these technologies are mostly applied. Industry 4.0 has the potential to improve products, adapt experiences, increase productivity, improve safety and reduce costs in many industries, most notably in the automotive industry. Instead of replacing people, which many fear, Industry 4.0 will focus on improving human capability, by creating efficiency that could not be achieved before. One of the strongest examples of application of Industry 4.0 can be seen in the production processes of the automotive industry, from the vehicle manufacturing process to the assembly process, as the paper

states. By installing a large number of smart sensors in the automotive production process, we are able to send information to the Cloud where we have the ability to analyze them and act accordingly. For example, one application is defect identification and preventive maintenance, which is possible by analyzing a large amount of Big Data that goes beyond human abilities. Of all Industry 4.0 technologies, it is expected that robotics and related artificial intelligence will have a profound impact on the production process in the automotive industry, as demonstrated by industrial robot applications in the world and in the automotive industry that is presented in the paper. Many applications of Industry 4.0 are being implemented gradually, with full effect expected in 15 to 20 years. The implementation of Industry 4.0 in the automotive industry results in increased productivity, reduced costs, increased product quality, reduced product life cycle, increased product diversity and flexible manufacturing, whereas companies are becoming recognizable in the global market.

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