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### DEVELOPMENT AND IMPLEMENTATION OF ADVANCED ROBOTICS IN THE AUTOMOTIVE AND ELECTRO-ELECTRONIC INDUSTRY OF CHINA

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**ABSTRACT:** It is known that in recent years there have been major changes in all branches of industry, especially in the automotive and electro-electronic industry, because new business methods are on the scene, and production processes are being transformed so that they are flexible. In the automotive and electro-electronic industry, the leading technology is robotic technology, the application of which increases the return on investment. Advanced robotics as the basic technology of Industry 4.0 in the new era of production in the automotive and electro-electronic industry plays a very important role because it enables: mobility, readiness, reliability, adaptability, transformation of production, integration with machines, increase of flexibility, improvement of quality, storage and production systems integrated as Cyber-Physical Systems, workers are freed from routine and repetitive tasks. The paper provides an overview of applied and issued patents in robotic technology, the application of the implementation of industrial robots, as well as advanced robots in the automotive and electro-electronic industries of China, is given, as well as the forecast of the application in the coming years.

**KEY WORDS**: Industrial robot, automotive industry, electrical/electronic industry, Industry 4.0, production processes

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# RAZVOJ I IMPLEMENTACIJA NAPREDNE ROBOTIKE U AUTOMOBILSKOJ I ELEKTRO-ELEKTRONSKOJ INDUSTRIJI KIN

REZIME: Poznato je da je poslednjih godina došlo do velikih promena u svim granama industrije, posebno u automobilskoj i elektro-elektronskoj industriji, jer su na sceni nove metode poslovanja, a proizvodni procesi se transformišu tako da budu fleksibilni. U automobilskoj i elektro-elektronskoj industriji vodeća tehnologija je robotska, čija primena povećava povraćaj ulaganja. Napredna robotika kao osnovna tehnologija Industrije 4.0 u novoj eri proizvodnje u automobilskoj i elektro-elektronskoj industriji igra veoma važnu ulogu jer omogućava: mobilnost, spremnost, pouzdanost, prilagodljivost, transformaciju proizvodnje, integraciju sa mašinama, povećanje fleksibilnost, poboljšanje kvaliteta, sistemi skladištenja i proizvodnje integrisani kao sajber-fizički sistemi, radnici su oslobođeni rutinskih i ponavljajućih zadataka. U radu je dat pregled primenjenih i izdatih patenata u robotskoj tehnici, primeni robota u svetu i Kini kao lideru u primeni robotske tehnologije u svetu. Data je analiza implementacije industriji Kine, kao i prognoza primene u narednim godinama.

**KLJUČNE REČI**: Industrijski robot, automobilska industrija, elektro/elektronska industrija, Industrija 4.0, proizvodni procesi

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### INTRODUCTION

We are witnessing the implementation of Industry 4.0 in the automotive and electroelectronic industry in the world where we move to increasingly present mobility, bridging the digital and physical environment, using the basic technologies of Industry 4.0. This leads us in a completely new way to wide possibilities of implementation of innovations, automation, optimization by which we raise the production processes in the automotive and electro-electronic industry to a higher level [1-3]. The very concept of production through the implementation of Industry 4.0 is such a concept that goes in the direction of production in which everything is networked. In production processes, machines and devices are connected by wireless connection and sensors, and they are also connected to a system that can independently make decisions motivated by a large amount of data. The concept of Industry 4.0 itself is not yet widespread, and the implementation of this concept is expected to advance and advance all aspects and segments of human life [4-6]. In reality, Industry 4.0 is a new phase in the organization and control of the industrial value chain, which primarily relies on CPS (Cyber-Physical-Systems), and the corresponding service, most often implemented in the Cloud Computing. There are big changes in all branches of industry, as well as new business methods, transformation of production systems, consumption, delivery and transport, changes occur thanks to the implementation of Industry 4.0 technologies.

Only part of the basic technologies of Industry 4.0 are: Robotics, Internet of Things (IoT), Big Data, Smart Sensors, Additive Technologies, Virtual and Augmented Reality (AR), Artificial Intelligence (AI), Digital Twins, etc.

Companies in the automotive, electro-electronic industry mainly apply robotic technology through the implementation of the first generation of industrial robots, service robots and advanced robots in their plants to meet the growing demands of customers, as the demand for various products and services has increased, along with product redesign and customization [7-9]. The development of robotics technology and other new technologies has led to second generation industrial robots. Compared to first-generation robots, collaborative robots have a number of advantages, some of which are: increasing productivity, increasing the speed of product production, providing greater reliability, precision, for example in assembly, and therefore improving quality, using machine vision technologies that improve the perception of robots, they can improve safety, increase the accuracy of the performed task, etc., which is a motivation for companies from the automotive and electro-electronic industry to implement them [10].

# 1 THE TREND DEVELOPMENT AND RESEARCH OF ROBOTIC TECHNOLOGY IN THE WORLD

In the last ten years, we have witnessed an increasing demand for the implementation of robotic technology as the basic technology of Industry 4.0, which companies are hastily implementing in their production processes in order to be competitive on the global market, especially companies from the automotive and electro-electronic industries. Developed countries in the world have adopted their Industry 4.0 implementation strategies because its

implementation itself has an impact on technological changes to increase GDP as shown in Figure 1 [10-13]. Likewise, in 2015, the Government of China adopted its strategy called "Made in China 2025", whose goal is to be among the most technologically developed countries in the world by 2025, but since it cannot achieve this by 2025, they divide it into several phases: Phase I until 2020, Phase II until 2025, Phase III until 2035 and the final phase in 2049, where Chinese industry should be a leading force on the global stage in the world.



a) China's strategy b) GDP per capita Figure 1 Representation of the Industry 4.0 a) strategy in China and b) the impact of technological changes to increase GDP in the World

Advanced countries and developing countries invest in research and development of advanced Industry 4.0 technologies, and implement them in the production processes of companies, and the goal is for companies to conquer the global market, which is changing. Investing in research, development and implementation in the aforementioned Industry 4.0 technologies brings an increase in GDP, as shown in Figure 1.b). Technological changes and inequalities through the ages, shows the increase in real GDP per capita by the introduction of advanced technologies in production processes and the complete environment [13].



Figure 2 Approved patents in robotic technology in the World in the period 2005-2019. in ten top countries

In developed countries throughout the ages, GDP per capita has been continuously increasing (Figure 1.b), such as the countries of the European Union, USA, Australia, Canada, New Zealand and Japan, while all other countries in the World have a slight increase in GDP per capita. Year after year, the difference in GDP between developed and non-developed countries is increasing, this is what developing countries need to understand

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and start investing in research and development and adopt their technological development strategies, so that their companies also start to be competitive in the global market.

The automotive industry and the electro-electrotechnical industry in many countries are the leading industries of development, and we can conclude that China is also one of the countries that develops and invests in these two industries, because China is the first country in the World in terms of vehicle production. About 30% of vehicles production is produced in China [14], and the same is the case with the electro-electronic industry. In these two industries, industrial robots are used the most in the world [15], and to create a true picture of development and research in robotic technology in the World, an analysis of the application of patents in ten top countries in the world was made and shown in Figure 2 [16-19]. In the period from 2005-2019, the top ten countries in terms of approved patents in robotic technology are: China, Japan, Republic of Korea, United States, Germany, Russia, France, European Patent Office, Taiwan and Italy. The leading country in the World is China, which in that period has 25,154 approved patents in robotics, which represents 34.6% of the total approved patents in the world for that period. In the analysis of approved patents in robotic technology, we took the year 2019 and presented it in Figure 3 [16-19].



Figure 3 Approved patents in the World in 2019 from robotic technology in ten top countries

Likewise, based on the diagram shown in Figure 3, we conclude that the following countries are in the first five countries in the world in terms of the number of approved patents: China, United States, Japan, Republic of Korea, Germany. China is in first place with 5,430 approved patents in robotic technology in 2019, which represents 43.3% of the total number of patents granted in the World in robotic technology. We come to the conclusion that the leading top countries in the development and research of robotic technology are: China, the United States, Japan, the Republic of Korea and Germany. Precisely those countries in which there are the most companies from the automotive and electro-electronic industry, where industrial robots are installed in the World which we will show in the next chapter.

# 2 THE TREND OF IMPLEMENTATION OF INDUSTRIAL ROBOTS IN THE AUTOMOTIVE AND ELECTRO-ELECTRONICS INDUSTRY IN THE WORLD AND IN CHINA

We analyzed the trend of the implementation of industrial robots of the first and second generation in the automotive and electro-electronics industry in the World and in China based on statistical data 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 the implementation of industrial robots on an annual level in the world is shown in Figure 4 [20-23].



Figure 4 Annual implementation of industrial robots in the World and China for the period 2012-2022 and ten top countries in the world in 2022

Based on the Figure 4, we conclude that the use of industrial robots in the World, as well as in China, is increasing from year to year, and a small drop in use was during the CORONA-19 virus pandemic, however, there was an increase in the use trend. In the World in ten years, the application increased from 118,000 units of robots in 2013 to 553,000 units of robots in 2022. In China, in 2012, the use of industrial robots amounted to about 12,200 units, and in 2022, the use was about 100,000 units of robots. China had the biggest jump in the use of industrial robots in just ten years, increasing its use by 12.6 times. China is the leading country in the implementation of robots in the top ten countries in the World in 2022. The first five countries are: China, Japan, the United States, the Republic of Korea and Germany, countries in which the automotive and electro-electronics industry has been developed or is developing, and where industrial robots are mostly used. The trend of using industrial robots in the automotive industry in the World and China in the period 2012-2022 on an annual basis is shown in Figure 5 [20-23].



Figure 5 Annual implementation of industrial robots in the automotive industry in the World and in China in the period 2012-2022

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Based on the diagram for the application of industrial robots in the automotive industry in the World and in China, Figure 5, we conclude that the trend of the application of robots in this industry is increasing both in the world and in China. In China, the growth trend of the use of robots in the automotive industry in 2012 was 19% of all robots used in this industry in the World. In ten years, China has increased its share of the use of robots in this industry to 74% in 2022 (Figure 5), where it has installed about 100,000 units of robots, which is about 35% of all industrial robots used in that year (Figure 4.) which gives us the first to conclude that China is fully automating production processes in the automotive industry. The trend of the use of robots in the electro-electronics industry in the World and in China is shown in Figure 6 for the period 2012-2022 [20-23].



Figure 6 Annual implementation of industrial robots in electro-electronics in the World and in China in the period 2012-2022

The trend of the use of robots in the electro-electronics industry in the world and in China is shown in Figure 6. For the period 2012-2022. In the electro-electronic industry, the use of robots is increasing year by year in the world and in China, only a small drop in use was during the CORONA-19 virus pandemic. In 2012, China had 17% of the total use of industrial robots in this industry in based on application in the world. In just ten years, China has increased its participation in the electro-electronics robot industry to 64%. China is the first in the world in the application of industrial robots, and also the first in the world in the application of the automotive and electrical-electronics industries. The percentage share of these two industries in relation to other industries in the World and in China is shown in Figure 6 [23].



Figure 7 Annual percentage implementation of industrial robots by industryin the World and in China in 2022

By analyzing the graphs shown in Figure 7, we conclude that until today, since the very implementation of industrial robots in production processes, they have been most represented in the automotive and electro-electronics industries, so that in 2022, around 53% of all applied industrial robots have been used in the world in these two industries, but their application is starting to increase in other industries as well (Figure 7.a). In China in the same year 2022, about 59% of its total application was applied in the automotive and electro-electronics industry, and conclusion is that complete automation of production processes in the automotive and electro-electronic industry is pending in China, and reasons are:

- In China, there has been an increase in the working hours cost, and the price of industrial robots has fallen and companies are introducing robots and automating production processes,
- One of the reasons why China has adopted a strategy called "Made in China 2025" with which it wants to become the most technologically developed country in the world.
- China invests in development and research in robotics technology because it wants to increase the quality of its products, reduce production costs, and make its companies competitive on the global market.
- China is implementing Industry 4.0 in which robotic technology is the foundation of Industry 4.0 technology and without its implementation it is impossible to fully automate production processes, etc.

China is the largest producer of automobiles in the world, as well as devices and components from the electro-electronics industry, and we see that the implementation of industrial robots in law in China is the largest of these two industries.

### **3 THE TREND OF IMPLEMENTATION OF INDUSTRIAL ADVANCED-**COLLABORATIVE ROBOTS

As we saw in the first chapter of this work, robotic technology is a key technology for the implementation of Industry 4.0, and its implementation leads us to completely smart production processes. The number of innovations and patents in robotic technology is increasing every day, and the leading country in terms of the number of registered and

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approved patents in robotic technology in the World is China. Investment in development and research in robotic technology has given birth to industrial robots of the second generation, or so-called collaborative robots, which are far more advanced than the industrial robots of the first generation.

Industrial robots of the first generation had to be fenced off from workers in the production process due to worker safety, they are robust, take up a lot of work space, while collaborative robots are smaller in size, take up less work space, work together with workers and workers are safe in their environment, they are more flexible and simpler to program and manage. In recent years, their implementation has been increasing every year in production processes, as shown in Figure 8 [21-23].



Figure 8 Annual implementation of collaborative robots in the World and China in the period 2017-2022.

In 2017, their implementation in the world amounted to about 11,000 units, while in China 4,290 units of collaborative robots were used. In just six years, its implementation has increased five times, so that in 2022 it was about 55,000 units of robots. In China, the implementation has also increased by 6.5 times in six years, as shown in Figure 8. Their implementation is production processes in industry made more flexible, and those tasks that were thought to be impossible to automate were automated. They have mostly found application in the automotive industry, especially in assembly and control, as well as in the electro-electronics industry in the assembly of printed circuit boards, testing electronic devices, etc. as Figure 9 shows [24-27].



Figure 9 Implementation of collaborative robots in the automotive and electro-electronic industry

In addition to the development of industrial robots of the second generation and their implementation in all production processes, the development and research in robotics technology has contributed to the development of service robots that are used in production

processes, and for now, service robots for logistics, which are implemented to control finished products, have the greatest application in supervision and monitoring of production processes in industry, etc. The trend of implementation of service robots for logistics is shown in Figure 10 [28].

We conclude that in recent years there has been a rapid implementation of logistics service robots in the production processes of all industrial branches, and the reason for this is the implementation of Industry 4.0, without the complete automation of warehouses, delivery of remanufactured materials, as well as the removal of finished products, where service robots for logistics are used, there is no application of Industry 4.0.



Figure 10 Implementation of service robots for logistics

Predictions are that the trend of using service robots will continue to increase in the coming years. Many companies engaged in the research, development and production of service robots have developed different constructions of service robots for logistics depending on the tasks they have to perform, and examples of their application in the automotive industry and electro-electronics industry are shown in Figure 11 [29-32].



Figure 11 Implementation of service robots in the automotive and electro-electronics industry

The very implementation of advanced robots in the automotive and electro-electronic industry is necessary because global competition requires the modernization of production capacities in order to satisfy increasingly demanding customers. We are witnessing that the growing consumer markets require the expansion of production capacities, and the cooperation between man and device will open up new applications and attract new customers. Improved quality requires sophisticated high-tech robotic systems that can provide all of the above [30-32]. The implementation of advanced robotic systems in the automotive and electro-electronics industry brings a number of advantages such as:

- industrial robots help workers in various tasks,
- can maintain efficient and flexible production,

- increase productivity,
- increase in accuracy, which improves the quality of production and processes,
- support human-robot collaboration, and flexible manufacturing at a higher level,
- increasing work safety in inadequate working conditions,
- reduced production and maintenance costs,
- reducing the participation of workers in the production process,
- reduction of the workforce in the conditions of performing difficult and repetitive tasks,
- mobile manipulation with adaptable grippers will serve different production cells, and etc.

Industrial robots of the second generation and service robots as the base technology of Industry 4.0 will transform the production processes of the automotive and electroelectronics industry, the communication between the devices themselves in the production processes, a great increase in flexibility, profitability and productivity, which leads us in the direction of smart production processes. Here we must mention that the implementation of robots in production processes does not take workers' jobs, but on the contrary helps industries to increase employment because they are more competitive and they are able to enter new markets [33-36]. Workers will be freed from routine, repetitive tasks and will be focused on jobs that require judgment, common sense, creativity, problem solving, widely varying skills and dexterity. Workers with gruesome words will need new education. The development of advanced technologies will have an impact on the development of various constructions of advanced robots and their ever-increasing application in production processes, both in the automotive and electro-electronic industries, as well as in other industries, but also in the entire environment around us, because everything is moving in the direction of making everything a smart factory, houses, infrastructure, cities, etc. In other words, workers will need new education. The development of advanced technologies will have an impact on the development of various constructions of advanced robots and their ever-increasing application in production processes, both in the automotive and electroelectronic industries, as well as in other industries, but also in the entire environment around us, because everything is moving in the direction of making everything a smart factory, houses, infrastructure, cities, etc.

### 4 CONCLUSIONS

Based on everything presented in the paper, we conclude that China is the leading country in the world when it comes to research and development of robotic technology, because it is the country in the world with the largest number of registered and approved patents in robotic technology. China has a strategy called "Made in China 2025", which it has innovated until 2049. The year in which it wants to become the most technologically developed country in the world and one of the reasons is that it is the first country in the world for the largest implementation of industrial robots. China is the first in the world in terms of the implementation of industrial robots in the automotive and electro-electronics industry, in which in 2022 it has applied about 59% of industrial robots. China is first in the world for the production of vehicles and electronics components and devices, and it wants to increase the quality of these products to a higher level, and it can only do so by applying industrial robots in production processes. In this way it increases flexibility, productivity,

reduces energy consumption, and reduces costs production, increases product quality, satisfies increasingly demanding customers and companies from China become recognizable on the global world market. In the coming years, we can expect an increasing use of all types of robots in the production processes of the automotive, electro-electronics industry in China, but also in other industries and environments.

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