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Implementation of Industry 4.0 and Robots in Production Processes of the Metal Industry

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***Abstract*— *We are witnessing major changes in all industries. Due to the application of new technological discoveries, new business methods are emerging, with the transformation of production systems, and a new form of consumption, delivery and transport. The course of development in the field of production in the world is directed towards Industry 4.0, which aims for production based on smart production processes. This requires the introduction of new technologies such as: robotics, Internet of Things (IoT), 3D printing, smart sensors, Radio Frequency Identification (RFID), etc. The application of the first-generation industrial robots introduced rigid automation of production processes. The major deficiencies of the first-generation robots are that they were fenced and took up a lot of production space. The development of robotics technology and other new technologies has led to the development of the second-generation industrial robots. Compared to first-generation robots, collaborative robots have a number of advantages. Robotic technology is one of the most important technologies in Industry 4.0, so the application of robots in the automation of production processes, with the support of information technology, leads to ''smart automation'', i.e. ''smart factor''. The paper presents the implementation of industrial robots and Industry 4.0 in the production processes of the metal industry, as well as the possibility of increasing productivity, reducing time, and increasing the quality of product manufacturing.*

***Keywords*— Industry 4.0, robot, automation, production process, metal industry.**

I. INTRODUCTION

There are many changes taking place on the world industrial and digital scene that we call Industry 4.0, or the Fourth industrial revolution. It represents the vision of the advanced industrial production based on CPS – Cyber-Physical-Systems, and new technologies, which primarily include Robotics & Automation, Internet of Things, Cloud Computing, 3D Printing, Intelligent Sensors, RFID – Radio Frequency Identification, etc. The goal of Industry 4.0 is to implement innovations from these technologies in all segments of society, especially in the production processes of all industries. The metal industry and its production processes represent a very important segment of industrial production. The direction of development of this segment is based on flexible automation leading to intelligent production processes. The implementation of Industry 4.0 in the production processes of the metalworking industry is motivated by technical and economic reasons, such as: increased productivity, flexibility in the production process, increased quality of finished products, reduced production costs, etc. The implementation of Industry 4.0 in the production processes of the metal industry is inconceivable without the implementation of industrial and service robots in the production process itself. Their implementation has technological and economic justification, as shown in [1-12,14,18]. The implementation of robots in the production processes of the metal industry provides a number of advantages, some of which are:

- Increased flexibility of the production process,
- Increased accuracy in the production process which gives better product quality,
- Increased productivity of the production process,
- Increased safety at work in inadequate working conditions,
- Reduced production and maintenance costs,
- Reduced participation of workers in the production process,

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- Reduced workforce in performing heavy and repetitive jobs.

This represents only a small part of the advantages, which are very significant in the conditions of larger capacity production, as evident in the metal industry.

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. METHODS

Theoretical analysis of Industry 4.0 and statistics on the application of industrial robots were used, obtained from the International Federation of Robotics (IFR), the European Economic Commission (UNECE) and the Organization for Economic Co-operation and Development (OECD) [1,3,4,26-30].

III. EXPERIMENTAL

The reference [19] provides the conclusion that the trend of application of innovations from the mentioned technologies of Industry 4.0 is continuously increasing in the world. The first place in the implementation and application of innovations from Industry 4.0 is held by the automotive industry. The reason for such order is a great global competition in the world, because all companies invest heavily in research, development and implementation of Industry 4.0 core technologies in order to remain competitive in the global market [3,6,25].

3.1 The Fourth industrial revolution - Industry 4.0 and its concept in production processes

The world has changed from the first industrial revolution with the invention of the steam engine in 1784, the second industrial revolution with the discovery of electricity and the third industrial revolution using IT systems and the Internet in 1969, to the fourth industrial revolution - Industry 4.0, due to the latest innovations from new technologies such as Robotics & Automation, Internet of Things, Cloud Computing, 3D Printing, Intelligent Sensors, RFID – Radio Frequency Identification, and their implementation in all segments of society, including production processes [3,13,15,16,17]. When it comes to production processes, and especially production processes in the metalworking industry, the difference between the third and fourth industrial revolution is shown in Fig. 1.

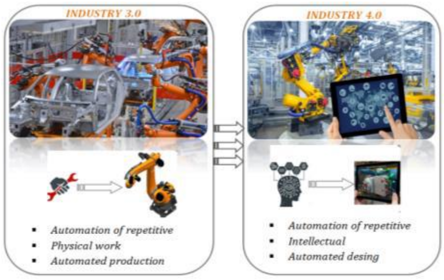


Fig. 1. Advantages of Industry 4.0 over the Third industrial revolution

As Fig. 1 shows, the third industrial revolution was recognizable by automated repetition, physical labor, and production automation. Here we must note that during the third industrial revolution, the automation of production processes was performed with first-generation industrial robots, whose workspace had to be separated by fences from the workers for their safety, thus creating rigid automation. Similar to the third industrial revolution, Industry 4.0 also uses automated repetition, intellectual work, and automatic design. Development, progress and implementation of basic technologies of Industry 4.0, such as: Robotics & Automation, Internet of Things, Cloud Computing, 3D Printing, Intelligent Sensors, RFID – Radio Frequency Identification, lead to the second-generation industrial robots, i.e. collaborative robots. They are implemented in production processes, and create flexible automation which is an advantage over the third industrial revolution. Invention of large number of innovations in digital technologies and their implementation in production processes through the use of computer hardware, software and networks is becoming more sophisticated and intelligent, resulting in their transformation, thus affecting society in all segments of life, including the global economy [1,3,6,19-22]. Industry 4.0, like any industrial revolution, creates an increase in knowledge in the world through the implementation of innovations from these new technologies, by using advanced software, as shown in Fig. 2.

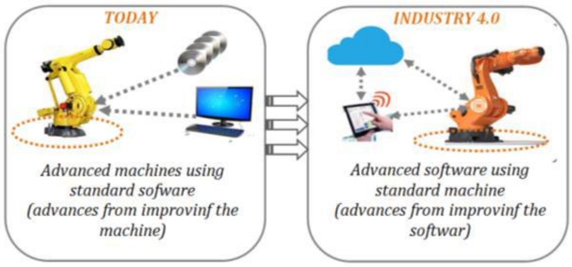
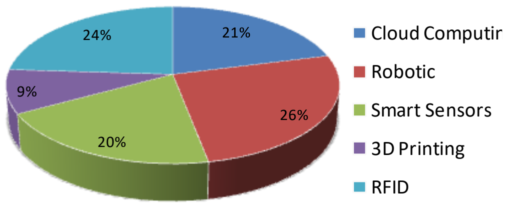


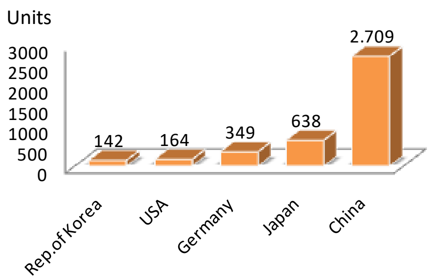
Fig. 2. Advantages of Industry 4.0 in the automation of production processes in the metal industry

In today's world, advanced machines with standard software are used in all production processes, including the metalworking industry. The Fourth industrial revolution is using advanced software for typical machines, as shown in Fig. 2. Advanced innovations and their implementation cause many advances in technology and processes, such as innovations in the basic technologies of Industry 4.0 [3]. As an illustration, Fig. 3 shows the number of patent applications in 2016 in five countries: China, USA, Japan, Korea, and Germany.

The analysis of the trend of patent-innovation applications from Industry 4.0 in 2016 shows that robotic technology is in the first place with 26 % of the total number of applied patents-innovations, which is to be expected because Industry 4.0 wants to achieve flexible automation, i.e. smart manufacturing processes that cannot be accomplished without industrial and service robots. Fig. 3b, shows the trend of patent-innovation applications in robotics in five countries: Republic of Korea, USA, Germany, Japan, and China. In terms of applied patents-innovations in robotics, the first place is held by China. However, we must keep in mind that this represents a large number of low-quality innovations, the reason being that government policy rewards the registration of innovations regardless of their quality and implementation.



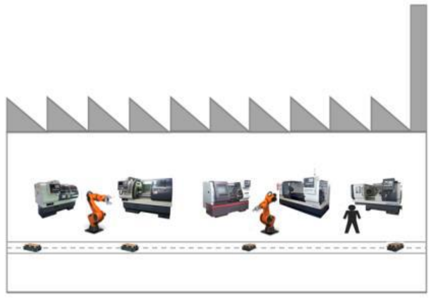
a – percentage of total patent applications



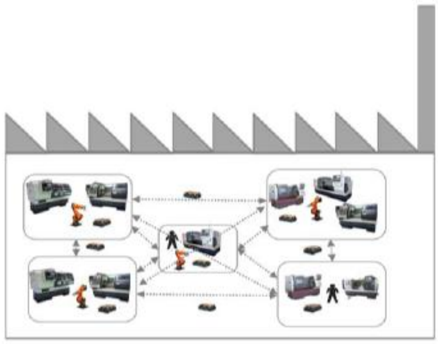
b-broj prijavljeni patenata iz robotike

Fig. 3. The trend of reported innovations in Industry 4.0 basic technologies in five top countries in 2016 [19]

The basic industries of the Industry 4.0 are based on innovations that are much faster and more widely implemented in the production processes of the automotive industry. The reason for such position is the impact of the global market, because for the company to survive in the market it must constantly modernize and innovate production processes, i.e. implement Industry 4.0. This especially refers to the metal industry which is the foundation of the automotive industry. In addition to the automotive industry, the metal industry with the linear mode of the production process is also shifting to the network production process, as shown in Fig. 4. In this process, the machine communicates with the M2M machine, the machines are serviced by collaborative robots, and the transport is arranged with service robots for logistics. The implementation includes completely smart solutions for local transport with the application of mobile robots for logistics. In the fourth industrial revolution or Industry 4.0, the second-generation industrial robots and service robots for logistics are implemented in the production processes of the metal industry [3,21-25].



a – Classic manufacturing process



b – Manufacturing process in Industry 4.0

Fig. 4. The linear production process is transformed into the network production process in Industry 4.0

The linear production process is switched to a network production process because machines communicate with each other, and the communication is provided by basic Industry 4.0 technologies. The production processes in the metal industry now have many advantages, of which some are:

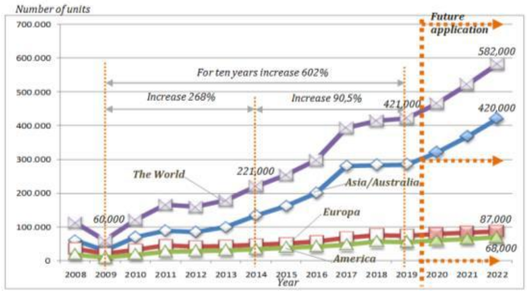
- When complete automation is complex, we are able to partially automate the execution of tasks. In other words, we have the possibility of different levels of automation.
- We can turn rigid automation into flexible automation.
- It is characterized by simple and manageable tasks for handling.
- Due to the division of operations between workers and robots, we have improved performance.
- The role of industrial and service robots in Industry 4.0 is the most important, because it connects the factory of real life with virtual reality, which opens greater prospects for application in global production.
- We can significantly improve non-ergonomic workstations with the help of collaborative robots, where we must keep in mind that worker safety is an absolute prerequisite.
- Reducing the product life cycle and increasing product diversity, require flexible automation, which will result in increased use of collaborative robots.

From the above mentioned, we can see that the concept of production processes in all industries, including the metal industry, is to implement second-generation industrial robots, collaborative robots, and service robots for logistics, to move from a linear production process to a network production process, to provide machine-to-machine communication, and to implement a large number of smart sensors. This enables online monitoring of the production process, online decision-making, permanent maintenance, fast changing serial production, etc. With the implementation of Industry 4.0, the production process in the metal industry goes in the direction of smart production process.

3.2 Implementation of industrial robots in production processes in the world

In order to get a real image of the implementation of industrial robots, it is necessary to make an analysis of the implementation of industrial robots in the world in the last ten years, and expected predictions of implementation in the coming period. The analysis was conducted based on statistical data on the implementation of industrial and service robots, provided by the International Federation of Robotics (IFR), The United Nations Economic Commission for Europe (UNECE) and the Organization for Economic Co-operation and Development (OECD). The trend of implementation of industrial robots in the world is shown in Fig. 5,[3,6,26-30].

The trend of implementation of industrial robots in the world is growing annually, as shown in Fig. 5.a), so that in 2019 a total of amount of 421.000 robot units were implemented.



a-annual

b-total

Fig. 5. Annual and overall trend of implementation of industrial robots in the world in the period 2008-2019 and estimated implementation by 2020

It is noticeable that in the period of five years from 2009-2014, the increase in implementation was 268%, while in the next five years the trend of implementation decreased slightly and amounted to about 90.5%. In ten years, in the period 2009- 2019, the implementation increased by 602%. This leads to the conclusion that the automation of production processes has accelerated, and Industry 4.0 has the credit for that. By analyzing the implementation of robots by continents, we see that Asia/Australia holds the first place, followed by Europe and America. Africa as a continent has not been considered because implementation is insignificant compared to these three continents. We can conclude that the implementation in Asia/Australia takes place as per exponential function, whereas the implementation in Europe and America is linear. In the next three years, it is estimated that the implementation of robots in the world will increase, so that in 2020, the use of about 582.000 robot units is expected. Regarding the total number of implemented robots in the world, Fig. 5.b), we see that the trend of implementation is exponential and continuously

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increasing. In the period 2009-2019, the increase was about 172 %, which leads us to the conclusion that production processes in the world are increasingly modernized and automated. The trend will continue in the future, so it is expected that in 2020 the total implementation of industrial robots will be around 4 million units.

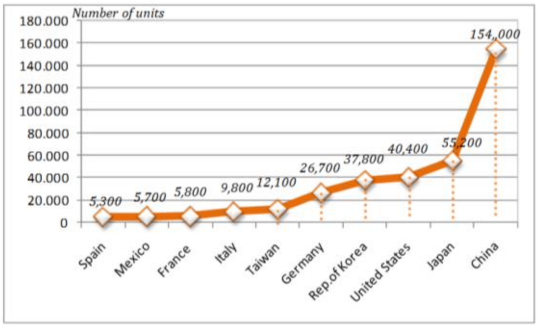

Fig. 6: Implementation of industrial robots in the top ten countries in the world in 2018

The analysis of the implementation of industrial robots in the top ten countries in the world in 2018, according to the number of implementations, has shown that most countries are from Asia: Taiwan, Republic of Korea, Japan and China. The highest implementation is recorded in China with about 154.000 industrial robot units, which confirms the fact that China is implementing its technological development strategy called ''Made in China 2025'', which aims to position China as the most technologically advanced country in the world by 2025. In order to get the real image of the implementation of industrial robots in the world, it is necessary to make an analysis of the implementation of industrial robots per 10.000 workers employed in production processes. The statistical data were taken from and shown in Fig. 7, [13,26].The density of industrial robots represents the number of multi-purpose industrial robots per 10.000 employees. In other words, it is the number of robots in relation to the number of employees in the manufacturing industry, which presents a measure of economic size, and allows us to compare average between countries. Here we must note that unique sources, such as the OECD statistical database, rely on local data sources. These data are often revised (employment data available only with a time distance of at least one year).

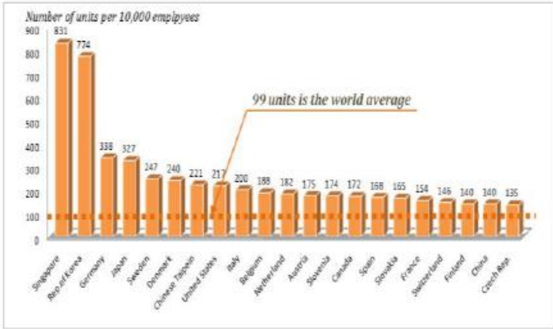

Fig. 7. Trend of installing industrial robots per 10.000 workers in production processes in the world in 2018

The density of robots in 2018 is shown in Fig. 8, only for those countries in the world that have a density greater than 95. Based on Fig. 7, it is suggested that in 2018 the average density of industrial robots in the world is 99 robot units per 10.000 employees in production processes. The density of industrial robots is the highest in Europe and equals 114 industrial robot units, followed by America with a density of industrial robots that amounts to 99 and Asia with a density of industrial robots of 91. Since Asia has the highest rate of implementation of industrial robots, as shown in Fig. 5 and Fig. 6, we can conclude that Asia will very quickly reach America's density of industrial robots per 10.000 employees in production processes.

3.3 Implementation of industrial robots in the production processes of the metal industry

The implementation of industrial and service robots in the production processes of the metal industry aims to increase productivity, reduce costs and achieve better product quality. Their implementation will achieve exactly what Industry 4.0 advocates, which is a higher degree of automation with satisfactory flexibility and greater production with economic justification, whether it is existing production processes or the introduction of new production processes. The metal industry covers all production and service processes, from the production of parts to assembly into semi-finished or finished products. Industrial and service robots in the metal industry are used in many tasks in the production process, including transport of materials before and after processing, process operations, assembly processes of subsets/sets/finished products, control processes (inter operative control and control of final products), etc. The implementation of fundamental technology of Industry 4.0 in the production processes of the metal industry, especially second-generation industrial robots and service robots for logistics, leads to greater flexibility and efficiency in production processes. The analysis of the implementation

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of industrial robots in the metal industry was performed based on statistical data of the International Federation of Robotics (IFR), the United Nations Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD), as shown in Fig. 8 and Fig. 9,[6.26-30].

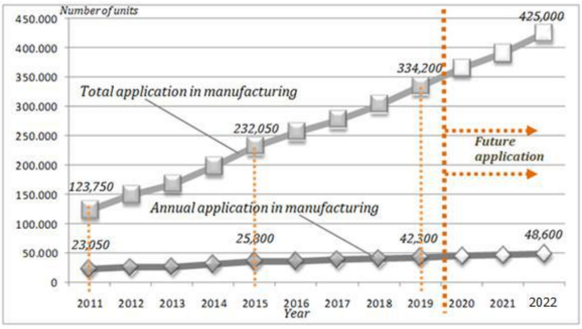

Fig. 8. Implementation of industrial robots in production processes in the world in the period 2011-2019 at the total and annual level, and estimates of implementation by 2022

The trend of implementation of industrial robots in the production processes of all industries in the world has a slightly growing trend on an annual basis, and is conducted linearly. In 2011, 23.050 robot units were implemented. In 2015 implementation increased to 25.800 robot units, and in 2019 the implementation amounted to 42.300 robot units. It is estimated that in the coming years, the trend of the implementation of industrial robots in production processes in the world will continue to grow. The overall trend of robot implementation in production processes in the world is growing, so that, in just eight years, from 123.750 robot units in 2011, the implementation amounted to about 332.200 robot units in 2019, which is an increase of about 170 %. In the coming years, the implementation of industrial robots in production processes in the world is expected to increase, and in 2020 the implementation of about 425.000 robot units is expected. This kind of trend of implementation of industrial robots is due to the fact that companies are introducing Industry 4.0 into their production processes, which would be unthinkable without the introduction of industrial robots. The highest number of implemented robots is recorded in the production processes of the automotive industry, and the largest part is in the welding of bodies, production of engines and various elements necessary in the automotive industry. In order to depict the real situation of the implementation of industrial robots in the production processes of the metal industry, we have conducted an analysis, as shown in Fig. 9.

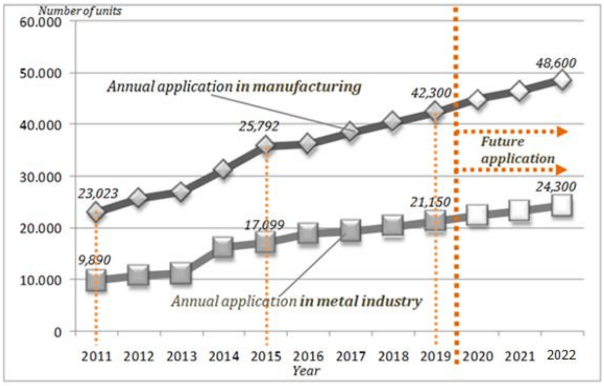

Fig. 9. Annual implementation of industrial robots in the production processes of all industries and the metal industry in the world in the period 2011-2019 and estimates of application until 2022

The trend of implementation of industrial robots in production processes in the metal industry has a growing tendency. 9.890 robot units were implemented in 2011, and in just four years the amount increased to 17.099 robot units, which is an increase of about 73%. In the next four years, the implementation increased to 21.150 robot units in 2019, which is an increase of 24%. The total increase in the implementation of industrial robots in the processes of the metal industry for the period 2011-2019 was 114%, which is very good. In the coming years, the implementation of industrial robots is expected to increase, so that in 2022 the implementation of about 24.300 robot units is expected. Of the total number of industrial robots implemented in production processes in the world on an annual basis, almost one half is implemented in the production processes of the metal industry, which can be seenin Fig.9. In addition to industrial robots, service robots for logistics are also implemented in the production processes of the metal industry, which are used for transport of materials, transport of semi-finished products from machine to machine, transport of finished products and transport of finished products in the warehouse during commissioning. In order to see their role and implementation, Fig. 10. shows the trend of their implementation.

The development of new technologies that form the foundation of Industry 4.0 has had a significant impact on the development of service robots for logistics. Many companies have developed different designs of service robots for logistics that are implemented in all production processes in the world, most of it in the production processes of the metalworking industry [15,17,20-25].

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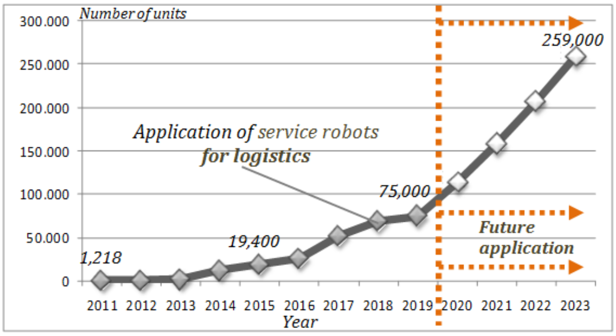

Fig. 10. Annual implementation of service robots for logistics in production processes in the world for the period 2011-2019 and estimates of implementation until 2023

Based on Fig. 10, we see that the trend of implementation of service robots for logistics is exponential, so that from the 1.218 robot units implemented in 2011, there was an increase to about 75.000 units of service robots for logistics, which is an increase of 6,050%. It is predicted that such high implementation of service robots for logistics will continue, and in 2023 the implementation of about 259.000 units of service robots for logistics is expected. This shows us that the implementation of Industry 4.0 is widely implemented in production processes in the world, including the production processes of the metal industry. The goal is to make production processes smart-intelligent without employees performing difficult and tedious tasks. The employees will be replaced by second-generation industrial robots and service robots.

IV. DISCUSSION

Robotic technology is the core technology of Industry 4.0, as evidenced by the number of patent applications in robotics 26% in 2016 worldwide Fig. 3. The trend of implementation of industrial robots in the world is growing Fig. 5.- Fig.7., and the lead by 2022 is that the implementation of robots will be a growing trend. In the metal industry is also a growing trend Fig. 8. and Fig. 9., and the reason is the implementation of industrial robots in the service of CNC machines, as well as the implementation of service robots for logistics in production processes in the metal industry. With the implementation of Industry 4.0, the trend of robot implementation in the metal industry will be growing. With the development of robotic technology in implementation are second-generation industrial robots-collaborative robots and service robots for logistics that are fully intelligent, and the implementation trend is much increased Fig. 10.

V. CONCLUSION

In order to survive in the global market, the aim of every company must be to reduce costs and at the same time increase productivity and quality of the final product, which can be achieved by implementing the basic technologies of Industry 4.0, primarily robotic technology and implementation of second-generation robots – collaborative robots and service robots for logistics. When designing any metal processing procedure in the metalworking industry, it is necessary to take care that this process is organized with as little human participation in operational tasks. The development of the metal industry in the world includes the implementation of Industry 4.0, because any deviation or slowdown in development reduces market competitiveness and inevitably leads to delay. The trend of implementation of industrial robots and professional service robots in the production processes of all industries is growing and it will continue in the years to come, as is shown in this paper. The decision to introduce robots in all segments of production processes of the metal industry would present one of the conditions for achieving greater efficiency in the work of industrial processes. The use of robots is no longer limited to industrial robots with specific requirements of a safe working environment, because the achieved robot-human interaction has created conditions for their joint work using collaborative robots, which will result in their increased implementation. The development and improvement of new technologies is expected in the coming years, as well as robotic technology and its implementation in the production processes of all industries, especially in the metal industry, which aims to make production processes smart-intelligent. The ultimate goal is to reach smart-intelligent factories.

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