Flexibile automation of production processes in the automobile and electrical / electronic industry of China

Isak Karabegović[*1], Predrag Dašić[2], Raul Turmanidze[3]

[1]Academy of Sciences and Arts of Bosnia and Herzegovina,
71000 Sarajevo, Bosnia and Herzegovina
[2]Engineering Academy of Serbia (IAS), 11000 Belgrade, Serbia
[3]Georgian Technical University (GTU),
Faculty of Transportation and Mechanical Engineering, Tbilisi, Georgia

Correspondance autor:isak1910@hotmail.com

Abstract: Since the 60s of the last century, the appearance of the first industrial robot has led to automation of production processes in the automotive industry, and their development and automation has continued to this day. The development of information-communication and sensor technology has led to the automation of production processes. The basic technologies of Industry 4.0 with their implementation in production processes lead us to completely intelligent production processes. In recent years, two industries stand out in which industrial robots are implemented the most, namely: the electrical/electronic industry and the automotive industry. For the past ten years, China has been the first country in the world to use the most industrial robots in production processes. This paper analyzes the trend of the implementation of industrial robots in the electrical/electronic and automotive industries in China, and compares it with the worldwide implementation of robots in these two industries and with the implementation of industrial robots in these two industries in Japan. At the end of the paper, an explanation is given for this trend of robot implementation in these two industries in China.

Keywords: Robotics, Industry 4.0, automation, automotive industry.

1. Introduction

It is known that industrial robots have been playing a very important and key role in the automotive and electrical/electronic industries for decades [1-3]. In the automotive industry, industrial robots and humans work together, and are used for: welding, painting, assembly of parts, quality control, while service robots are used for transportation, monitoring and control of production processes. The application of industrial robots in the automotive industry enables: manufacturers to speed up production, reduce production costs, improve quality, have incredible precision, reduce waste and electricity consumption, and also contribute to the environmental sustainability of vehicle production [4-6]. Likewise, industrial robots play a key role in the electrical/electronic industry. Their implementation in this industry enables greater efficiency, increased precision and increased

durability. Industrial robots in the electronic industry precisely place electronic components on printed circuit boards, and in electronic component warehouses they search and collect the necessary elements, test electronic devices to see if they are functional and of good quality, use them for sealing and casting materials on electronic components, place labels and pack finished products, as well thus they prepare finished products for delivery to the customer [7-9]. By using industrial robots in the automotive and electrical/electronic industry, the advantages are huge and varied, such as: with robots we can automate production for small series of products, we perform monotonous, repetitive tasks with robots, thus reducing the burden on employees from hard work, which affects the increase productivity. With them, flexibility is enabled, they do not need a break because they can perform tasks continuously. Industrial robots are the basic technology for the implementation of Industry 4.0, which represents a significant transformation of production processes in order to obtain intelligent processes. Industry 4.0 is based on the digitization of production processes. All phases, from design to final product, are performed digitally and integrated into a complete system. In addition to robot technology, the key technologies of Industry 4.0 include: machine learning (ML), Internet of Things (IoT), big data (BD), artificial intelligence (AI), cloud computing (CC), etc. their implementation enables better production management and optimization of production processes, reduction of costs and resources. The implementation of Industry 4.0 enables real-time monitoring, problem identification, process optimization and better strategic decisions [10,11]. The introduction of Industry 4.0 requires organizational changes, employee training and safety measures, creating a better future for companies and workers. The development and research of robotic technology contributes to faster and easier implementation of Industry 4.0, and its possibilities are immeasurable [12-14]. China is the first in the world to implement industrial robots, which will be analyzed in the following chapters.

2. Implementation of industrial robots in the World and in China in the last ten years

In the World as well as in China, we will get a real picture of the application of industrial robots by following their application in the last ten years. An analysis of the use of industrial robots was made based on statistical data 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 the implementation of industrial robots on an annual basis in the world and in China is shown in Fig. 1 [15-18]. Analyzing the trend of the use of industrial robots in the world on an annual basis, we conclude that it is growing from year to year, we only have a decline in the trend at the time of the COVIC-19 virus pandemic, because certain companies had to stop in order to reduce the spread of the virus, and that was in 2019 and 2020 .year (Fig. 1a).

In twelve years, there was an increase in the use of industrial robots from 118,000 units of robots to 560,000 units of robots, which represents an increase of 4.7 times. We assume that this trend of increasing the use of industrial robots in the world will continue in the coming years, and the reason for this conclusion lies in the fact that all companies implement advanced technologies of Industry 4.0, where robotics is among the fifth technologies.

Likewise, the use of industrial robots in China is increasing year by year as shown in Fig. 1b, with a slight decrease during the COVID-19 virus pandemic in 2019 and 2020, there is already an increasing trend in the use of robots in China than in the World.. In 2010, the use of industrial robots in China was small, only 13% of the world's use of robots in that year, however, in twelve years, China will become the leading country in the world in terms of the use of robots, so that in 2022, the use will amount to 52% of the world's use.

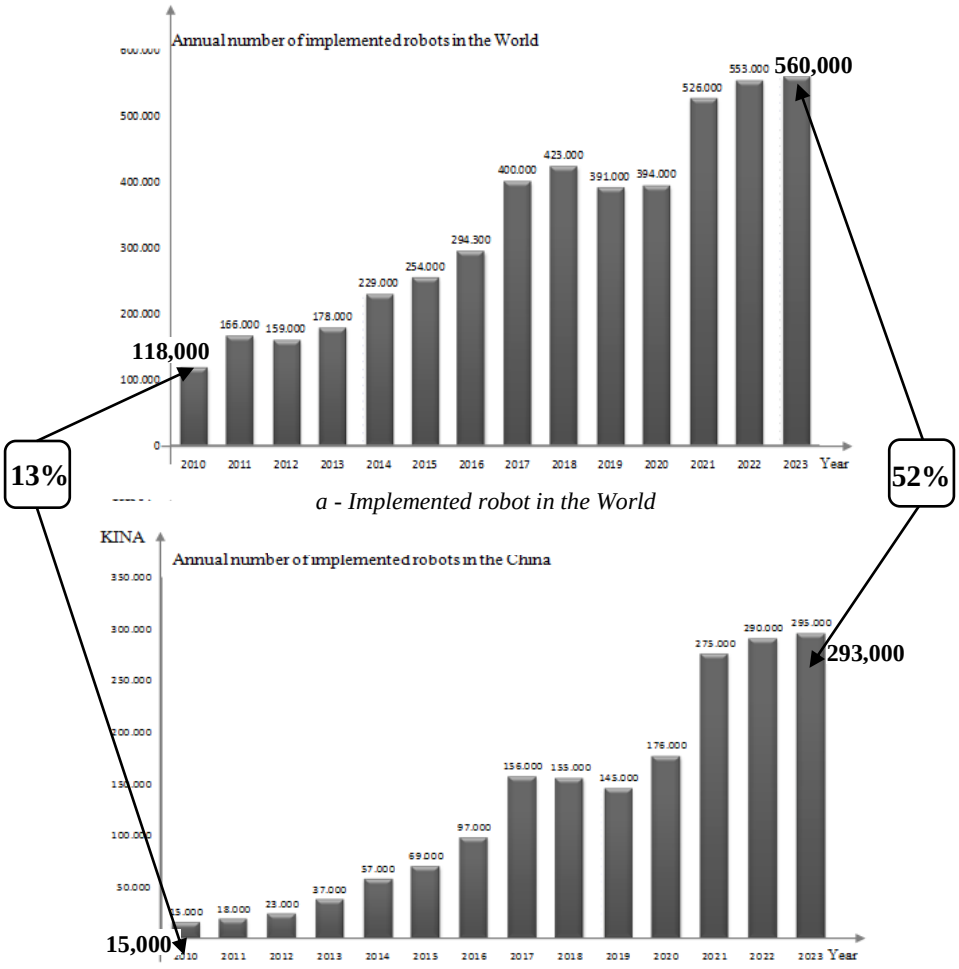


Fig. 1. Annual deployment of industrial robots in the world and China in the period 2010-2023

In order to have an overview of which countries are the leaders in the use of industrial robots in the year 2022 in the world, Fig. 2 shows the use of industrial robots in fifteen top countries in the world with the highest use [17].

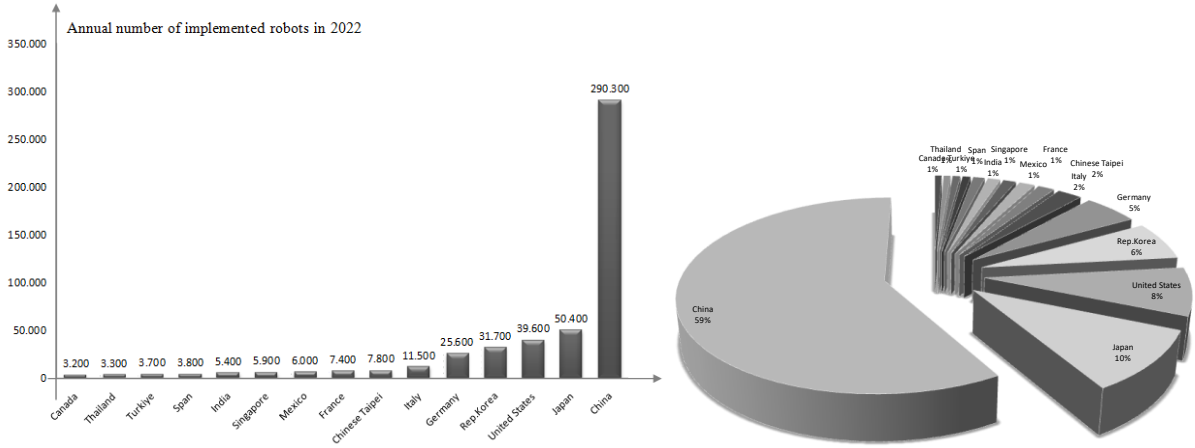


Fig. 2. Implementation of industrial robots in fifteen top countries in 2022

We conclude that the first five countries in the world with the largest application are: China, Japan, the United States, the Republic of Korea, and Germany, and the other ten countries are ordered by the size of application in Fig. 2. We see that China is the leading country in the world in the application of industrial robots and most countries in the world. The increase in the use of robots in China in ten years is shown in Fig. 3.

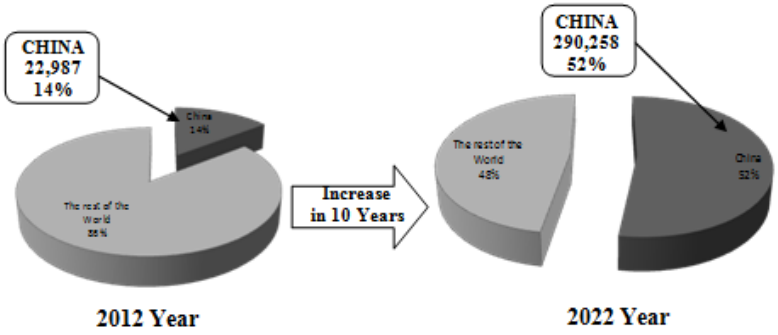


Fig. 3. Ten-year increase in the use of industrial robots in China

We conclude that China, the leading country in the use of robots in the world, in just ten years from 14% of the world's use, increased its share to 53% of the world's use of industrial robots in the period 2012-2022.

3. Implementation of industrial robots in the automobile and electrical/electronic industry in China

From the very beginning of the application of industrial robots, the automotive industry was the first to implement robots in its production processes, so we can state that such a trend has continued to this day, although industrial robots have begun to be implemented in other industrial branches, especially in recent years, when development of robotic technology and collaborative robots, as well as the application of Industry 4.0 in which robotic technology is the base technology for its application [15-18].

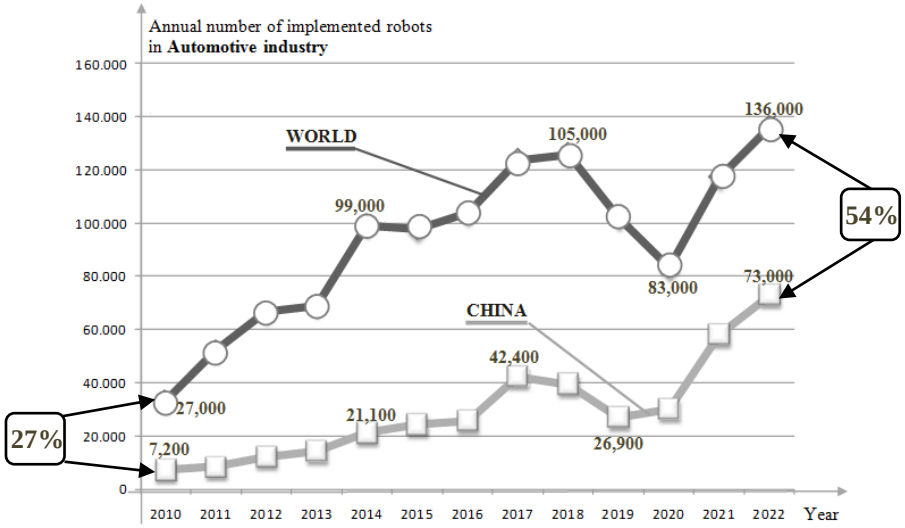


Fig. 5. The trend of the implementation of industrial robots in the automotive industry both in the world and in China for the period 2010-2022

The use of industrial robots in the automotive industry in the world is continuously increasing every year as shown in Fig. 5, only there was a drop in their use during the pandemic of the COVID-19 virus in 2019 and 2020. Likewise, the trend of using robots in the automotive industry in China is growing year by year. In 2010, China used robots in the automotive industry for about 27% of the world's use, but in twelve years it increased its participation in the world's use to 54%, which puts China in first place in terms of the use of industrial robots in the automotive industry. The relationship between the applications of industrial robots in the electrical/electronic industry is also similar, the application trend is shown in Fig. 6 [15-18].

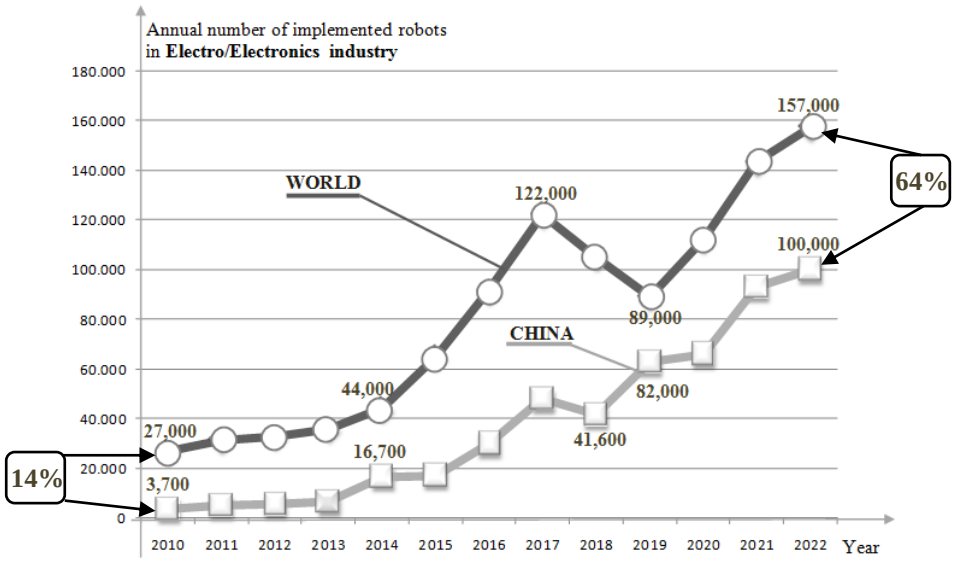
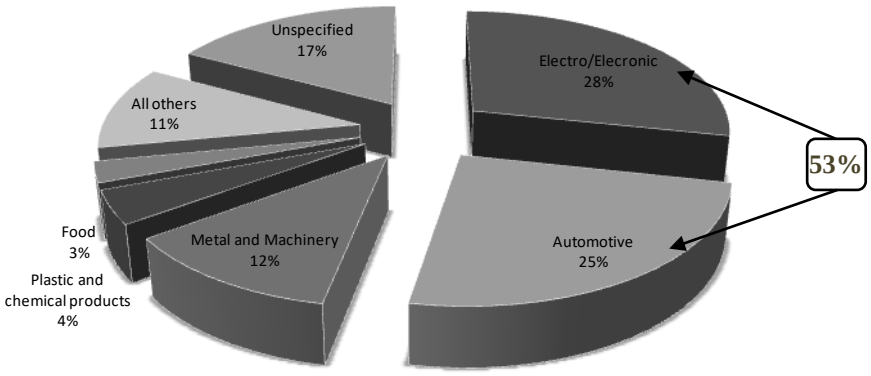
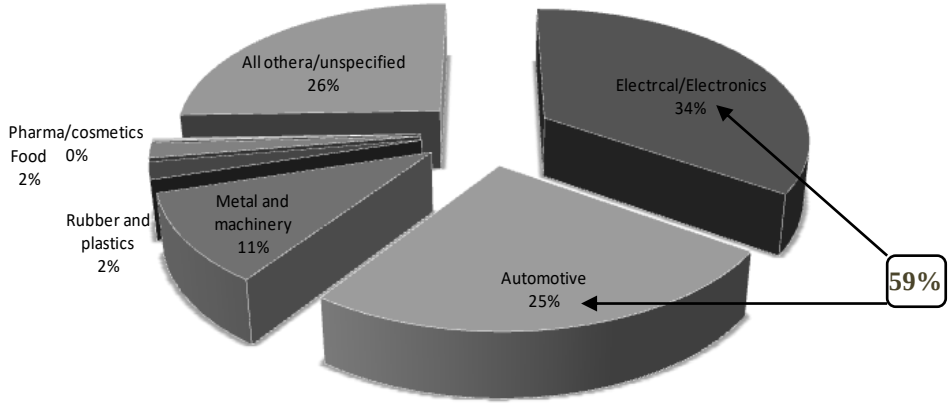


Fig. 6. The trend of the implementation of industrial robots in the electrical/electronic industry both in the world and in China for the period 2010-2022

Analyzing the diagram in Fig. 6, we conclude that the trend of using robots in the electrical/electronic industry is increasing from year to year both in the world and in China. Year by year, China takes an increasing part in the application of robots in this industry in the world. Only in 2010, China's participation amounted to about 14% of the worldwide use of robots in the electrical/electronic industry, and in twelve years, China increased its participation to 64% of the world's use of robots in the electrical/electronic industry. In addition to the automotive and electrical/electronic industries, industrial robots are applied in other industries so that the application of industrial robots in other industries is increasing every day, which is shown in Fig. 7 [19, 20]. We can conclude that in the world the largest number of applied industrial robots is in the automotive and electrical/electronic industry in 2022, about 53% of the total number of applied robots in the world (Fig. 7a), electrical/electronic industry with 28%, followed by the automotive industry with 25%. In third place is the industry of metals and machines with about 12%, then plastics and chemical products 4%, food 3%, there are 17% of unspecified applied robots, which is represented in other industrial branches. The number of applications of robots in other industries is increasing day by day, and research and development of both robotics and other technologies that are implemented in robotic technology contribute to this. The use of robots in the automotive and electrical/electronic industries in China (Fig. 7b) is higher than in the world, so that in 2022 it amounted to 59%.



a – Of robots in the World by Industry in 2022



b – Of robots in the Kina by Industry in 2022

Fig. 7. Implementation of industrial robots by industry in the World and China in 2022

As in the world, in China, the electrical/electronic industry is in first place in terms of the use of robots with about 34%, followed by the automotive industry with 25%, and in third place is the metal and machinery industry with 11%, followed by the rubber and plastic industry with 2% food with 2% etc. This trend of the application of industrial robots both in the world and in China will change in the future due to the implementation of second generation industrial robots whose application trend in the world and in China is shown in Fig. 8 [19-23].

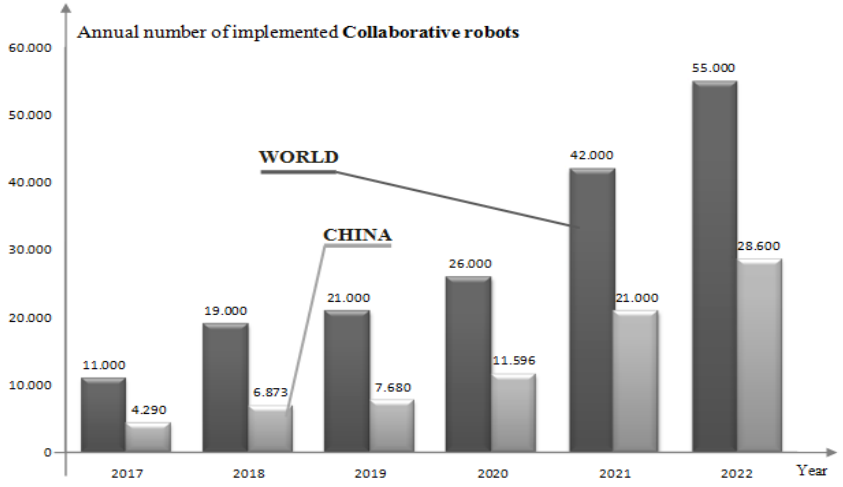


Fig. 8. Implementation of collaborative robots in the world and in China in the period 2017-2022

From the diagram with Fig. 8 shown in the picture, we see that industrial robots of the second generation (collaborative robots) have been increasing in the last six years for the period 2017-2022 in the world and in China. There are many reasons why the use of collaborative robots is increasing in the world and in China, let's list just a few [24-26]:

- Safe work of workers in the robot workspace (work of robots and workers together).
- Collaborative robots are characterized by simple and easy-to-handle tasks.
- By using collaborative robots, it is possible to significantly improve performance, when operations are divided between workers and robots.
- Using collaborative robots, we have the possibility of various levels of automation in the production process, so that we can partially automate tasks in those cases when complete automation is too complex or not economical.
- Non-ergonomic workstations can be significantly improved with collaborative robots, where we must keep in mind that worker safety is an absolute prerequisite.
- Collaborative robots have the most significant role in Industry 4.0, which connects the real-life factory with virtual reality, which opens up future perspectives in global manufacturing.
- Reducing the product life cycle and increasing the variety of products require automation flexibility, which will result in an increase in the use of collaborative robots, but simplification - ready-to-use applications are increasingly popular with customers, which will result in an increased use of collaborative robots in small and medium-sized companies.

4. Conclusion

After the analysis, we conclude that the application of robotic technology in the world is increasing from year to year, and the first five countries in terms of the application of industrial robots are China, Japan, the Republic of Korea, the United States and Germany. China is the leading country in the world in the implementation of robotic technology in production processes with the participation of 52% of the total use of robots in the world, and only ten years ago China used only 14% of industrial robots compared to all countries in the world. China implements the most industrial robots in the electrical/electronics and automotive industries in 2022, 59%. In addition to this two industries in the world and in China, the application in other industries is increasing thanks to the development and research of robotic technology and other Industry 4.0 technologies. It is to be expected that in the coming years, this trend of industrial robot application will continue in the world as well as in China.

References

[1] I. Karabegović, R. Turmanidze, P. Dašić, Structural network for the implementation of ”Industry 4.0” in production processes. *International Scientific Journal ”Industry 4.0”,* 7 (1) (2022), pp. 3–6. https://stumejournals.com/journals/i4/2022/1/3.full.pdf.

[2] K. Schwab, *The Fourth Industrial Revolution*. World Economic Forum, Geneva, Switzerland, 2016.

[3] V. Majsorović, D. Đuričić, R. Mitrović, *Industry 4.0*: *Renaissance of engineering* (in Serbian). Univerzitet u Beogradu, Mašinski fakultet Beograd, Beograd, Srbija, 2022.

[4] I. Karabegović, A. Kovačević, L. Banjanović Mehmedović, P. Dašić, *Integrating Industry 4.0 in Busniess and Manufacturing*. IGI Global, Hershey, PA, USA, 2020. – 661 pp. ISBN 978-1-7998-2725-2. doi: 10.4018/978-1-7998-2725-2.

[5] I. Karabegović, V. Majstorović, *Industry 4.0*: *Digital transformation is shaping the future*. Society of Robotics in Bosnia and Herzegovina, Bihać, BiH & ANU-BiH, Sarajevo, BiH, 2024.

[6] B. Esmaeilian, S. Behdad, B. Wang, The evolution and future of manufacturing: A review. *Journal Manufacturing System*, 39 (2016), 79–100. doi: 10.1016/j.jksy.2016.03.001.

[7] K. Wang, Intelligent predictive maintenance (IPdM) system – Industry 4.0 scenario. *WIT Transactions on Engineering Sciences*, 113 (2016), 259–268. doi: 10.2495/IWAMA150301.

[8] I. Karabegović, E. Husak, E. Karabegović, M. Mahmić, China is the leading country in the world in the implementation of robotic technology as the basic technology of Industry 4.0. In: *Book of Abstracts of the 12th International Conference „Machine and Industrial Desing in Mechanical Enginering (KOD-2024)*; Balatonfüred, Hungary; 23-26 May 2024. Novi Sad (Serbia): University of Novi Sad, Faculty of Technical Sciences, 2024, pp. 128–129. ISBN 978-86-6022-339-7.

[9] J.M. Muller, O. Buliga, K.I. Voigt, Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, 132 (C) (2018), 2–7. doi: 10.1016/j.techfore.2017.12.019.

[10] I. Karabegović, Improving innovativeness and competitiveness in Germany, Japan and China through the analysis of the application of robotics as an Industry 4.0 technology in the manufacturing industry. In: *Proceedings of the International Scientific Conference, Industry 4.0 in Circular Economy and Environmental Protection and Recovery*: Beograd, Serbia; 15th December 2023. Union of Engineers and Technicians of Serbia, Belgrade, Serbia, 2023, pp. 38–51. ISBN 978-86-82563-26-6.

[11] I. Karabegović, R. Turmanidže, P. Dašić, Analysis of patent trends from Industry 4.0 and the implementation of robot technology in the countries of China, USA, Japan, Republic of Korea and Germany. In: *Proceedings of the 6th International Scientific Conference, Conference on Mechanical Engineering Technologies and Applications (COMETa-2022)*; East Sarajevo, Bosnia and Herzegovina; 17-19 November 2022. East Sarajevo (Bosnia and Herzegovina): University of East Sarajevo, Faculty of Mechanical Engineering, 2022, pp. 273–286.

[12] I. Karabegović, E. Karabegović, M. Mahmić, E. Husak, Chapter 1: The implementation of Industry 4.0 by using industrial and service robots in the production processes. In: *Handbook of Research on Integrating Industry 4.0 in Business and Manufacturing*, IGI Global, Hershey, PA, USA, 2020, pp. 1–30. doi: 10.4018/978-1-7998-2725-2.ch001.

[13] G. Chryssolouris, D. Mavrikios, N. Papakostas, D. Mourtzis, G. Michalos, K. Georgoulias, Digital manufacturing: History, perspectives, and outlook. *Proceedings of the Institution of Mechanical Engineers*, Part B: *Journal of Engineering Manufacture*, 223 (5) (2009), 451–462. doi: 10.1243/09544054JEM1241.

[14] E. Karabegović, I. Karabegović, E. Hadzalić, Industrial robot application trend in world's metal industry. *Inzinerine Ekonomika –Engineering Economics*, 23(4) (2012), 368–378. doi: 10.5755/j01.ee.23.4.2567.

[15] "*World Robotics Report*: *'All-Time High' with Half a Million Robots Installed in one Year*". Frankfurt (Germany): International Federation of Robotics (IFR), 2022. https://ifr.org/ifr-press-releases/news/wr-report-all-time-highwith-half-a-million-robots-installed [Accessed; June 26, 2024].

[16] M. Bill, C. Müller, W. Kraus, S. Bieller, World Robotics Report 2023, 2023. [Online]. Available: https://ifr.org/ifr-press-releases/news/world-robotics-2023-report-asia-ahead-of-europe-and-the-americas.

[17] International Federation of Robotics, "Executive Summary World Robotics 2022 Industrial Robots", 2022. [Online]. Available: https://ifr.org/img/worldrobotics/Executive_Summary_WR_Industrial_Robots_2022.pdf.

[18] I. Karabegović, M. Mahmić, E. Karabegović, E. Husak, Comparative analysis of the implementation of robot technology as the basic technology of Industry 4.0 in America (USA) and China. In: *Proceedings of the 14th International Scientific Conference (ETIKUM-2023)*; Novi Sad, Serbia; 7-9 December 2023. Novi Sad (Serbia): University of Novi Sad, Faculty of Technical Sciences, 2023, pp. 33–40. ISBN 978-86-6022-617-6.

[19] K.D. Thoben, S. Wiesner, T. Wuest, Industrie 4.0 and smart manufacturing – A review of research issues and application examples. *International Journal Automation Technology*, 11 (2017), 4–16. doi: 10.20965/ijat.2017.p0004.

[20] I. Karabegović, E. Karabegović, M. Mahmić, E. Husak, The application of service robots for logistics in manufacturing processes, *Advances in Production Engineering & Management*, 10(4) (2015), 185–194. doi: 10.14743/apem2015.4.201.
[21] I. Karabegović, The role of industrial and service robots in the fourt industrial revolution. *ACTE Technica Corviniensis – Bulletin of Engineering*, 11(2) (April 2018), 11–16.
[22] I. Karabegović, E. Karabegović, M. Mahmić, E. Husak, Implementation of Industry 4.0 and industrial robots in the manufacturing processes. *Lecture Notes in Networks and Systems*, 76 (2020), 3–14. doi: 10.1007/978-3-030-18072-0_1.
[23] I. Karabegović, E. Husak, E. Karabegović, M. Mahmić, How the core technologies of Industry 4.0 are changing the automotive industry in the world, with a focus on China. *IOP Conference Series*: *Materials Science and Engineering*, 1271 (2022), Article no. 012017: pp. 1–14. doi: 10.1088/1757-899X/1271/1/012017.
[24] M. Beaupre, (2015), Collaborative Robot Technology and Applications, International Collaborative Robots, Workshop, Columbia, 7th October 2015. https://www.robotics.org/userAssets/riaUploads/file/4-KUKA_Beaupre.pdf.
[25] E. Ostrgaard, (2015), Collaborative Robot Technology and Applications, International Collaborative Robots, Workshop, Columbia, 7th October 2015. https://www.robotics.org/robotics/international-collaborative-robots-workshop.
[26] A. Shikany, (2014), Collaborative Robots: End User Industry Insights, , International Collaborative Robots, Workshop, USA, California, 30th September 2014. https://www.robotics.org/robotics/international-collaborative-robots-workshop.