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ORIGINAL RESEARCH PAPER

Comparative analysis of automation of production process with industrial robots in Asia/Australia and Europe

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ABSTRACT: The term "INDUSTRY 4.0" or "fourth industrial revolution" was first introduced at the fair in 2011 in Hannover. It comes from the high-tech strategy of the German Federal Government that promotes automation-computerization to complete smart automation, meaning the introduction of a method of self-automation, self-configuration, self-diagnosing and fixing the problem, knowledge and intelligent decision-making. Any automation, including smart, cannot be imagined without industrial robots. Along with the fourth industrial revolution, ''robotic revolution'' is taking place in Japan. Robotic revolution refers to the development and research of robotic technology with the aim of using robots in all production processes, and the use of robots in real life, to be of service to a man in daily life. Knowing these facts, an analysis was conducted of the representation of industrial robots in the production processes on the two continents of Europe and Asia /Australia, as well as research that industry is ready for the introduction of intelligent automation with the goal of establishing future smart factories. The paper gives a representation of the automation of production processes in Europe and Asia/Australia, with predictions for the future.

KEYWORDS: *Automation; Collaborative robot; Industrial robot; Production process; Smart factories*

INTRODUCTION

It is a well-known fact that industrial robots, like service robots, are installed in almost every industrial production process. Any automation or modernization process would be unimaginable without robotic technology. The development of robotic technology, information technology of new materials and new technologies in the world lead to the development of new types of industrial and service robots and their increased presence in the automation of production processes. The strategies of most countries in the world are focused on increasing the productivity of the production processes, and this can only be achieved by modernization and automation of industrial production. For example, the German Federal Government promotes automation-computerization of industrial production, and in 2012 a working group of the German government presented recommendations for the introduction of the fourth industrial revolution called "Industry 4.0" in industrial production processes. The goal of "Industry 4.0" is to achieve "intelligent automation", implementation of which lead us to the future factory called "smart factory". The strategy of Japanese government is developing robotic technology called "robotic revolution", which refers to the use of robots in all production processes, to be of service to a man in daily life. In its national strategy, or 10-year development plan called "Made in China 2025", The Chinese government aims to become one of the best technological and industrial nations.

All these facts give us the right to conclude that the development of robots and the increasing use in the production processes of the industry will appear soon

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in the years to come. For these reasons, in order to acquire a true image on the rate of automation of production processes in the world, and in what time frame will the implementation of the "smart factory" happen, it is necessary to perform the analysis of the representation of industrial robots on two continents of Asia and Europe, because the countries that adopted the above-mentioned strategies are in these continents.

In order for these countries to achieve their strategic objectives in industrial production processes they have to introduce more flexibility, adjustability, modularity, change fixed structures with flexible, increased productivity, introduce intelligent (smart) machines and robots in automation, introduce decentralization of decision-making, so that production processes can make decisions independently, and only in the event of an error or conflicting objectives decisions will be delegated to a higher level (Geravand *et al.*,2016; Doleèek and Karabegoviæ, 2008; Doleèek and Karabegoviæ, 2002; Kalpakjian and Schmid,2014; Sulavik *et al.*, 2014; Ray*et al.*, 2016; Holdren,2012; Kozul-Wright, 2015; Association for Advancing Automation,2015; iTechnic Ltd *et al.*, 2013; Yang, 2016; Struijk, 2012; Roehricht, 2016; McKerrow, 1991; Wolka, 2013; Pluess, 2015).The above said can only be achieved with the use of industrial and service robots that will be supported with information technology (IT).

RESULTS AND DISCUSSION

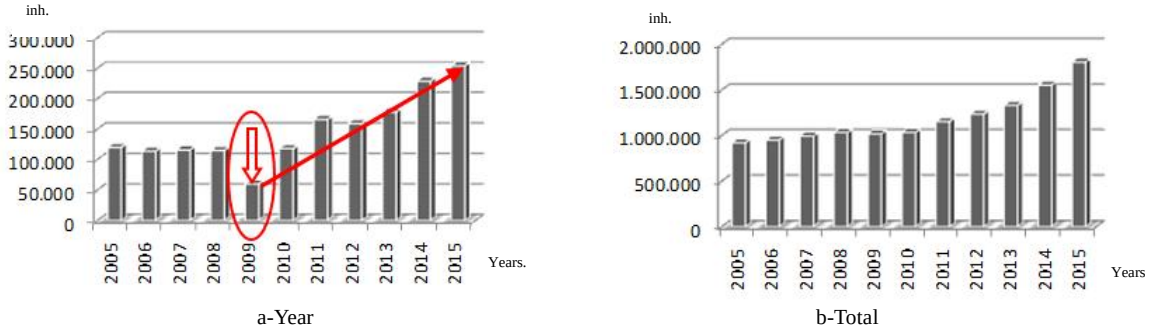
The representation of industrial robots in automation of production process in the industry worldwide

For this analysis in the introduction of the paper, it is necessary to conduct the analysis of the representation of industrial robots in the world for the past ten years. Data for statistical analysis were taken from the International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD) (Karabegoviæ, 2016; Karabegoviæ and Doleèek, 2016; Karabegoviæ and Husak, 2016), which are shown in Fig. 1.

The presence of industrial robots in the world on annual level for the period 2005-2008 is considered to be constant and amounted to 110.000 industrial robot units every year. The beginning of the economic and industrial crisis in 2008 and its continuation in 2009, reflected on the presence of industrial robots in 2009, when the lowest number of 60.000robot units were applied in the world. In period 2009-2015 there was a linear tendency of increased presence of industrial robots in production processes in the world, so that in 2015 it reached the number of 254.000 units of industrial robots. If we conduct an analysis of the overall representation of industrial robots in production processes in the world in the last decade, we come to the conclusion that every year there is a growing tendency of representation of robots, so that with 923.000 robot units represented in 2005, in 2015 the representation amounted to approximately 1.807.000 units of industrial robots. As can be seen, the total number of industrial robots applied in production processes in the world increased two times in ten years.

The representation of industrial robots in the automation of production process in all industries in Asia/Australia and Europe

Based on Fig. 1 there is a continuous increase in the representation of industrial robots in the automation of production processes in all industries worldwide. According to literatureliterature (Karabegoviæ, 2016; Karabegoviæa and Husak, 2016; Mannan and Khurana, 2012; Rochricht, 2016) the number of



a-Year b-Total

Fig. 1: The representation of industrial robots worldwide on annual and total level for the period 2005-2015

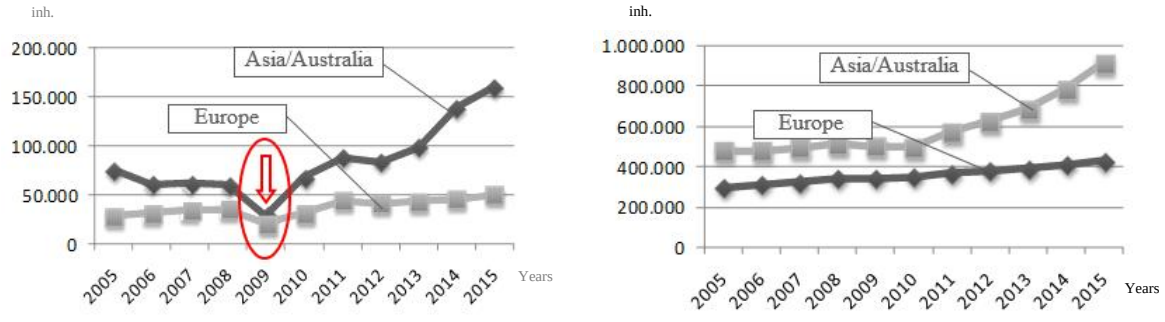
representation of industrial robots on continents is largest in Asia/Australia, followed by Europe, with America in the third place. Number of representation of industrial robots on the continent of Africa is so small in relation to these three continents (Asia/Australia, Europe, and America) that it is not suitable for the analysis. We need to conduct the analysis of the representation of industrial robots on the continents of Asia/Australia and Europe on annual and total level for the past ten years. The representation of industrial robots for the automation of production processes in Asia/Australia and Europe for the period 2005-2015 is presented in Fig. 2.

Based on Fig. 2 (a – Year) which shows the annual application of industrial robots in the automation of production processes on the continents of Asia/Australia and Europe, it is come to the conclusion that there is far greater application of industrial robots in Asia/Australia than in Europe. There was similar representation of industrial robots in 2009, which amounted to about 20-23.000 robot units on both continents. It was the lowest application of industrial robots on both continents recorded in the past ten years, reason of which was the economic and industrial crisis that began in 2008 and ended in late 2009.

Since 2009 there was an increasing tendency in the application of industrial robots in Europe and Asia/Australia each year (although far greater number of applied robots in the Asia/Australia), so that in 2015 around 50.000 robot units were applied in Europe, and about 160.000 robot units in Asia/Australia, which is three times more than in Europe.

When considering the overall application of industrial robots on the two continents Fig. 2 (b – Total) indicates that Asia/Australia has far greater number of installed robots in production processes compared to Europe. In the period 2005-2010 the difference was about 200.000 robot units. However, in period 2010-2015 the difference increased annually, so that in 2015 there were around 430.000 robot units in Europe, while in Asia/Australia there was a total of about 915.000 robot units applied in the automation of production processes. Based on that analysis it could be concluded that the Asia/Australia holds advantage over Europe in the application of industrial robots for automation of production processes in their industries. It is conducted that the analysis of the application of industrial robots in three countries on every continent, which show the highest numbers in the application of industrial robots. Based on the statistics published in (Makowieckaja, 2015; Karabegoviæ*et al.*, 2011; Karabegoviæ and Husak, 2014; Karabegoviæ and Doleèek, 2016; Karabegoviæ and Husak, 2016; Rochricht, 2016), these countries are shown in Fig. 3.

There are three countries that are interesting from the point of application of industrial robots in Asia/Australia: Japan, Republic of Korea and China. By conducting an analysis of Fig. 3 (a – countries in Asia) it is seen that a decade ago the first place in the application of industrial robots in production processes was held by Japan, followed by Republic of Korea and China. This tendency was maintained until 2011. It is important to emphasize the fact that in 2009 there was the lowest application of industrial robots in all three countries, as a consequence of economic and industrial crisis in the world. After 2012 and until 2015, i.e. in the last three years, the situation has changed (Dolphin, 2015).



a-Year b-Total

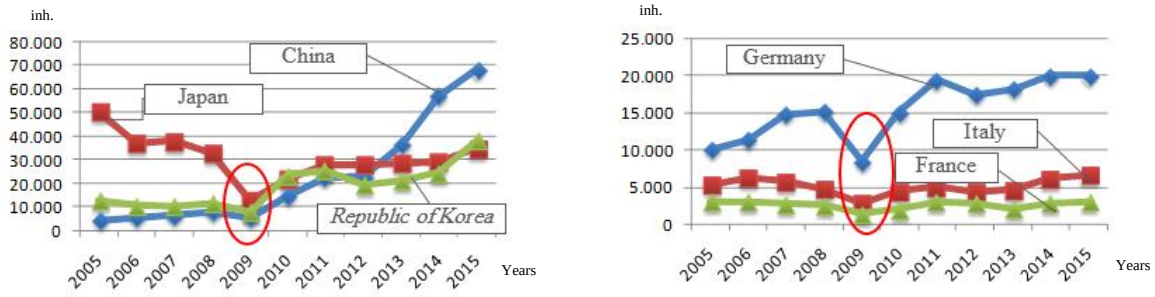
Fig. 2: Annual and total representation of industrial robots in automation of industrial production processes in Asia/Australia and Europe (Karabegović, 2016; Karabegović and Husak, 2014; 2016; Karabegović and Doleček, 2016)

China has become a leader in the application of industrial robots in Asia, followed by Republic of Korea and Japan. In order to observe the difference, it is mentioned that the application of industrial robots in 2005, when Japan applied around 50.000 robot units, Republic of Korea around 13.000 robot units and China approximately 4.500 robot units. Through this it could be concluded that in 2005 Japan applied ten times more robots in the automation of production processes than China. This image is constantly changing, and in ten years in 2015 China applied around 68.500 robot units, Republic of Korea around 38.000 robot units, and finally Japan around 35.000 robot units. It is noticeable that China applied almost twice as much robots units than Japan. This is a consequence of the development strategy of a particular country. For example, China has adopted a national ten-year strategy entitled "Made in China 2025", whose aim is to make China the leading country in technology development in few years. Unlike China, Japanese developing service robotics that has primary goal to assist past requirements, and the second goal is for service and industrial robots to work alongside, without industrial robots being fenced because of the safety of workers. The analysis of the application of industrial robots in European countries where most robots are used in the automation of production processes revealed the following three countries: Germany, Italy and France. In these countries more than 2.000 industrial robot are applied annually. Based on Fig. 3 (b – European countries), it is seen that the order in the last ten years is completely the same. In the first place is Germany which applied the highest number of industrial robots, second is Italy, and in the third place is France. It have to be noted that in the last ten years Germany has doubled the application of industrial robots with around 10.000 robot units in 2005 to about 20.000 industrial robot units in 2015.The tendency of application of industrial robots in Italy and France may be said to be almost constant in the last decade with small fluctuations. When Europe is in question, Spain have to be singled out, because in 2015 they applied around 2.300 industrial robots in its industry for the automation of production processes (Karabegoviæ and Husak, 2014). The expected result of the application of industrial robots in the future is that this tendency will continue.

The representation of industrial robots in different industries worldwide, with an overview of Asia/ Australia and Europe

In order to see how industrial robots are used in the industry during the automation of production processes, an analysis of the application of industrial robots by industry in the last five years must be made. This analysis is shown in Fig. 4 (Karabegoviæ, 2016; Karabegoviæ and Husak 2014; Karabegoviæ, Doleèek, 2016; Rochricht, 2016).

With the analysis of Fig. 4, it could be concluded that most of industrial robots are used in the automotive industry for the modernization and automation of production processes in welding car bodies, body painting, assembly and control. This is quite logical because in 2015 around 93 million vehicles of various models were produced worldwide (Wolff, 2015).It could be determined that in 2014, as well as 2015, total of 97.000 units of industrial robots were applied worldwide. Based on Fig. 3 we can see which countries in the world (on continents of Asia/ Australia and Europe) conduct automation of production processes in the automotive industry.



a – Countries in Asia

b – Countries in Europe

Fig. 3: Annual and total representation of industrial robots in the countries in Asia (China, Japan and Republic of Korea) and the countries in Europe (Germany, Italy and France)

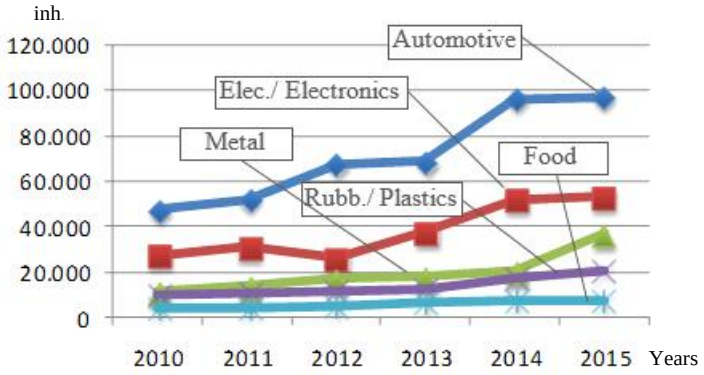


Fig. 4: The application of industrial robots worldwide by industry in period 2010-2015 on annual basis

These are China, Japan, Germany, Republic of Korea, Italy and France, but also Spain, as they are using industrial robots in the automotive industry. The second place in the application of industrial robots worldwide is held by the electrical/electronics industry, which is applying half as much industrial robots as the automotive industry. In the last two years the electrical/ electronics industry applied around 53.000 robot units. It should be mentioned that countries in Asia apply most industrial robots in the electrical/electronics industry, led by Republic of Korea and Japan. The third place in the application of industrial robots is taken by metal industry. It have to be noted that the metal industry produces components for the automotive industry, so this tendency of application is quite reasonable. The fourth place in the application of industrial robots is held by rubber and plastic industry, and in last place is the food industry.

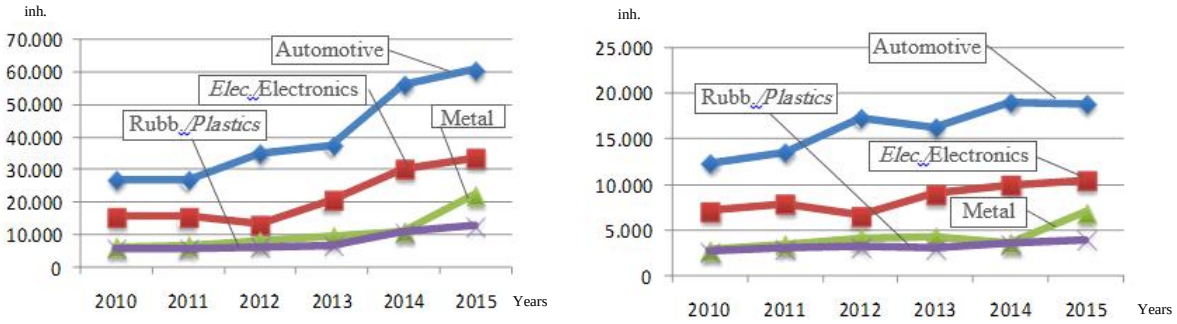
Based on the diagram shown in Fig. 2 (a – Asia), it is concluded that automotive industry in Asia used industrial robots for automation of production processes in the highest percentage. In second place in applying industrial robots is the electrical/electronics industry. The analysis of the tendency of the application shows that the automotive industry in Asia uses almost two times more industrial robots in comparison to electrical/electronics industry in the last five years. In order to understand what kind of relation it is, an example of the application of robots in 2015 is given in these two industries. In 2015 automotive industry applied around 61.000 industrial robot units, while electrical/electronics industry applied around 33.000 robot units. In third place is metal industry, followed by plastic and rubber industry.

When the application of industrial robots by industry in Europe is in question, Fig. 5 (b – Europe), the structure is the same. In the first place is the automotive industry, where the use of robots in the last six years ranges from 12.000 to 19.000 robot units, so that in 2015 the application was the highest with around 19.050 units of industrial robots. It brings us to conclusion that in the same year Asia applied 61.000 units of industrial robots in automotive industry, which is three times more than in Europe in the same year. The second place in Europe is held by the electrical/ electronics industry, whose tendency in application in the past six years ranges in between 7.000 and 10.000 industrial robot units. In the same period in Asia the tendency for electrical/electronics industry is15.000 to 33.000 industrial robot units, which in last year is three times more than in Europe.

In third and fourth place in the application of industrial robots in Europe are metal industry and plastic and rubber industry. This is similar to Asia, only the number of robot units is twice lower.

The representation of industrial robots in the automation of production process per 10.000 workers and per population

Realistic picture of industrial development and automation of manufacturing processes in a country, it is necessary to make an analysis of the application ofindustrial robots by employed workers in the industry. Fig. 6 shows the application of industrial robots per 10.000 workers by certain countries in the world. Analysis data were taken from (Karabegoviæ and Doleèek, 2014; Karabegoviæ*et al.*, 2011; Karabegoviæ and Husak, 2016).



a – Asia b – Europe

Fig. 5: The application of industrial robots on continents of Asia/Australia and Europe by industry in period 2010-2015 on anabasis (Karabegovića and Doleček, 2014; Karabegović and Husak, 2014; 2016)

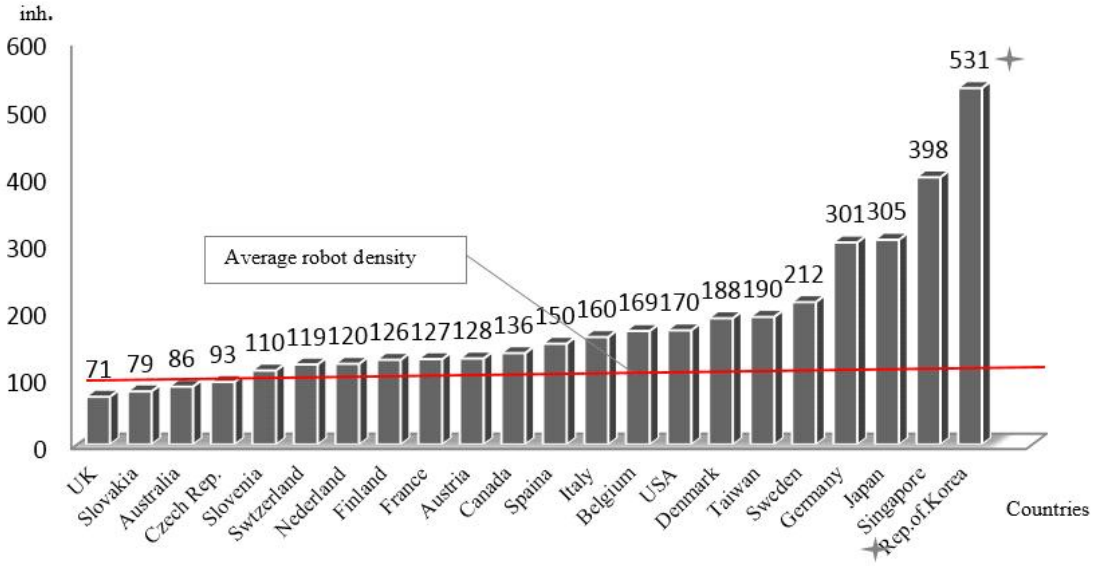


Fig. 6: The representation of industrial robots per 10.000 workers in the production processes by countries worldwide

As Fig. 6 indicates, world average is 69 industrial robots per 10.000 workers employed in the industry. Only 22 countries in the world are above this average, while all other countries are below the average in the application of industrial robots in industry production processes. The top three countries in the world are in Asia: Republic of Korea with average of 531 robot units, Singapore with 398 robot units and Japan with 305 robot units per 10.000 workers. A total of five countries in Asia have a higher average application of industrial robots in production processes. Total of thirteen countries in Europe demonstrate the application of industrial robots above average, so that it could make a conclusion that throughout Europe there is greater representation of industrial robots in production processes in relation to the number of workers employed in the industry. The leading countries in Europe in the application of industrial robots by the number of employees are: Germany with 301 robot units, Sweden with 212 robot units, Denmark with 188 robot units, Belgium with 169 robot units, Italy with 160 robot units and Spain with 150 robot units per 10.000 workers. In order to see the tendency of application of industrial robots per 10.000 workers, it is

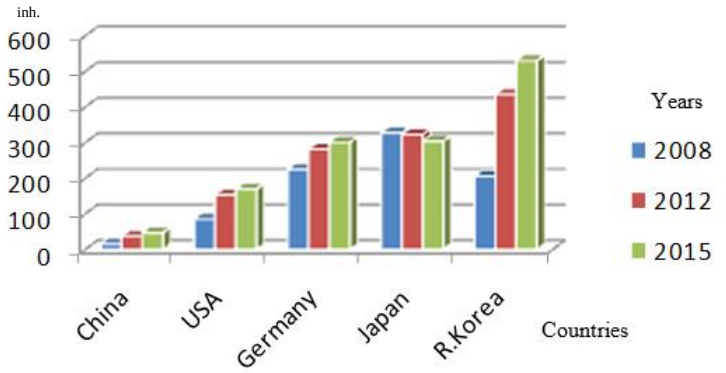


Fig. 7: The representation of industrial robots per 10.000 workers in the industry production processes in Republic of Korea, Japan, Germany, USA and China for the period 2008-2015 (Karabegović and Doleček, 2014; Karabegović and Husak, 2016; Rochricht, 2016).

needed to conduct the analysis in several countries for 2008, 2012 and 2015. Fig. 7 shows the analysis in Republic of Korea, Japan, Germany, USA and China. It could be concluded that there is the growing trend in all listed countries in the last seven years. Here it must be emphasized Republic of Korea, which showed an enormous increase from 200 robot units in 2008 to 531 robot units in 2015 per 10.000 workers. Japan experienced mild downward trend in this period, which leads us to the fact that Japan as a country has a slightly different strategy in terms of representation of industrial robots in production processes. Japan has developed automotive industry where the largest representation of industrial robots is, but lately there has been organization of the production process of automotive industry in other countries of Europe and America.

Fig. 8 shows the trend of application of industrial robots on the continents of Africa, Asia/Australia, America and Europe in the period 2012-2015 years per million population. Here it is seen that in this period on all continents there is a growing tendency in application of industrial robots, based on which it is concluded that automation and modernization of production processes in all industries using industrial robots is being conducted on all continents. It could be seen that in Africa, the application of robots in relation to population is so low, that it is not acceptable for discussion. By comparing the application in industrial robots in Europe and Asia, it is seen that use in Europe is far more extensive and it ranges from 150 to 200 robot units. This tendency was expected for two reasons.

The first and the main reason is that Asia is densely inhabited, and when the total number of industrial robots is divided with number of inhabitants this tendency is obtained, even if Asia as a continent in the first place by the application of industrial robots in production processes. The second reason is that in Europe more countries are developing the automotive industry where industrial robots for automation of production processes are mainly used, for example welding car bodies where processes are fully automated with industrial robots.

The representation of industrial robots in the following period until 2019

To obtain complete picture of the representation of industrial robots in production processes in the industry in Europe and Asia/Australia, it is necessary to observe the tendency of application of industrial robots in the following years. Fig. 9 shows the tendency of application of robots in the coming period in the world, Asia/Australia and Europe by 2019. The statistical data were taken from (Karabegoviæ *et al.*, 2011; Karabgoviæ, 2016). The diagrams shown in Fig. 9 shows an increasing tendency from year to year worldwide. Predictions are that the annual implementation of industrial robots in the world will be around 400.000 robot units in 2019. In period 2016 to 2019, it is expected that the tendency of application of industrial robots in Asia/Australia will be increasing, and it is estimated that around 280.000 robot units will be applied for the automation of production processes. In Europe, the tendency in the following period will be constant with

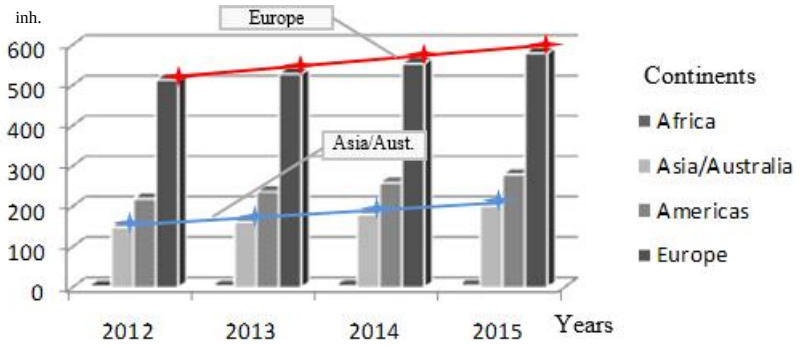


Fig. 8: The representation of industrial robots by continents per 1.000.000 inhabitants for the period 2012-2015 (Karabegović and Doleček, 2014; Karabegović and Husak, 2016; Rochricht, 2016)

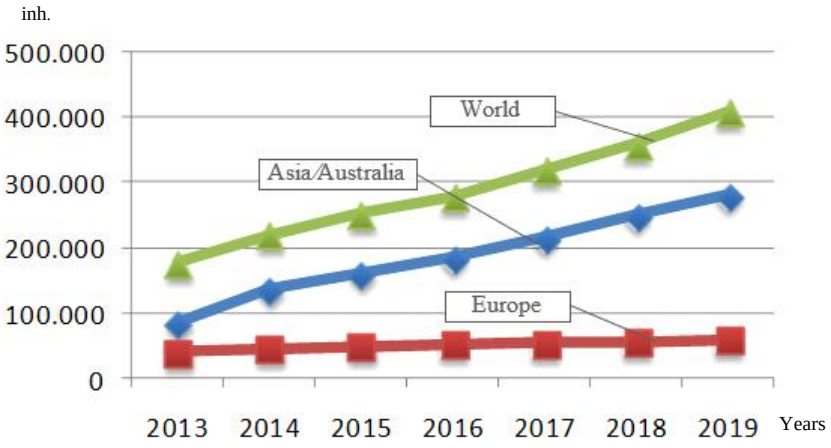


Fig. 9: The representation of industrial robots in the world, Asia/Australia and Europe by 2019

small variations, and it is expected that in 2019 around 51.000 robot units will be applied. By comparing the application of industrial robots in the coming period in Europe and Asia/Australia, it could be seen that Europe is losing pace compared to Asia, because the difference is changed annually, and it could be concluded that in 2019 Asia will apply five times more industrial robots than Europe. This trend is logical because in the recent years China has become the first in the world in the production of vehicles, as well as the application of industrial robots. In 2016 around 68.500 robot units were applied in China, and it is anticipated that in 2019 around 190.000 robot units will be applied in China [xx]. Today's producers are faced with several problems such as: competition, increasing production costs, and increased diversity of products. The complexity of products requires greater flexibility, precision and reliability, which are already outside of the range of skills of the workers in the production process.

The price of implementation of industrial robots in the production process was about two-year salary for a worker. However, regardless of price this generation of robots cannot meet and solve the problem of manufacturers that just be mentioned.

Traditional industrial robots will be further developed to meet the needs of today's automation of production processes, along with a wide range of form factors, capacity and capabilities. However, so-called collaborative robots (or cobots) are being developed, costing around a quarter of two-year salary for a worker. They are able to work side by side with the workers, they are lightweight and flexible, and they can easily be moved and reprogrammed to perform other tasks. With the application of collaborative robots production processes become flexible and easily automated. In this way there would be the ability to greatly lower the threshold and barrier of the automation process, and also the possibility of automation in the field of very complex and expensive

production processes. Thus, there are new come up solutions in automation of production processes that can be applied to small and medium companies. The president of the International Federation of Robotics Shinsuke Sakakibarasaid that fast development and advancement of technology, including artificial intelligence, will lead to solving more complex tasks with robots, not only in the automation of production processes in the factories, but also in restaurants, shopping services, and care of elderly (Wloka, 2013).

CONCLUSION

Based on the analysis of the representation of industrial robots in the automation of production processes in industries in Europe and Asia/Australia, the following conclusions are brought:

- The representation of industrial robots in production processes on annual level is continuously increasing worldwide. Also,there is a growing tendency in the overall level, as shown in diagrams in Fig. 1.
- The representation of industrial robots in Asia/Australia and Europe in the production processes has a growing tendency on annual and total level. However Asia/Australia applies far more industrial robots annually and the difference between the two is increasing. It could be concluded, on the basis of Fig. 2 that in 2015 Asia had an advantage of two to three times more robot units in comparison to Europe.
- The leading countries in the representation of industrial robots in Asia/Australia are China, Republic of Korea and Japan, whereas the leading countries in Europe are Germany, Italy and France. It could benoted that these countries on both continents have well developed automotive industry. Asian countries have higher representation of industrial robots in production processes, as indicated in Fig. 3.
- The highest representation of industrial robots in the world is in the automation of the production process of the automotive industry. In the second place is the electrical/electronics industry, the third place is the plastic and rubber industry, and the last one is the food industry (Fig. 4). This is the logical arrangement of the representation of industrial robots in production processes in various industries worldwide, because about 90 million vehicles are produced in the world on the annual level, which would be impossible without automated production processes. In addition, the development of new electrical devices (TVs, projectors, phones, etc.) with new models continuously being developed, require the introduction of industrial robots in the production process.
- Completely identical representation of industrial robots by industry is presented for Asia/Australia and Europe, and worldwide, as shown in Fig. 5. On both continents the order is as follows: automotive industry is in the first place, followed by: electrical/electronics industry, metal industry, and rubber and plastic industry. In Asia/Australia the representation of industrial robots is said to be three times higher than in Europe in almost all industry branches.
- Based on Fig. 6, it could be concluded that world average is 69 robot units per 10.000 employed workers. First three place in the world are held by three countries in Asia: Republic of Korea with 531 robot units, Singapore with 398 robot units and Japan with 305 robot units per 10.000 workers employed in the production processes. There are only 22 countries in the world that are above the average, while all others are below the world average. 13 countries in Europe have the average that is above world average, whereas there are only 5 such countries in Asia/Australia. We can conclude that the Europe as a continent has greater representation of industrial robots in the production processes in relation to the number of workers employed in the industry.
- The result of the analysis of the representation of industrial robots per 10.000 workers by countries in Europe and Asia/Australia in the last seven years is such that there is a growing tendency in all analyzed countries (Fig.7), except for Japan. The first reason for the declining trend in the representation of industrial robots in Japan is the dislocation of production processes of the automotive industry in countries with cheap labor, and the second reason is the development of other industries, for example electrical/electronics industry where use of industrial robots is lower.
- Following the analysis of the representation of industrial robots per 1 million inhabitants by continents (Fig. 8), it could be resulted that the first place is held by Europe, followed by America, Asia/Australia and Africa in the end. The tendency of representation is growing on all continents. By comparing representation in Europe and Asia/Australia, it is seen that Europe has almost three times higher representation than Asia, which is to be expected having in mind the population of Asia/Australia.
- The analysis of the tendency of representation of industrial robots in the coming period with predictions to 2019 (Fig. 9), indicates that there is a growing tendency in Europe and Asia/Australia, with the difference between Asia/Australia in relation to Europe increasing annually. One of the reasons is development strategy of China named “Made in China 2025” which aims to make China one of the best technological and industrial nations in the world.

Today, there are far more complex products that require greater flexibility, precision and reliability that are already out of range skills of workers in the production processes. However, the traditional industrial robots will be further developed and implemented to meet the needs of today's automation of production processes, with a wide range of form factors, capacity and capability.

In the following period, the application of collaborative robots would be experienced, which are far lighter than the traditional industrial robots. They can be easily moved and reprogrammed to perform other tasks, they are flexible and can work side by side with the workers, while traditional industrial robots were separated by protective barriers from the workers so that they wouldn't get hurt. With the application of collaborative robots, automation of the production processes becomes easier and simpler, and can be applied by small and medium companies. The use of ''cobot'' robots with the support of information technology will lead to smart automation, and eventually to "smart factories".

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CONFLICT OF INTEREST

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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