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Robotic Implementations in Welding Engineering

Abstract: The effect of robotisation on the competitiveness of enterprises continues to grow; therefore, manufacturers increasingly often purchase industrial robots, making the proper concept of a robotic station even more important. The article presents the present state and development trends in robotisation in Poland and overseas, indicates issues accompanying implementations of welding robots and presents possible preventive measures.

Keywords: robotisation in welding, robotic implementation in welding

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The industrialisation of the economy and the growing market of consumers determine the permanent development of the automation and robotisation of production plants. Today's market is globalised and borderless. Staying competitive in such a market requires the use of modern technologies offering new possibilities. The International Federation of Robotics (IFR) announced that 2014 was another year of record global sales with 229 thousand robots sold (Fig. 1), i.e. approximately 15% more than in 2013. According to IFR forecasts, the demand for industrial robots and other means of automation will continue to grow [10, 13, and 23].

According to forecasts, equally high sales of robots will mark the years 2015-2017, with an annual growth in global sales amounting to

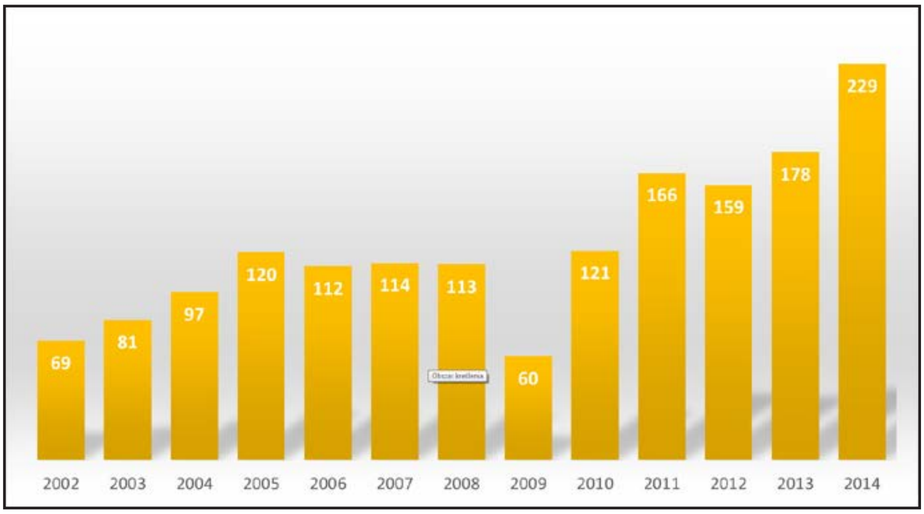

Fig. 1. Global annual sales of industrial robots (source: IFR)

Table 1. Annual sales of industrial robots in Europe along with forecasts (*) for the years 2012-2017 (source: IFR)

	2012	2013	2014*	2015*	2016*	2017*
Europe	41,218	43,384	46,000	47,000	49,000	55,000
Czech Rep.	1,040	1,337	1,800	2,000	2,300	2,600
France	2,956	2,161	2,300	2,400	2,600	2,800
Germany	17,528	18,297	19,500	19,500	20,000	21,000
Italy	4,402	4,701	4,800	5,000	5,200	5,500
Spain	2,005	2,764	3,000	3,500	3,600	3,800
Great Britain	2,943	2,486	2,500	3,000	3,200	3,500
Others	10,344	11,538	12,100	11,600	12,100	15,800
In total	159,346	178,132	205,000	232,850	258,900	288,000

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approximately 12% (Table 1). According to the IFR data, similar to the previous year, the greatest robotic market is that of China. A demand for robots in China has been growing since 2008 with annual sales rising by 36%. The majority of the global sales of robots take place in countries which for many years have aspired to leading positions in robotisation, i.e. Asian countries and Australia (with a 16% demand) and countries from both Americas (with a result of 6%). In 2014 there was 1.5 million industrial robots. By the end of 2017 this number is expected to grow to approximately 2 million [7, 10, and 23].

Robot Sales in Poland

In comparison with other European countries, Poland remains one of the least robotised countries in the region (Fig. 2). In the years 2003-2014, the number of robots per 10 thousand workers increased from 2 to 19, whereas over the past 3 years in Hungary, the Czech Republic and Slovakia this indicator has grown by 17, 20 and 34 items respectively. According to the recent data by GUS (Central Statistical Office in Poland), the robotisation potential of the Polish production industry is large and the number of means of automation, including robots and manipulators, is on the rise. The years 2009-2011 in Poland saw 2040 robots and manipulators, with a further 1264 starting operation in the following year. In 2013, Polish production used 11,389 industrial robots and manipulators [7, 9, and 10].

Analysing only the increase in the number of industrial robot installations in Polish production companies, it can be seen that in the past three years the dynamics of robotic implementations in Poland has decreased with the number of new machines increasing by a mere half if compared with the previous year. In comparison with Europe as a whole, this trend is significantly lower. As can be seen in Figure 3, the greatest group of means of automation in Poland is composed of computers for controlling and adjusting technological processes (38%), automated production lines (19%) and robots and manipulators (11%) [12, 13, 20].

The greatest growth in the number of means of automation included robots and manipulators (as much as 10% on an annual basis). The growing robotisation trend is manifested by the development of computer-aided applications dedicated to improving human-robot "cooperation", e.g. a Computer Aided Fixture Design module responsible for ready components of robots in CAD simulations or mapping functions aimed to improve the efficiency of on-line programming [15, 18, and 21].

Advantages Resulting from Robotisation

According to a report developed by Instytut Badań nad Gospodarką Rynkową (IBnGR – Institute for Market Economics), Polish entrepreneurs are beginning to notice the necessity of increasing production efficiency and

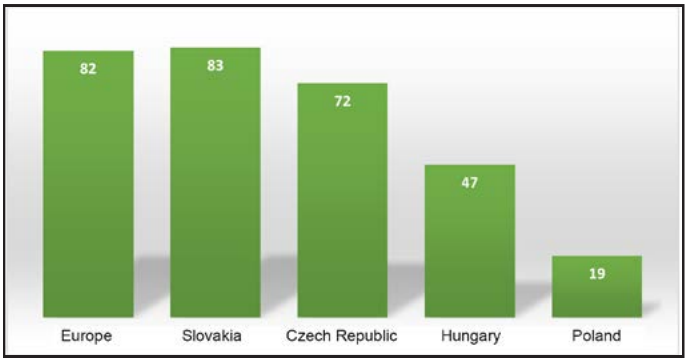

Fig. 2. Robotisation density in Polish industry compared with other countries of the region (pcs/10k workers) (source: FANUC bulletin)

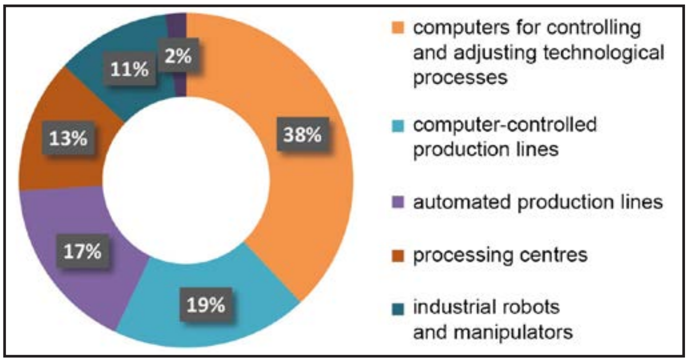

Fig. 3. Structure of means of automation in Poland in 2012 (source: GUS – Central Statistical Office)

competitiveness of their businesses in relation to robotisation. This growing interest frequently translates into investments. The report mentioned above was based on a survey of 100 production companies, where the primary reason for robotisation was the necessity of increasing production capacity (approximately 80%), increasing company competitiveness (approximately 50%), improving quality (approximately 40%) and eliminating human presence in conditions posing hazards to life and health (20%). In most cases, companies which decided on robotic implementations could enjoy forecast advantages, particularly as regards economic as well as production and market-related aspects [7, 9, and 14].

Eighty per cent of companies which have already invested in robotisation increased their production while simultaneously decreasing unitary production costs. All of the surveyed companies stated that production robotisation had increased company international competitiveness and 37% of them saw their overseas sales grow following robotic implementations. In addition, 53% of companies advanced their technological level and 84% saw improved quality of their products. Figure 4 presents advantages resulting from installations of robots in production companies taking into consideration characteristic areas [7, 9, and 14].

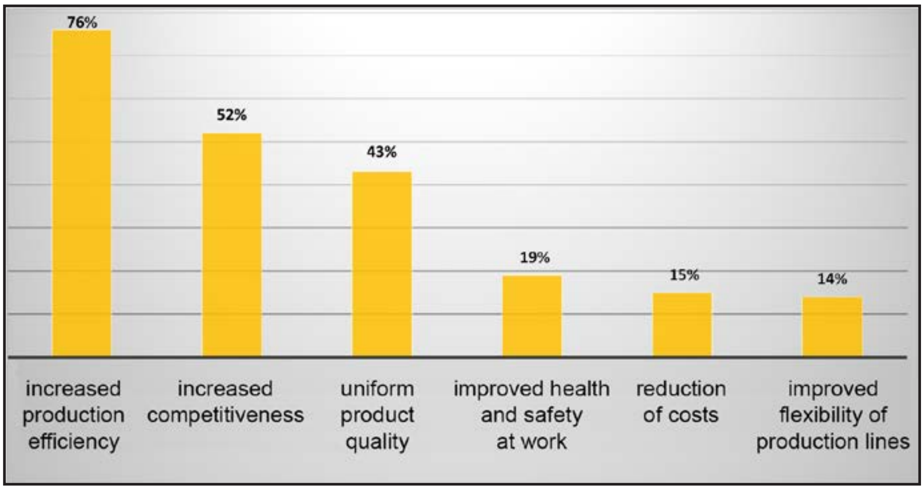

Fig. 4. Advantages resulting from robotisation in production companies (source: FANUC bulletin)

In spite of numerous and unquestionable advantages arising from the robotisation of welding processes, when implementing robotised systems for the first time, it is necessary to watch out for many potential traps and avoid typical mistakes resulting in quality-related problems and increased operating costs. Autonomous and conscious decision-making when selecting robotic devices and systems can prevent many mistakes.

Defining a Company's Needs

The first step is to develop characteristics of production processes and specify the composition of a robotic welding station. A proper concept of such a station is very important and strongly affects the final result. A robotic welding station is composed of many elements, the most important of which include a welding robot with dedicated software applications and a welding machine with necessary fixtures, e.g. filler metal wire feeder, current-carrying wires, tracking systems, positioners, manipulators etc. Properly adjusted parameters of a welding robot and of a welding power source are of key importance as regards the efficiency of a welding process. As welding robots can achieve a rate of up to 12 m/s in a linear direction, it can be concluded that the welding power source characteristic will be a welding process limiting factor. In addition, some basic welding methods such as MIG/MAG (131, 135, 136, and 138) require a mere 0.025 m/s. As can be seen, the potential of industrial robots significantly exceeds welding rate-related requirements. However, it does not mean that a robot can be slow, as during welding it must use its velocity-related potential not only for activities connected with welding, but also for movements connected with positioning the welding torch, runs performed between welds or between elements being welded - the faster, the better. The optimum solution includes a fast robot and a highly efficient welding power source [2, 3, and 19].

Another important issue is the integration of a welding machine with an industrial robot. A question that arises is whether a solution where all of the components of a robotic welding station come from one manufacturer is truly the best solution. Compact solutions provide excellent communication between all components, and the producer's task is to adapt a robotic station to the organisation of production in a given company. As an alternative solution, a customer could have almost all devices of any parameters at their disposal, yet such a situation entails additional costs, time and training required during the integration and operation of a station consisting of components provided by various manufacturers. When creating a network of communication between a robot and a welding machine, it is necessary to take into account features of these devices, or in other words, bear in mind that parameters in the form of data should be appropriately processed and fed to the robot and make it react in a specific manner. The adjustment of parameters is the user's responsibility, yet during processes such parameters should be controlled and monitored by the robot. The performance of this task cannot be based on one relay only. The system should be adjusted so that the user could access all of the functions offered by the source. If the communication between devices manufactured by various producers is proper, such a solution may appear to be the best [3, 8, and 19].

Another crucial aspect is how to define robot arm-related needs. Often, the extension of an operating range entails the extension of the entire arm of a robot. Such a solution is not always convenient as it increases the total robot weight, which in turn negatively affects the acceleration and, indirectly, the maximum velocity of movements performed by a robot. Welding robots are expected to use related tools at high velocities. Usually, a robot arm does not weigh more than 6 kg. An optimum solution may consist in placing the robot on a rail moving along an element being processed or installing a manipulator combined with the robot. If the budget for investments is high enough, an interesting solution could be a robotic station consisting of several welding robots. Such a solution might enable the division of a big operation area into several smaller areas "covered" by several robot arms and, in addition, increase the efficiency of welding processes [1, 3, 4, 11, and 19].

Selection of Adequate Software Applications

The programming of industrial robots can be divided into *off-line* and *on-line* programming. *Off-line* programming is more common in industrial applications and more frequently offered by manufacturers of robots. Off-line programming is based on CAD (Computer Aided Design) systems and simulates welding processes by creating a robot movement trajectory in a computer programme environment (tool path design). The adaptation of *off-line* programming-based software applications to individual production purposes requires time and numerous tests. Unfortunately, the risk of collision is very high. The major problem is the fact that in welding processes, a welding torch is not in direct contact with an element being welded. Therefore, it can be stated that *off-line* programming in the CAD environment is used for the simulation and verification of processes. Such a generated programme can later, on a step-by-step basis, be translated into an actual process. Depending on the type of production, it may appear that real-time, i.e. *on-line*, programming lasts shorter than import from the off-line environment. An additional advantage is the possibility of using video systems. Such solutions enable scanning elements by means of video laser sensors indicating welding areas. The above named systems are characterised by an easily integrated function of robot arm movement tracking [3, 5, and 15].

Manual Skills and Professional Experience of Welding Personnel

In order to fully use the potential of robots and automated systems, robotic applications should not exclude or ignore invaluable experience and qualifications of welding personnel. In Poland, there are almost four thousand holders of international or EU welding engineering-related certificates and over 10 thousand holders of certificates confirming NDT qualifications. A survey conducted by Instytut Spawalnictwa and involving 200 welding companies, revealed that every company participating in the survey employed at least one specialist holding an international diploma (Fig. 5) [16, 17].

A natural consequence of implementing technologically advanced equipment in a given company is an increase in personnel qualifications. It is important to acquire knowledge related to the daily operation of industrial robots, requiring completing a series of appropriate courses. An operator of welding robots should have qualifications satisfying requirements formulated in PN-EN ISO 14732:2014-01 (previously PN-EN 1418:2000) *Welding personnel – Qualification testing of welding operators and weld setters for mechanised and automatic welding of metallic materials*. Usually, requirements for applicants wishing to participate in such training include being 18 years of age, completion of primary or vocational education and the capability of working as a welder confirmed by a medical certificate. An operator who has passed a state examination confirming their qualifications and holds a certificate confirming the completion of related training can perform automated welding using the following methods: 131 (MIG) – metal inert gas welding of aluminium; 135 (MAG) – metal active gas welding; 136 (MAG) – metal active gas/flux cored arc welding; 141 (TIG) – tungsten inert gas welding. In addition, technical personnel should possess knowledge of maintenance, repairs, wiring systems etc. Eighty per cent of companies surveyed by the IBnGR (Institute for Market Economics) have confirmed improving qualifications of their workers in relation to robotic implementations. As robots usually replace workers on stations where conditions are harmful or work is particularly monotonous or strenuous, the general level of industrial health and safety rises as well [16, 17].

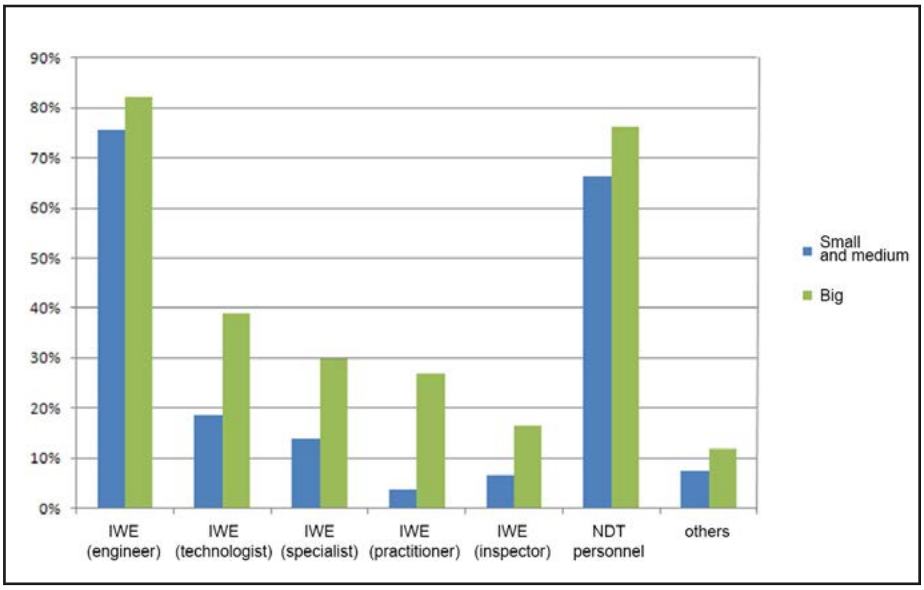

Fig. 5. Welding personnel with international diplomas employed in companies participating in the survey (according to % of replies)

The effective use of software applications requires the appropriate selection of operations. It should be noted that in spite of complex computer simulations, software applications are not able to replace a welding engineer's knowledge and experience. Robotic implementations in a selected industrial process of a given company entail a number of organisational changes, among other things, in the structure of personnel employment. Robotic implementations may, but do not need to lead to downsizing. In order to study employment structure-related changes, the IBnGR (Institute for Market Economics) performed surveys at industrial companies using welding robots (Fig. 6) [16, 17].

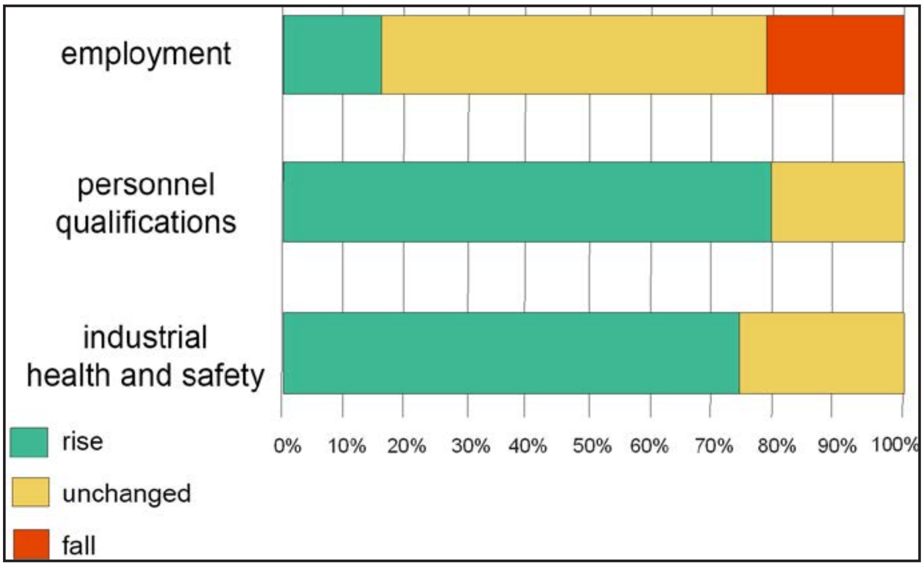

Fig. 6. Effect of robotisation on employment, personnel qualifications as well as industrial health and safety (source: IBnGR)

Welding processes performed under water are a challenge in themselves, all too often accompanied by accidents (e.g. Deepwater Horizon). Successful robotic implementations confirm how important the role of robots and automatic equipment has become and demonstrates that their use is often the only chance to process an order safely [6, 16, and 22].

Typical installations of industrial robots are rarely accompanied by problems. These may appear later, i.e. in production processes. Therefore, it is worth considering a scheme aimed at preventing breakdowns and failures. In order to avoid problems resulting from the specific character of a given technology, it is necessary to appropriately prepare a device for monitoring welding processes, create back-up copies of software applications and use sensors helping locate or verify locations of problems as well as to develop a plan and provide resources enabling the removal of failures [19].

It appeared that employment was reduced only in 20% of surveyed companies, in 65% employment stayed the same, whereas in 15% of the companies, due to increased production capacity, employment was increased. The surveyed companies included enterprises representing the automotive industry, mining, metal industry as well as electric and electronic sectors [16, 17].

The assets resulting from robotisation include improvements in repeatability, quality and efficiency of processes and the replacement of human labour in conditions hazardous to life and health. The number of dangerous conditions accompanying welding works is on the rise, among others, due to the use of new materials. The reduction of worker exposure to such perils requires the use of welding fume exhausts and appropriate protective clothing as well as, if possible, the control of process parameters. One of solutions aimed to reduce exposure of humans to occupational hazards is robotisation, successfully applied when welding harmful materials or working in confined spaces, at high temperatures etc. The most dangerous occupational activities include *off-shore* and *on-shore* applications. Welded structures used in such applications are very demanding and often made and processed in very hazardous conditions, e.g. in oil and gas output industries.

Summary

According to the IFR data, in spite of highly qualified welding personnel, Poland is one of the least robotised countries in the world. Taking into consideration present expert forecasts and trends observed on the global industrial market, it can be expected that the demand of Polish companies for industrial robots, including welding robots, will grow in the years to come. This growth will largely be dictated by competition-related pressure. The above named IFR forecasts justify the conclusion that robotisation is a worldwide trend. Reasons underlying the development of robotisation are the possibilities and opportunities offered thereby. Robotic welding equipment provide the fast rate, efficiency, quality and repeatability of welding processes. In order to fully “enjoy” robotisation-related advantages, it is necessary to precisely identify one's needs, appropriately select software applications, carefully recruit personnel operating robotic stations and properly organise production involving robotic stations.

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