Industry 4.0 – industrial robots

Olaf Ciszak
olaf.ciszak@put.poznan.pl

Poznań University of Technology, Institute of Mechanical Technology
Piotrowo 3 Street, 60-965 Poznan, Phone: +48 61 665 21 62

Abstract. The paper presents the place, role and importance of modern industrial robots in the era of today's changes taking place in industry – the industrial revolution – Industry 4.0. In the following, the basic technical data of the most popular Collaborative Robots were discussed and compared. Also the didactic Flexible Production System, built according to the Industry 4.0 concept at the Institute of Mechanical Technology - Poznan University of Technology, was presented.

Keywords: Industry 4.0, industrial robot, collaborative robot, Flexible Production System

1 Introduction

It is not difficult to resist the impression that the concept of: automation, robotics, maintenance, production engineering, etc. entering beyond the production industries. It is a continuation of technological development of the last few decades and has a revolutionary character.

For the reality, that is shaped as a result of the mentioned innovations, terms such as: Industry 4.0, Advanced Manufacturing, Smart Production, Integrated Industry (Fig. 1) are used.

The name Industry 4.0 has been widely accepted in Europe. It was created during the work initiated by the German government in 2010 on the recognition and analysis of upcoming landmark changes of strategic importance for the German economy. In 2011, at the Hanover Fair, this term was used for the first time in presentations regarding the future of the industry. As a result of the work group of representatives of German business, industry and science, a document was published in 2013, presenting recommendations for the implementation of the program called "Strategic initiative INDUSTRIE 4.0", which presents the vision of the new reality, shaped by revolutionary changes in industry [1-11].

Industrial production is described by key KPI performance indicators - Key Performance Indicators. They specify the goals, resulting from the company's development strategy. By definition, these goals should be ambitious, so as to ensure building competitive advantages, while being realistic and achievable.

So, in this case, the KPI values, like [1]:

- increase in productivity by 15-25%,
- reducing machine downtime by 30-50%,
- reduction of warehouse costs by 20-50%,
- reducing the time of introducing a new product to the market by 20-50%,

they are an ambitious challenge in real conditions.

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In the conditions of stable development, these values are not reachable, but when there are groundbreaking changes, jumps value of the indicators to be possible – in this case, the Revolution is required.

The words of Prof. Klaus Schwab, founder and chairman of the World Economic Forum, describes the idea very well: “We are at the beginning of a revolution that is fundamentally changing the way we live, work, and relate to one another. In its scale, scope and complexity, what I consider to be the fourth industrial revolution is unlike anything humankind has experienced before.” [4]

Fig. 1. Industry 4.0 – Smart Factory [8]

2 Revolution for the forth

Regarding the production activity, the described changes are becoming the fourth industrial revolution (Fig. 2). As in the previous three, the trigger factor for transformations, is breakthrough innovation in technology.

The fourth industrial revolution is caused by:

- introduction of comprehensive digitalization,
- basing in decision processes on virtual simulations and real-time data processing,
- machine-machine communication and machine-man,
- new generation technologies.

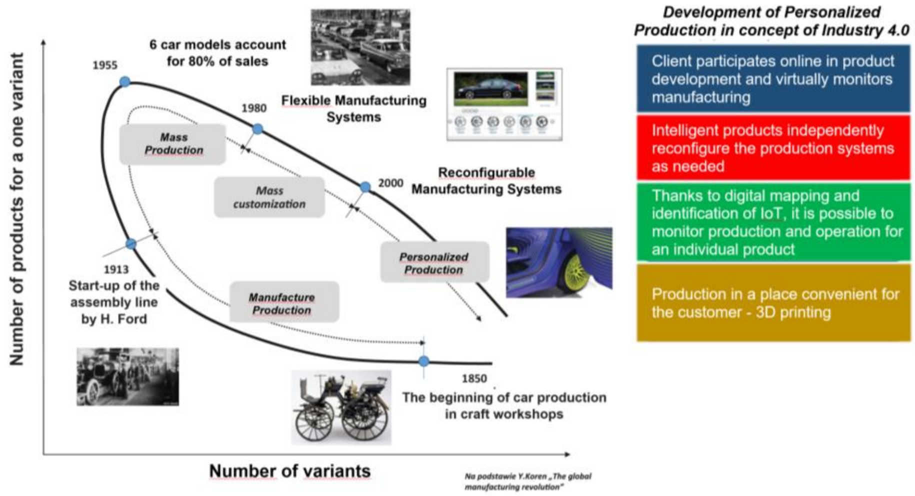

Fig. 2. Changes in production paradigms based on the example of the automotive industry [1]

2.1 Idea of Industry 4.0

Based on data obtained from surveys carried out by the editorial offices of Control Engineering Polska, we can present a few key conclusions regarding the understanding of the idea of Industry 4.0 and the use of its elements on the Polish market [1].

Frequently appearing answers for the question: What is industry? - how respondents understand the concept of industry 4.0?:

- digitization of the industry,
- line automation integrated with the IT facility,
- Internet communication integrated with products,
- automation by using RFID, robotics and 3D printing,
- industrialization, factory development through production management in real time (MES class systems), streamlining data management processes: faster response to failures, data transparency,
- removal of difficulty and organization of communication, resignation from hierarchical communication, simplification in human-machine communication, extensive use of digital simulation techniques for the needs of control and production management,
- applying the latest technological solutions to manage the existing processes in the company by: analyzing data using the cloud, automating production processes and thus reducing production costs and equalizing the costs of manufacturing a unit and serial product,
- intelligent production lines able to diagnose their problems and failures.

2.2. Time for investments

82% of the surveyed representatives of Polish companies are willing to invest in technologies that fit into the concept of Industry 4.0. Over 40% of respondents plan to implement these investments over the next 23 years. Every fifth person surveyed wants to implement their investment plans within the next year. The same number of participants in the study declares that it will do so in an undefined period (Fig. 3).

However, every tenth respondent wants to spread the investment for the next five years. It should be emphasized that investing in modern technologies that form the foundation of the Industry 4.0 concept is in the opinion of the surveyed people: significant (42%), very significant (36%), moderately significant (10%), not very significant (6%) or not significant at all (6%) [1].

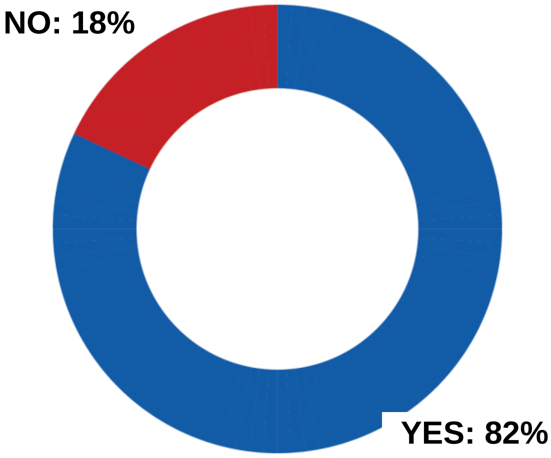

Fig. 3. Planning investments in technologists that are part of the Industry 4.0 concept [1]

2.3. Planned investments

From the perspective of planned investments, the main areas related to Industry 4.0 are mainly data / IT (64%) and robotics (51%) for Polish companies. Other important areas where investments are first planned include: communication (36%), RFID technology (28%) and 3D printing technology (10%) [1].

Benefits

The connection of the network of elements of generation infrastructure and emerging products is perceived by the respondents as an effective tool allowing to increase the efficiency and flexibility of response to any sudden changes.

Generally speaking, it can be said that the main benefits resulting from the implementation of the Industry 4.0 concept are in the opinion of the survey participants optimization of production and perfect management, which in turn leads to increased efficiency and reduced production costs.

Worries

The main threats related to the implementation of the Industry 4.0 concept were primarily: data security and security of people working on machinery, as well as limiting employment and related progressive unemployment. The biggest obstacles in implementing the idea of Industry 4.0 are, in the opinion of respondents, too large scale of expenditures necessary for the implementation of modern solutions, as well as the lack of qualified employees with appropriate knowledge in the field of IT.

Many respondents are also afraid of too much reliance on complex automation and increased maintenance costs [1].

2.4. Key technical innovations

Key technical innovations, considered as factors facilitating the fourth industrial revolution, are [5-11]:

- a new quality of communication in which both the digital world and the real world are connected with each other, thanks to which machines, products in different processing phases, systems and people - having an individual IP address - exchange digital information via the Internet protocol,
- intelligent sensors with built-in systems of individual identification, data processing and communication,
- data processing in the cloud or fog, with response dynamics at the level of milliseconds,
- analytics of large data sets on all aspects of product development and production,
- techniques of simulating the operation of real objects in their virtual maps, based on data provided and processed in real time, allowing testing and optimization of the configuration of production processes before introducing physical changes,
- direct communication between devices,
- advanced human-machine interfaces,
- cybersecurity solutions, ensuring secure, reliable communication and identification as well as management access to systems and devices,
- a new generation of robots, characterized by active interaction with the environment and with other robots and adaptation to changing conditions and requirements.

3 Cooperation of human - machine

One of the elements of the future factory is a human cooperating directly with the machine and robots. The best example of this is the cooperating "cobots", which thanks to their openness of the system, safety and sensory functions, most often designed like a human hand and special communication interfaces, are fully ready for the arrival of the Industry 4.0 era. For the first time, man and machine can solve tasks requiring the highest precision in close cooperation. New industrial robots - Collaborative Robots (CR) – "Cobots" like LBR iiwa or Motoman HC10 or another (Fig. 4) redefines the possibilities in the field of industrial robotics – of course all in accordance with the Industry 4.0 philosophy.

Analyzing available technical data (Table 1) and application experience, modern cooperating robots are characterized by:

- work safety - cat. II / III (the required level of safety in the direct contact of the arm with the operator and the environment is realized by advanced sensors of forces and moments installed on each rotary axis of the robot),
- configuration flexibility - after fencing the station - CR can work with the maximum allowable speeds - corresponding to typical industrial robots - a hybrid type system,
- costs of buying a CR are slowly approaching the prices of conventional robots,
- programming option available - Teach in,
- the most common group of CR in the range of payload from 7 to 10 kg,
- the maximum payload of the CR is 35 kg,
- available in the offer of most robot manufacturers.

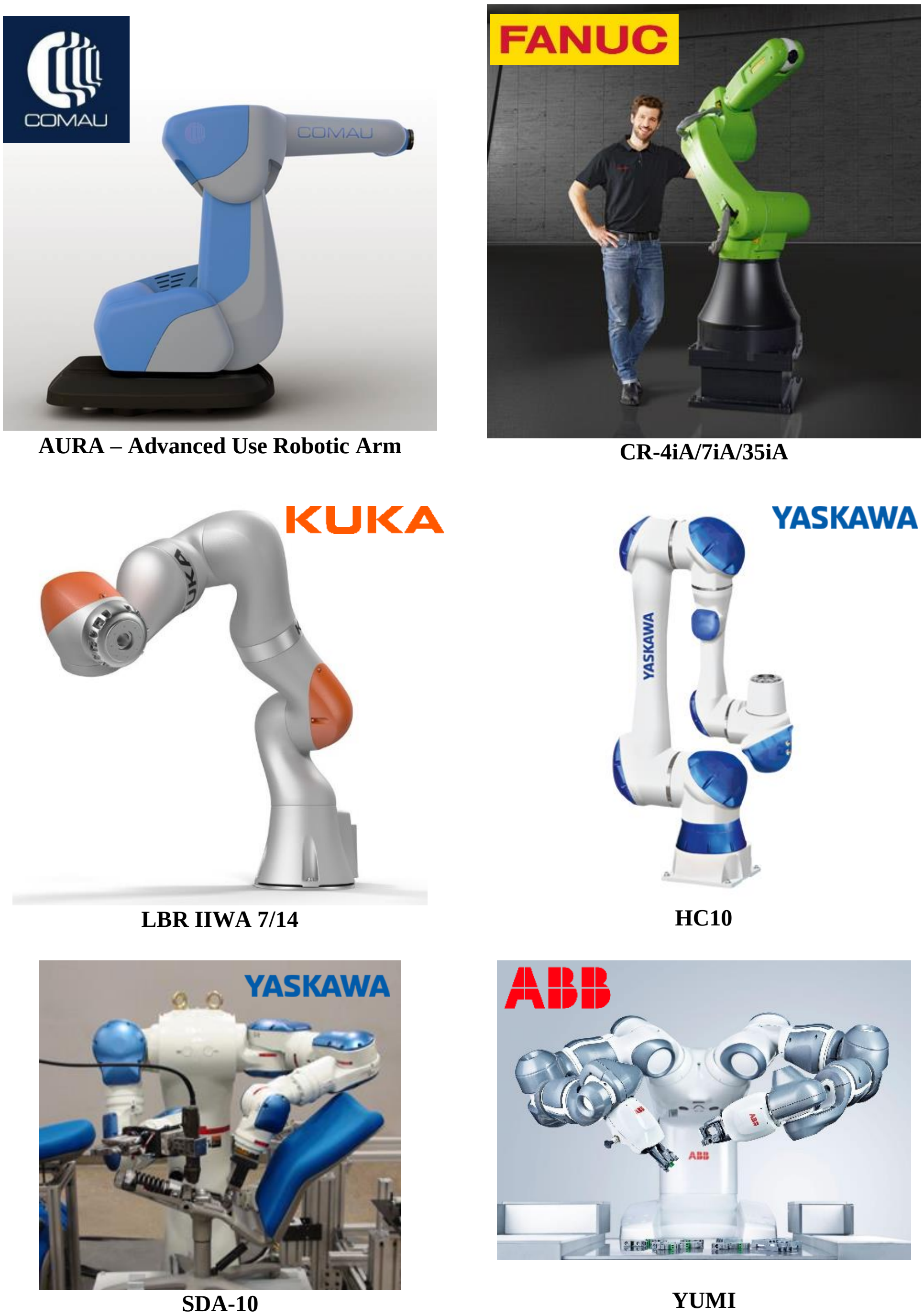

Fig. 4. Example of industry collaborative robots [13]

Table 1. Collaborative robots – technical data

Parametr	**Motoman HC10**		**UR10**		**KUKA LBR iiwa 14**		**Fanuc CR15iA**	
Axes	6		6		7		6	
Payload	10 kg		10 kg		14 kg		15	
Repeatability	0,1 mm		0,1 mm		0,1 mm		0,2 mm	
Range	1200 mm		1300 mm		Vertical: 1306 mm / Horizontal: 820 mm		1441 mm	
Motion range/Maximum speed								
J1	±180°	130°/s	±360°	180°/s	±170°	85°/s	340°	800 mm/s (1500 mm/s - if the area is monitored by a safety sensors)
J2	±180°	130°/s	±360°	180°/s	±120°	85°/s	180°	
J3	-5 - +355	180°/s	±360°	180°/s	±170°	100°/s	305°	
J4	±180°	180°/s	±360°	180°/s	±120°	75°/s	380°	
J5	±180°	250°/s	±360°	180°/s	±170°	130°/s	280°	
J6	±180°	250°/s	∞°	180°/s	±120°	135°/s	900°	
J7	-	-	-	-	±175°	135°/s		
Performance Level	Performance level (PL) d Category 3 according to EN ISO 13849-1		Stop category (IEC 60204) : Emergency Stop Cat: 1 Safeguard Stop Cat: 2 Performance level (ISO 13849-1 PLd		Kategorie 3 und Performance Level d nach EN ISO 13849-1		Certyfikat bezpieczeństwa TÜV ISO 10218-1:2011, kategoria 3, PL=d (ISO 13849-1 PLd)	

A compilation based on materials and catalog information according to the producers' offer [13]

4 Flexible Production System - ready for industry 4.0

The rapid development of industrial automation components leads to an increase in demand for employees ready to handle the most modern machinery and equipment. The situation in the industry requires university to prepare courses taking into account the directions of development of manufacturing techniques. Transmitted knowledge must remain valid for several years, until the entry of students into the labor market. Division of Technology Design of Poznan University of Technology has implemented a Flexible Production Systems (FPS) Laboratory (Fig.5). It is realized vision of a production system ready for Industry 4.0 based on universal machines and equipment, which may carry out a variety of production tasks, easily scalable and reconfigurable. Integration in one place, many manufacturers of hardware and advanced software make the students who have had courses can gain complete knowledge of modern production systems. The laboratory is universal, can teach management and production planning, assembly process design, PLC programming, using CNC machine tools and robots. It is used by students of Mechanical Engineering, Mechanical Engineering and Mechatronics [12].

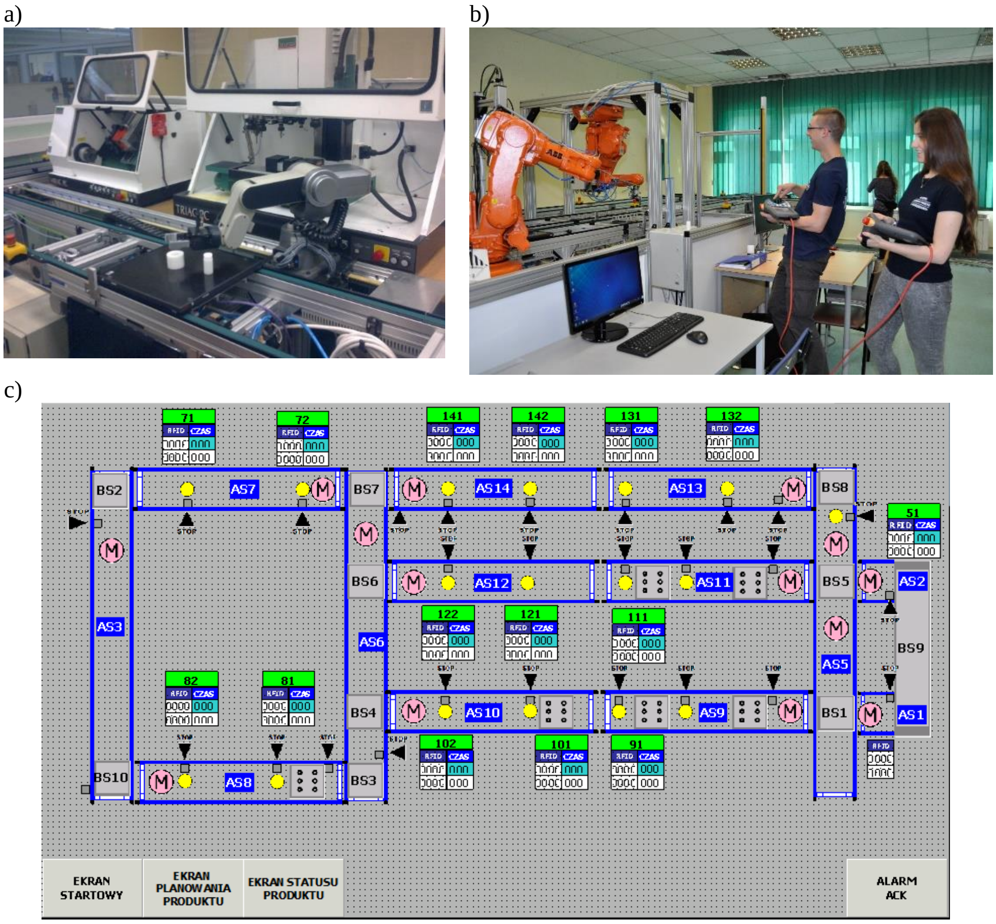

Fig. 5. Flexible Production System – ready for Industry 4.0: a) CNC cell, b) Robot cell, c) example of visualization of the line control on the HMI [12]

Summary

At the present time, with the development of autonomous robots, modern automation, cyber-physical systems, the Internet of Things, Internet services, etc., - the industrial landscape is again being transformed - we are witnesses the fourth industrial revolution. Industrial robots, which are one of the key elements and drivers in industry 4.0, have grown considerably since the last decades of the 20^{th} century. Nowadays, industrial robots are standard equipment in factories - become more productive, flexible, comprehensive, safer and cooperate "hand in hand" with a human. The robot can learn from its human colleagues and can independently check, optimize and document the results of its own work when connected to the data cloud. The expectations of industry regarding the new era of robots are growing every day, slowly comes the autonomous humanoid robots known to us from science fiction novels and films.

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