Some New Robotization Problems Related to the Introduction of Collaborative Robots into Industrial Practice

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Abstract: *The appearance of collaborative robots is a natural stage of development of industrial robotics. Research aimed at enabling the work of robots and people in the common area (collaborative workspace) have been conducted for several decades. However, only recently the research results are implemented in industrial conditions. This is mainly due to the introduction of lightweight robots of low payload, which are equipped with special construction solutions and functions in the control area. Thanks to this, these devices can safely collaborate with people in a common workspace. The application of a collaborative robot in the robotization project of an industrial process creates new technical problems and more. The robots themselves, as well as robotic installations, must continue to comply with the applicable safety requirements, in accordance with the relevant directives. Introduction to the use of collaborative robots also creates new legal problems. The article presents the current state of development of collaborative robots in the technical, legal and standardization aspect. The presented material is based mainly on information from the Polish market.*

Keywords: *collaborative robots, robotization, industrial applications, safety, law, standards*

1. Introduction

In the development of industrial robotics, from the beginning, there have been two directions. On the one hand, people try to build devices that will replace humans. On the other hand, the concepts of devices that will work along with them. One of the most important priorities of the designers of the first robotic installations was to move a human away from the danger area [1]. The human was replaced by an industrial robot whose work area was protected by special fences equipped with lock and sensory systems. These protections prevented the robot from contacting people in special installation operating modes.

The concepts of introducing robots into the human environment became real only in the 1980s [2]. This was mainly connected with the development of mobile systems that allowed robots to move. A separate group was created, called "service robots". From the beginning, it was planned that they will be used by people who have no technical preparation. At the same time, tasks set before these robots require operation in the vicinity of people, often in direct contact with them. So they have to communicate with people by sending/receiving information in real time. They must also be safe in contact with a human, so that they do not a threat to him. Today, manufacturers offer a whole range of service robots that comply with these requirements, both for commercial and personal use. The dynamics of sales growth in this segment is much higher than in industrial robots, and most forecasts present that this trend will continue in the coming years.

The warm welcoming of service robots by users, the rapid development of this group of devices and the steady increase in the value of their sales as well as the systematic expansion of markets, all this affected the attempts to transfer some solutions to industrial robotics. It can be said that the development of service robots has contributed to the realization of the idea of robots collaborating with humans in industrial environments. Of course, the main reason for works aiming to introduce these concepts into practice and use in industrial conditions was the real need reported by the users. In many production areas, there are processes and operations today that can be carried out faster, cheaper, achieving the highest quality, with closer collaboration between a human and a robot. However, the implementation of such common work stations requires new technical solutions. Robots with special features are designed, that make these devices much safer than traditional industrial robots. These are the robots with small payload (lifting capacities), whose bodies (casings) have no sharp edges, and are sometimes covered with soft material. Their control implements special functions and mechanisms, e.g. enabling collision detection or limiting the movement dynamics in special situations. A new group called "Collaborative robots" or "Cobots" is created. The term "Cobot" was proposed for the first time by an intern in the 1990s postdoctoral internship at Northwestern University (Illinois, USA). His idea of a new definition was a response to a competition announced in a research laboratory to come up with a better name for the device on which he was working. It was a device supporting a man in moving objects and manipulating them. Research directors J. E. Colgate and M. Peshkin filed a patent application in 1997 for such a device and called it "Cobot" (US Patent 5,952,796). At that time, they also published several articles presenting the idea of robot-human collaboration [3]. To this day, they constitute an inspiration for many new projects regarding collaborative robots. At the same time, technical and organizational solutions that will enable the sharing of workspace by human and by traditional industrial robot are developed. For this purpose, robots are equipped with sensory systems that recognize human presence in their working range and the potential possibility of collision. New methods of robot programming are developed (e.g. lead-through programming, also called hand guiding of the tool) and new, more effective ways of human-robot communication are introduced.

The collaboration of humans and industrial robots in its working area creates new opportunities, but also poses new threats. A chance to limit those threats is to increase the level of knowledge about safety in robotic installations among employees of production plants. Dissemination of knowledge and good practices in this regard among current and potentially future industrial robot users, from pupils through students, teachers/coaches, production workers to representatives of technical and management staff is as important as the introduction of new technical solutions improving safety.

2. State of the Art – Robot Manufacturers

Although the idea of robots collaborating directly with humans is known from the beginning of robotics, for its practical implementation it was necessary to wait until the beginning of the 21st century. The precursor was Universal Robots, founded in 2005 in Denmark. Four years later, the company introduced the UR5 model into the market – advertised as the world's first collaborative robot. Initially, it met with many skeptical forecasts as to the chances of developing this new concept. However, the market success of UR robots quickly resolved all doubts. Following the Danes, all world's major robot manufacturers began to present their proposals of models adapted to collaboration with humans.

The UR5 robot has 6 degrees of freedom, a payload of 5 kg and a working range of 85 cm, with a total weight of 18 kg. From the very beginning, it was very well accepted in the market, mainly by small companies. The first products were sold in Denmark and Germany, but the company quickly expanded its activity to other European countries. In 2012, UR entered the Chinese market and since 2013 it has been present in the USA. In the same year, the premiere of the new UR10 model with a payload of 10 kg and a range of 130 cm took place. In 2015, Universal Robots launched UR3 – its lightest model, with a payload of 3 kg. At the same time, it was the first model specifically designed for human-robot collaboration, mainly while performing light assembly tasks. In 2015, Universal Robots was bought by the Teradyne corporation, a supplier of, among others, equipment for industrial installations of automated production. All 3 robot models are still offered under the Universal Robots brand.

KUKA offers a LBR iiwa collaborative robot, designed mainly for assembly works of light details requiring high precision. Its manipulator has 7 degrees of freedom (rotary joints) and a kinematic system modelled on the human arm. KUKA LBR iiwa is available in two versions with a payload of 7 and 14 kg and a range of 800 and 820 mm, respectively. Modern KUKA Sunrise Cabinet control of the LBR iiwa robot enables quick start up of the robot itself as well as the entire robotic installation. It also provides effective communication between the operator and the robot itself and its very simple operation and programming. These robots have extensive sensory equipment. They have built-in sensitive torque sensors in all seven axes. Thanks to them, the LBR iiwa robot faultlessly and quickly recognize collisions, and the control system immediately takes appropriate action, for example, reduces force and speed. These sensors allow to perform the most delicate assembly tasks without damaging the elements. In its technical brochures, KUKA emphasizes that LBR iiwa robots have very good precision of movement, their construction ensures positioning repeatability of ± 0,1 mm.

KUKA LBR iiwa robot manipulators have rounded shapes, without sharp edges, which improves human safety in case of possible contact. The smaller model weighs 22 kg, and a larger 30 kg. They can be mounted on the floor, on the wall or on the ceiling.

FANUC presented the first collaborative robot in 2015. It was a CR-35iA model, with a payload of 35 kg, making it, at that time, the world's strongest robot of this type. In the first half of 2016, FANUC presented another, smaller model of the collaborative robot – CR-7iA with a payload of 7 kg. Manipulators of both models are painted in a characteristic green color. They have built-in intelligent sensors that immediately stop the robot after touching a human or other object. Depending on the needs, the collaborative robots can be equipped with a 2D or 3D vision sensor that allows detecting the positions of the workpieces.

The first two-arm collaborative robot was Baxter, presented in 2012 by Rethink Robotics. Its manipulator (body) consists of a head, a body (torso) and two arms. On the robot's head there is a sonar with a 360° scan range and a camera that can be used to detect objects, including people around the robot. Each of the arms has 7 degrees of freedom. Both arms are able to work independently carrying out various activities or collaborate in one task. The force/torque sensors are installed in the manipulator's joints.

Baxter has implemented functions that allow recalculation of the trajectory and generation of a new path, in the case of changes in its environment, which make it impossibly implementation of previously learned movements in collision-free way. Thanks to this function, the robot can react to objects appearing in its operating area, including a human entering this area. In 2015, Rethink Robotics launched the Saw-

yer™ model on the market, smaller, faster, designed for high precision tasks.
The company also offered a special Intera® software package. It integrates the user interface and modules facilitating and accelerating the robot's installation and adapting it to new tasks, which in turn allows to reduce the costs of robots implementation.

Unfortunately, in 2018, Rethink Robotics declared bankruptcy. All patents and trademarks were acquired by the Hahn group [14], a global specialist in the field of automation and robotics, until recently one of the distributors of Baxter and Sawyer robots. Part of the Rethink Robotics staff (more than 20 employees), was employed by Universal Robots in its American branch located in the same city, in Boston. For many years, this is the first case of the collapse of the robot manufacturer. The fact that it was a collaborative robots specialist shows that the market for these devices is not as easy as it was sometimes foreseen.

In 2015, Kawasaki launched the "duAro" model on the American market – a robot designed to collaborate with a human, the manipulator of which has two arms in the form of SCARA modules. Each arm works independently, but their movement can be synchronized in a simple way, because they are controlled from a common controller. This allows the robot to be used in works requiring careful two-hand carrying of delicate parts and subassemblies (e.g. electronics), precision assembly or quality control. The construction, dimensions and method of programming have been designed so that you can easily replace manual work without unnecessary modifications of the workplace and without the need to use covers.

The ABB has developed a two-arm YuMi® robot – IRB 14000 which collaborates with a human and is intended for assembly of small parts (payload 500g, repeatability +/- 0,02 mm). The robot's arms are flexible, which limits the possibility of injuries when in contact with a human. The ABB additionally offers a specifically designed set of grippers for this robot and a system for locating parts, using a camera integrated with the gripper.

Fig. 1. Workplace with YuMi® – IRB 14000 robot during Automatica 2014 fair

The range of the robot arms (590 mm) is similar to the range of human arms. The robot is relatively lightweight, weighs approx. 38 kg. This is important when planning the space in the production plant and allows to install YuMi® on existing workplace where people are currently working. An example of the workplace with this robot has been presented by ABB at the fair since 2014 (Fig. 1).

Two-arms robot was also presented by Epson. At the Automatica 2018 fair it showed the WorkSense W-01 model (Fig. 2). The payload of each robot's arm is 3 kg. By synchronizing the movements of both arms, the robot can lift an object weighing as much as 6 kg.

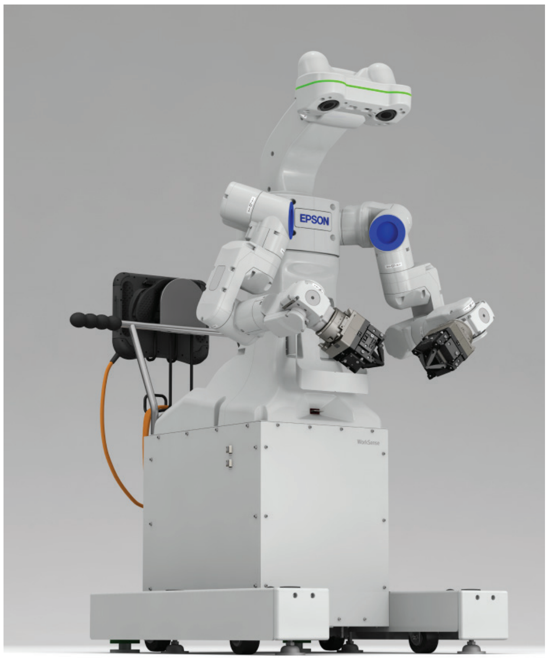

Fig. 2. WorkSense W-01 – Epson's dual-arm robot (Epson Automatica 2018 Press Release)

In recent years, many companies have been introducing collaborative robots to their offer. They are both: large producers of industrial robots, in addition to the abovementioned ABB, KUKA, Fanuc also Yaskawa, Kawasaki, Nachi, Stäubli, Denso and other, as well as the new, often start-up type, companies that are trying to enter the market. At the same time, manufacturers of standard industrial robots put a lot of effort so that their products could work in a shared area with humans, like a typical collaborative robot.

3. From a Standard Industrial Robot to a Collaborative Robot

In many centers, works are being carried out on equipping traditional constructions of industrial robots with such an equipment that ensures safe human work in their vicinity. These works are aimed at equipping robots with senses similar to those in which nature provided living organisms, including humans. The implementation of solutions that perform the functions of appropriate receptors and feedback signal generators will allow in the future to perform new forms of human-robot communication, which will directly result in improving the safety of people who will interact with robots. This applies to both solutions in the field of industrial and service robotics.

Among the areas of research related to artificial senses, the tactile human-robot interactions take a significant place. Work in this field is carried out in many centers, most often with the support of governmental or international programs. Different concepts are being developed, however, studies often end at the stage of laboratory tests [10], [11]. Only few results of research projects are further developed towards their practical use. One of such solutions is the so-called "artificial skin" in which the robot are "dressed". The role of such "artificial skin" may be, for example, to feel the touch of a foreign object and to stop the robot's movement quickly after determining the occurrence of this touch. Work on such a solution to this problem was already carried out at KUKA ten years ago. However, they did not end with the creation of a commercial product. KUKA moved towards the creation of its own cobot, LBR iiwa, which has been offered for several years on the market.

At the same time similar research was conducted by the Austrian company Blue Danube Robotics GmbH from Vienna [13]. In this case, the work on "artificial skin" for traditional industrial robots was from the beginning focused on obtaining a commercial product. As a result, this company, numbering less than 30 employees, has created an innovative technology under the name of AIRSKIN. The product is a soft, pressure-sensitive so-called "Safety skin".

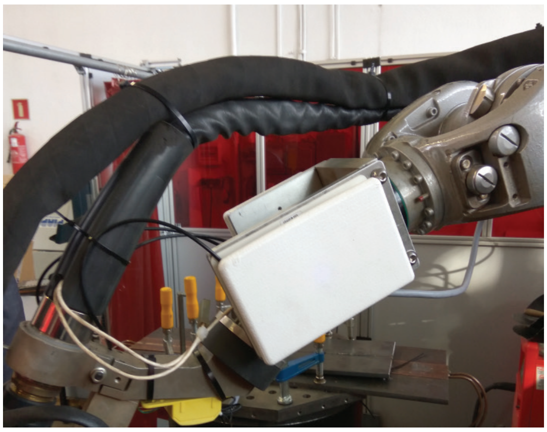

Fig. 3. AIRSKIN pad's mounted on the robot wrist in the PIAP lab

The coating made from AIRSKIN consists of several parts connected together (so-called pads), which are mounted directly on the robot arms (Fig. 3). It can be electrically connected in series simultaneously up to 15 parts (pads) placed on the robot. These parts are made of thermoplastic polyurethane (TPU) and are designed individually for each type of robot and each of its arm, as well as for arms tooling (EoAT-End of Arm Tooling), such as grippers or flanges. The company also offers several standard pad models, for self-use by the applicator. Connections are made using external cables.

Each part (pad) is equipped with an electronic safety system consisting of a micropump, a filter, a pressure sensor and an electronic control system. Air under slight positive pressure (about 400 Pa) is pumped into each part. It is therefore not required to supply air under pressure to each pad by a separate duct. The sensor's task is to continuously measure the pressure inside the pad. Any change in the value of this pressure caused by the deformation of the coating by touching it is immediately recognized. This state is passed to the robot safety system with two secure channels and should cause safe stopping of the robot. The response time of the safety system in the "safety skin" is 9 ms.

The forces that occur during the collision of a robot equipped with a "safety skin" with an obstacle encountered – a human, are suppressed by the softness of this skin. The braking distance of the robot after the receiving of the collision signal should be absorbed by the thickness of the "safety skin". This is why the parameter of this thickness is important, which must already be taken into account when designing this skin for a given robot/application. Each part (pad) is equipped with a connection module (ACM-Airskin Connection Module) used for connection with other pads, or robot safety system.

Fig. 4. AIRSKIN presentation during Automatica 2018 fair

AIRSKIN "safety skin" by Blue Danube Robotics GmbH has obtained a safety certificate according to ISO 13849 PLe / Cat3 and is officially offered on commercial terms. The company has developed coating for several models of popular industrial robots, including ABB, UR, KUKA (Fig.4).

4. Legal Status

Real problems of human-robot coexistence began to increase along with the progress of computer science and the development of artificial intelligence. An intelligent robot becomes a device with a large range of autonomy, able to react or modify its actions based on the information received and the recognized state of the environment, without human intervention. This type of behavior is also characteristic of collaborative robots operating in production installations. It will also be important for robots that will work in domestic and public environments. These independent, sometimes creative activities will be the source of new legal problems.

It should be noted that the very understanding of the word "robot" changes in front of our eyes. The robot is a car without a driver moving along a public road, a flying, unmanned transport vehicle or a device shaped like a human serving him in a hotel or restaurant. The emergence of these new, generally intelligent robots raises further legal and ethical problems. There is a need to determine the principles of creation and operation of robots, as well as the responsibility for the effects of their activities. The problem is how to establish legal principles, and within them the limits of robot autonomy, as well as the principles and ways in which compliance with these limits should be controlled, and next how to proceed when these borders are broken. The fundamental principles of civil law will have to be fundamentally changed. It seems highly probable that it will be necessary to create a new category of law, which will be addressed to a new entity called – "autonomous robot" or simply "robot". Already, the first works are being undertaken to develop legal norms specifically for these devices that would regulate robots' behavior and enable the assessment of situations created by them or in connection with their activity. Both scientists, lawyers and politicians are convinced of the necessity of these pre-emptive actions.

At the beginning of 2015, a group of Members of the European Parliament (EP) called for the development of robots' rights and prepared a report to this end, in which the definitions, scope and principles of regulation of robots, ethical standards and principles of responsibility for accidents involving robots, including, for example, automatic vehicles were proposed. The EP law committee adopted a report made by a group of Members on this matter, followed by an appropriate resolution containing recommendations for the European Commission on civil law provisions on robotics [4]. The adopted Resolution is only the beginning of possible legislative work. Their further fate, however, is not certain. Already a few months after the adoption of the said resolution, an open letter from the group of experts in the field of artificial intelligence and robotics appeared in the electronic media [9]. Generally, they negate the sense of the work that the European Commission intends to initiate. The signatories of this letter express their concerns about the negative consequences that may arise from the creation and application of a special law for robots. Special concerns are raised regarding the creation of the legal status of an "electronic person" for autonomous, self-learning robots. The authors of the letter believe that the legal status of a robot cannot arise either from nature or from legal provisions.

It seems that creating a law regarding robots in this form or another will eventually become a necessity. Its development is and will be a difficult task, requiring the inclusion of many issues not only in the field of the field of device design and construction, manufacturing engineering and economics, but above all in the field of ethics, medicine and sociology. It seems certain that this law cannot be simply transferred from legal regulations applicable to persons.

5. Applicable Standardization Regulations

European Union legislation on the safety of products, which are included in the New Approach Directives, apply to large groups of products. One of such groups are machines, and matters related to their safety are regulated by the Machinery Directive MD [5]. Her provisions regarding the so-called essential requirements have a significant impact on the projects of automated and robotic industrial installations. It also takes into account the electrical requirements for machines. The feature of devices powered by electricity is the ability to emit signals that disrupt electromagnetic fields, which are interference for other devices. At the same time, these devices are sensitive to signals (disturbances) emitted by other devices. Therefore, robotic installations are also subject to the so-called Directives on electromagnetic compatibility EMC [6]. These two MD and EMC directives are a basic set for the assessment of equipment and entire robotic and automated installations. Depending on the specific application area, other directives may also be considered, regarding, for example, pyrotechnic articles (2013/29/EU), medical devices (93/42/EEC), devices used in a potentially explosive atmosphere (ATEX 2014/34/EU).

The essential requirements of EU directives (and regulations) are detailed in the so-called harmonized standards. Standards are not part of European law and their application is voluntary, but fulfilling the requirements of these standards gives the certainty that a particular machine complies with the New Approach Directives (principle of presumption). In the light of EU law on the safety of products, robots belong to machines, but constitute a separate group (category). So, on the one hand, there is a group of norms strictly referring to robots, but on the other, there are also provisions in many general machine standards that including robots. There are also standards dedicated to robotic systems. Therefore, the "machine" word that follows is also inclusive of robots and robotic systems.

Below are the most important norms strictly related to robots and environments in which they work.

- ISO 10218-1:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots.
- ISO 10218-2:2011 Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration.

- ISO 12100 Safety of machinery – General principles for design – Risk assessment and risk reduction.
- ISO 13850:2016-03 Safety of machinery – Emergency stop function – Principles for design.
- ISO 13855:2010 Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body.
- IEC 60204-1:2010 Safety of machinery – Electrical equipment of machines – Part 1: General requirements.
- IEC 62046: Safety of machinery – Application of protective equipment to detect the presence of persons. This is an IEC standard that defines the requirements for the selection, location, configuration and commissioning of protective equipment designed to detect temporary or continuous presence of persons, in order to protect those persons against dangerous part (dangerous parts) of the machine in industrial applications.
- EN ISO 11161:2007/A1:2010E, Safety of machinery – Integrated production systems – Basic requirements

In 2016, the ISO/TS 15066 Robots and robotic devices – Collaborative robots document was published. It has the status of so-called technical specification, and therefore a set of guidelines and recommendations relating to collaborative robots. It can be said that they complement the requirements given in ISO 10218-1 and ISO 10218-2 standards for industrial systems of collaborative robots and their working environment. Although this document is not a standard, it seems that its application is justified during the design, construction, implementation and operation of installations with collaborative robots. It is currently the only document recognized by ISO, which covers these problems.

The importance which the international standardization organization gives to the problems of robotics, including the safety in human-robot contact is confirmed by the fact that in 2016 a new technical committee ISO/TC299 [12] dedicated exclusively to robotics was established. It is currently responsible for ongoing work, including further processing of the ISO/TS 15066 document and initiating new directions in the robotics area.

It should be clearly emphasized that the implementation of collaborative robots, by assumption safer in contact with humans, does not change the required procedures for assessing robotic installations in terms of safety. A person placing a robotic installation on the market (sale, commissioning) must carry out an analysis of the existing risk and provide appropriate measures to reduce hazards. It is only for a safe machine or application that an EC Declaration of Conformity can be issued and the marking can be applied [7].

6. Conclusion

The number of industrial robots working in industrial plants is constantly growing. This means that each day more and more people, employees of these plants have contact with robots. Until recently, it was mainly a contact through tight, solid fences that secured robotic cells. Currently, due to interest in the concepts of collaborative robots, ideas of robots that will collaborate side-by-side with humans and will not be fenced or specially secured appear more often. This is certainly a path towards the natural integration of the human worker and robot worker. It must be remembered, however, that the most important is the safety of man, above all the one working in close proximity to the robot.

Currently, there is a kind of chaos on the market in the areas of collaborative robots. This applies to both documents and devices offered by manufacturers, applied solutions and implemented applications. In the field of standardization, the ISO/TS 15066 "Robots and robotic devices – Collaborative robots" is an attempt to toward ordering there matters. However, it should be remembered that this document has at the moment a status of technical specification, so these are recommendations that determine the technical requirements that a robot collaborating with a human should fulfill. However, this is not an obligatory document to be used.

At the same time, there is a competitive battle on the market of robot and robotic systems manufacturers for a new area related to collaborative robots. In many cases, the information presented on the websites and in the press as sponsored articles is of a marketing nature. Numerous advantages and benefits of using these solutions are indicated, and no significant restrictions are mentioned [8].

These observations concern both the Polish market, known to authors from daily activities in automation and robotics, and, more broadly, the European Union market. In the common EU market, the same laws and standards apply in all countries. Therefore, the final conclusions of the considerations presented concern the entire common economic area. The basic issue for which future users of collaborative robots should be clear about is the need to carry out the normal procedure for assessing whole robotic installation in terms of safety and issuing the EC declaration of conformity.

The special problem on the Polish market is the limited access to standardization documents, especially those introduced to the PN (Polish Norms) collection by the method of recognition and published in the original language version:

- these standards are very expensive in general, especially for small businesses,
- sometimes the argument that potential users of these documents certainly know English perfectly

well and understand what they mean is a misunderstanding.

It is of the utmost importance to disseminate reliable information on collaborative robots, including good practices and examples of their successful applications, used in various technologies and industry sectors. Polish Committee for Standardization does not bring such activities. This is an appropriate task for scientific and research units, also for universities, but how often it happens in such situations, there is the problem of financing. It is very likely that similar troubles are in other EU countries, especially among the so-called new members.

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REFERENCES

[1] M. Hägele, K. Nilsson, J. N. Pires,"Industrial Robotics". In: B. Siciliano, O. Khatib (eds), *Springer Handbook of Robotics*, 2008, 963–986 10.1007/978-3-540-30301-5_43.

[2] J. F. Engelberger, *Robotics in service*, MIT Press, 1989.

[3] M. Peshkin, J. E. Colgate, "Cobots", *Industrial Robot: An International Journal*, vol. 26, no. 5, 1999, 335–341 10.1108/01439919910283722.

[4] "European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL))". European Parliament, www.europarl.europa.eu/doceo/document/TA-8-2017-0051_EN.html. Accessed on: 2020-03-03.

[5] "Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery (Machinery Directive)". European Parliament, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF. Accessed on: 2020-03-03.

[6] "Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive) ". European Parliament, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0030&from=EN. Accessed on: 2020-03-03.

[7] M. Głowicki, "Coboty – zagadnienia bezpieczeństwa przy integracji robotów współpracujących (eng. Cobots – security issues in the integration of collaborative robots)", *Napędy i Sterowanie*, vol. 19, no. 4, 2017, 30–34 (in Polish).

[8] Z. Pilat, W. Klimasara, M. Pachuta, M. Słowikowski, M. Smater, J. Zieliński, "Possibilities of practical introduction of colaborative robots in various manufacturing technologies implemented in an industrial environment", *Pomiary Automatyka Robotyka*, vol. 22, no. 1, 2018, 59–65 10.14313/PAR_227/59.

[9] "Open letter to the European Commission". www.robotics-openletter.eu. Accessed on: 2020-03-03.

[10] "Perfect skin: more touchy-feely robots". European Commission, https://cordis.europa.eu/article/id/91025-feature-stories-perfect-skin-more-touchyfeely-robots. Accessed on: 2020-03-03.

[11] "Kaspar the social robot". University of Hertfordshire, www.herts.ac.uk/kaspar. Accessed on: 2020-03-03.

[12] "About [ISO/TC 299 Robotics]". International Organization for Standardization, https://committee.iso.org/home/tc299. Accessed on: 2020-03-03.

[13] "Home". Blue Danube Robotics GmbH, www.bluedanuberobotics.com. Accessed on: 2020-03-03.

[14] "About us". HAHN Robotics, www.hahnrobotics.com/en/about-us. Accessed on: 2020-03-03.