SAFETY REQUIREMENTS RELATED TO COLLABORATIVE ROBOTS IN THE CZECH REPUBLIC

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The main topic of this paper is concentrated on collaborative robots. Specifically preparation of their implementation in terms of safety requirements specification in the Czech Republic. Firstly, the paper is concentrated on a description of collaborative robots, their advantages and disadvantages. Then the main subject of the paper is described in the analysis of the safety requirements in relation to the legislative conditions of the Czech Republic. Not respecting the safety requirements can have significant consequences for a company implementing collaborative robots. The paper describes three important parts of the safety requirements: technical standards related to machines, legislative machinery regulations and technical standards related to industrial robots and collaborative robots. The important parts of the safety requirements are mentioned specifically with references.

KEYWORDS

Collaborative Robot, Safety Requirements, Legislative, Technical Standards, Czech Republic

1 INTRODUCTION

Industry itself is a significant part of the world economy. Development in industry led to Industry 4.0 or the fourth industrial revolution that is currently one of the most frequently mentioned topics in modern industry. See Fig. 1. for a basic overview of the four industrial revolutions. Industry 4.0 has a huge impact on industry itself and robotics as a part of it. Development in robotics led from traditional industrial robots to collaborative robots that complement the traditional ones in specific cases. This paper is concentrated on collaborative robots.

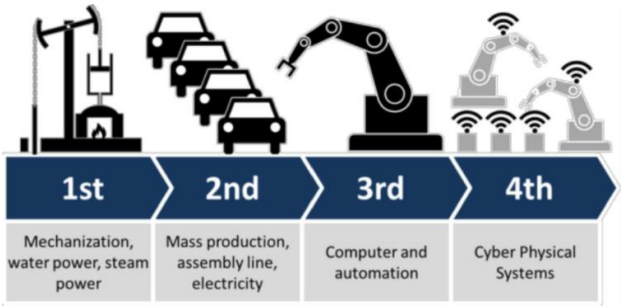

Figure 1. The four industrial revolutions [Basl 2017]

For successful implementation of collaborative robots in an industrial plant, the plant has to fulfill special requirements. Very important ones are the safety requirements that are the main topic of this paper. Not respecting the safety requirements can have significant consequences for the company and the plant itself. The legislative conditions that cover this area differ from country to country, but they have many similarities. This paper considers the legislative conditions in the Czech Republic that are very similar to those in other EU member countries. The information presented in this paper could provide inspiration for other countries about what their safety requirements analyses should concentrate on with regards to the implementation of collaborative robots.

Firstly, the paper is concentrated on a description of collaborative robots, their advantages and disadvantages. Then the main subject of the paper is an analysis of the safety requirements related to the legislation in the Czech Republic. In the paper there are descriptions of three important parts of the safety requirements: technical standards related to machines, legislative machinery regulations and technical standards related to industrial robots and collaborative robots.

2 COLLABORATIVE ROBOTS

A collaborative robot ('cobot') is an industrial robot that is designed to cooperate with human operators. [Broum 2019] Development in robotics led from traditional industrial robots to collaborative robots that are a new trend in robotics and complement traditional robots in specific cases.

The difference between traditional industrial robots and collaborative robots is in their cooperation with human operators. With traditional robots, it is important that they are working for people. They are separated from people. However, collaborative robots are designed to work together with people.

Traditional industrial robots are big, heavy, strong and robust devices that work on specific tasks. Fences, sensors and signalization are set up around them for safety reasons. Industrial robots are generally designed to work for people and they perform activities in a restricted area according to relatively complex programs. [Broum 2019]

An example of a traditional industrial robot locked in a safety cage is shown in Fig. 2.

Figure 2. Traditional industrial robot locked in a safety cage [ARC Robotics 2019]

Collaborative robots are in comparison designed to work with human operators and create values together. For example, a cobot is able to pick up an object from a box, insert it into a device (a press, etc.), then remove it and put it on a pallet or hand it directly to a human operator. [Broum 2019]

An example of a collaborative robot cooperating with a human operator is shown in Fig. 3.

Figure 3. Collaborative robot [Belanger-barrette 2015]

As mentioned above, the main difference between traditional industrial robots and collaborative ones is their collaboration with human operators. This is also linked to their location in the work place. The design of collaborative robots respects their collaboration with human operators. Collaborative robots are equipped with detection sensors and special safety functions to recognize the contact or even the location of a human operator. The potential contact surface of a collaborative robot is also usually made of safe materials to absorb energy. Some collaborative robots are even programmed to shut down immediately if there is a potential danger to a nearby human operator. This eliminates the need for safety cages. Even if collaborative robots are relatively safe, many safety-related problems can arise during the use of collaborative robots, therefore safety requirements need to be analyzed. Traditional robots are not equipped with sensors for detecting human operators, so they need to be limited by safety cages and sensors that are often expensive and prevent easy access. This leads to minimization of potential risks from collision with human operators, but on the other hand it prevents their collaboration. [Poor 2019]

Apart from collaboration with human operators, another difference is in programming the two types of robots. Collaborative robots are usually far easier to program; the modern programming environment is one part of it, the second is that to program a collaborative robot it is enough to move the robot body itself to the desired locations (even by moving the collaborative robot body by hand), save it to the program and the collaborative robot can perform it afterwards. Traditional robots on the other hand usually need advanced knowledge of programming and programming experience. [Poor 2019]

Examples of collaborative robots applications [Broum 2019]:

- Packing
- Palletizing
- Machine operations
- Laboratory analysis
- Screwing
- Welding
- Polishing
- Assembly of components
- Product quality control
- Machining
- Pick and Place
- Transfer between workplaces
- Sorting (packaging etc.)
- Orientation of components
- Circuit board testing
- Operation of hydraulic presses
- Operation of injection molding machines

The advantages and disadvantages of collaborative robots over traditional industrial robots are mentioned in Tab. 1.

Advantages
Easier programming
Easier to control and collaborate with
Easier maintenance and repair
Higher sensitivity in contact with humans
No need for protective cages or covers
Includes cameras and sensors for detecting objects and people
Relatively small dimensions (Easier to manipulate with)
Greater potential in current industry
No robot overload (resistance, pressure, current sensors)
Real-time algorithms for settling no-collision paths
Possibility to purchase additional accessories

Disadvantages
Relatively high price
To reach maximum potential utilization, it is necessary to purchase relatively expensive components and accessories
Lower toughness of the device
The robot stops in the middle of operation due to human contact
Not very precise and clear legislation for this type of robot
Industrial application is only 10% compared to traditional industrial robots

Table 1. Advantages and disadvantages of cobots over traditional industrial robots [Waldman 2017]

3 SAFETY REQUIREMENTS RELATED TO COLLABORATIVE ROBOTS

As a basis for successful collaborative robot implementation it is important to obtain all the information related to the safety requirements that need to be met. Although a collaborative robot is designed for collaboration with human operators it is necessary to find the legislation that permits and regulates this collaboration. By 'legislation' we mean standards, laws, regulations etc. The main topic of this chapter and the paper itself is an analysis of the safety requirements related to collaborative robots. This will give important information about what is and what is not approved, what are the limitations and rules for collaboration between collaborative robots and human operators. This is in relation to the legislative conditions in the Czech Republic, that are very similar to those in other EU member countries. The information presented in this paper could provide inspiration for other countries about what their safety requirements analyses should concentrate on with regards to the implementation of collaborative robots. There are three subchapters below. The first one is related to technical standards related to machines, the second one explains machinery regulations, and the third one describes technical standards related to industrial robots and collaborative robots.

3.1 *Technical standards related to machines*

A technical standard describes the requirements related to a product, process or service to be suitable for their purpose under specific conditions. A technical standard sets out basic requirements for quality, safety, compatibility, interchangeability, health and environmental protection. It is a document based on the agreement of all stakeholders related to the solution. This is different from legislative regulations that may arise without the agreement of all sides concerned. [Broum 2019]

Technical standards can be generally divided into Czech technical standards and European (or international) standards. Original Czech technical standards can be created only in sections that are not covered by European or international technical standards. [Broum 2019]

The technical standards related to machines that are relevant to industrial and collaborative robots are:

- CSN EN ISO 12100: 2011 - Safety of Machinery - General Principles of Construction - Risk -Assessment and Risk Reduction
- CSN EN 60204-1 ed.2 + A1, Rev.1 - Safety of Machinery - Electrical Equipment of Machines - Part 1: General requirements
- CSN EN ISO 13849-1: 2016 - Safety of Machinery - Safety Parts of Control Systems - Part 1: General Principles of Construction
- CSN EN ISO 13849-2: 2013 - Safety of Machinery - Safety Parts of Control Systems - Part 2: Validation
- CSN EN 1037 + A1: 2008 - Safety of Machinery - Prevention of Unexpected Start
- CSN EN ISO 13850: 2016 - Safety of Machinery - Emergency Stop - Design Principles
- CSN EN ISO 13857:2008 + Rev.1:2010 - Safety of Machinery – Safety distances to prevent access to danger points by the upper and lower limbs
- CSN EN 349+A1:2008 - Safety of Machinery – Smallest gaps to prevent compression of human body parts
- CSN EN ISO 14120:2016 - Safety of Machinery – Protective covers – General requirements for the design and manufacture of fixed and movable protective covers
- CSN EN ISO 13855:2010 - Safety of Machinery – Location of protective devices with respect to the approach speeds of human body parts
- CSN EN ISO 14119:2014 - Safety of Machinery – Blocking devices connected with protective covers - Principles for design and selection
- CSN EN 61000-6-2 ed.3:2006 - Electromagnetic compatibility (EMC) – Part 6-2: Generic standards - Resistance to industrial environments
- CSN EN 61000-6-4 ed.2:2007+A1:2011 - Electromagnetic compatibility (EMC) – Part 6- 4: Generic standards – Emissions - Industrial Environment
- CSN EN ISO 4414:2011 - Pneumatic – General rules and safety requirements for pneumatic systems and their components

There are three important points related to the technical standards above:

- Tools implemented to a collaborative robot
- Contact of a collaborative robot with sensitive parts of the human body
- Electromagnetic compatibility

Regarding tools implemented to a collaborative robot – it is always necessary to make a risk analysis. If there is a possible risk from a tool, a manipulated component, the environment, etc., it is important to take action that leads to risk elimination or reducing it to an acceptable level.

Possible contact of a collaborative robot with sensitive parts of the human body (for example: eyes) is a very common reason to put a collaborative robot in a safety cage.

Regarding electromagnetic compatibility, it is important that the robot has to be designed to prevent dangerous movements and situations influenced by expectable electromagnetic interference (EMI), radio frequency interference (RFI) and electrostatic discharge (ESD).

3.2 *Legislative machinery regulations*

Legislative machinery regulations relevant to manufacturers and operators of machines are described in this subchapter. They are also relevant for collaborative robot operators and manufacturers. The legislative regulations important for the manufacturer are:

- Directive 2006/42 / EC of the European Parliament - 17 May 2006 related to machinery and about the change of Directive 95/16 / EC (revised).
- Regulation No. 176/2008 Coll. on technical requirements for machinery.
- Act No. 22/1997 Coll. on technical requirements of products and about the change of supplements to certain laws.
- Government Order No. 117/2016 Coll. on the conformity assessment of products in terms of electromagnetic compatibility when the products are placed on the market.
- Government Order No. 118/2016 Coll. on the conformity assessment of electrical equipment to be used within certain limits of supply voltages.

Manufacturers using mechanical devices also have to apply the following regulation:

- Government Regulation No. 378/2001 Coll. on detailing requirements for safe operation and use of machinery, equipment and tools.

The most important ones will be shortly commented.

- Directive 2006/42 / EC of the European Parliament - 17 May 2006 related to machinery and about the change of Directive 95/16 / EC (revised).

The directive 2006/42 / EC defines basic requirements on safety and health protection. Special requirements related to specific groups of machines are added. [Directive 2006/42/EC 2006]

- Regulation No. 176/2008 Coll. on technical requirements for machinery.

The regulation No. 176/2008 Coll. implements a directive 2006/42 / EC into Czech legislative conditions. The regulation adjust technical requirements related to:

- Machinery
- Replaceable additional devices
- Safety components
- Lifting accessories
- Chains, ropes and straps
- Removable mechanical transmission devices
- Incomplete machinery

[Regulation No. 176/2008 Coll. 2008]

- Act No. 22/1997 Coll. on technical requirements of products and about the change of supplements to certain laws.

The act No. 22/1997 Coll. adjust determination of technical requirements of product that can have significant influence of health, safety, environment and property. Rights and obligations of the distributors and inspectors of compliance.

Related to the act No. 22/1997 Coll. there is also conformity declaration (CE). The manufacturer releases conformity declaration based on an assessment of the product with the requirements of a specific government regulation. On top of release of conformity declaration there is requirement to sign the product with CE sign, the CE sign is shown in Fig. 4.

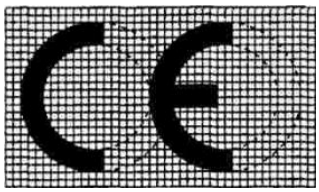

Figure 4. Conformity Declaration [Directive 2006/42/EC 2006]

- Government Regulation No. 378/2001 Coll. on detailing requirements for safe operation and use of machinery, equipment and tools.

The important part is in paragraph No.3. There is stated that for safe operation of machinery, technical equipment, devices and tools must be used appropriate protective equipment against life and health threatening of workers.

3.3 Technical standards related to industrial robots and collaboratice robots

The target was to find the legislative information that would define a collaborative robot and regulate its operation. The most important robot and robotic standards are:

- CSN EN ISO 8373: Robots and Robotic Devices - Dictionary
- CSN EN ISO 10218-1: Robots and Robotic Devices – Safety Requirements of Industrial Robots - Part 1 Robots
- CSN EN ISO 10218-2: Robots and Robotic Devices - Safety Requirements of Industrial Robots -Part 2: Robot Systems and Integration
- CSN EN ISO 9946: Industrial Robots for Handling - Characteristic Properties
- CSN EN ISO 9787: Industrial Robots for Handling - Coordinate systems and motion terminology
- CSN EN ISO 14539: Industrial Robots for Handling - Handling of Objects Using Grip Modules - Glossary and Characteristics
- CSN EN ISO 9409-1: Industrial Robots for Handling - Mechanical Interfaces - Part 1: Cover Board
- CSN 9409-2: Industrial Robots for Handling - Mechanical Interfaces - Part 2: Shafts

The important technical standards are CSN EN ISO 10218-1 a CSN EN ISO 10218-2 that define the term ‘collaborative robot’. Collaborative robots are part of the general group of industrial robots in these standards. [Broum 2019]

The technical standard CSN EN ISO 10218-1 also defines the concept of operational cooperation, a condition in which purpose-built robots operate in direct interaction with a person within a designated work area. [CSN EN ISO 10218-1 2012]

The standard gives also a list of risks (mechanical, electrical thermal and others), for example [CSN EN ISO 10218-1 2012]:

- Movement or rotation of the sharp tool on the end effector
- Moving parts of the robot
- Rotary movement of any robot axis
- Handling products and materials

According to the standard there have to be done risk analysis to identify any possible danger.

The risk assessment shall take particular account of [CSN EN ISO 10218-1 2012]:

- Intended robot operations, including learning, maintenance, adjustment and cleaning.
- Unexpected start
- Access of persons from all directions
- Reasonably predictable misuse of the robot
- Control system failure
- Risks associated with the specific application of the robot

Risks must be eliminated or reduced firstly by design or its modification, then by safety protection and other additional measures. Any remaining risks must be reduced by other measures (e.g. warnings, signs, training)

The technical standard CSN EN ISO 10218-2 is specifying the safety requirements for the integration of industrial robots and industrial robot systems as defined in ISO 10218-1 and the industrial cell (s) of the robot. [Waldman 2017]

Integration includes the following [CSN EN ISO 10218-2 2011]:

- Design, manufacture, installation, operation, maintenance, etc.
- Information necessary for the design, manufacture, installation, operation, maintenance, etc.
- Components of industrial robot system or cell

This standard further defines:

A collaborative robot is a robot designed to interact directly with humans within a designated collaborative workspace. [CSN EN ISO 10218-2 2011]

A collaborative workspace is a space within a secure area where the robot and human perform tasks simultaneously during production operations. [CSN EN ISO 10218-2 2011]

The important chapter of the technical standard is chapter 4.5 Eliminating danger and reducing of the risk. The chapter states that once a danger has been identified, it is necessary to assess the risks associated with the robot system before applying appropriate risk reduction. Risk reduction is based on the following basic rules [CSN EN ISO 10218-2 2011]:

- Risk elimination by the design or reducing the risks by substitution
- Safety protection to prevent human from being in contact with the danger or by ensuring that the danger turned into a safe condition before contact with the human
- Providing additional protective measures such as information for use, training, labels, personal protective equipment, etc.

These technical standards do not clarify forces or pressures related to safe contact with the human. There is also no specification how to create a work area suitable for cooperation. This is one of the reasons that companies place collaborative robots in safety cages or outside the work area of the human as stated by the regulations mentioned so far. On the other hand, there is currently a technical specification ISO / TS 15066: 2016 that defines how to design a work space for humans and collaborative robots. Technical Specification ISO / TS 15066: 2016 is in addition to the previously mentioned technical standards CSN EN ISO 10218-1 and CSN EN ISO 10218-2. [Broum 2019]

It is also important to mention the certificate TÜV SÜD, which means that if a cobot is implemented with this certification it is possible to use humans and collaborative robots together in the workplace. [Poor 2018]

4 CONCLUSIONS

The subject of this paper is collaborative robots and the safety requirements related to their implementation in the Czech Republic. The information presented in this paper could provide inspiration for other countries about what their safety requirements analyses should concentrate on with regards to the implementation of collaborative robots. The information presented here can ensure successful collaborative robot implementation. It shows the importance of the analysis of the safety requirements which establish an important basis for their implementation. Not respecting safety requirements can have significant consequences for the company.

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