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SAFETY AND RISK ASSESSMENT AT AUTOMATED WORKPLACE

Urgency of the research. *Automated workplaces are growing up in present, especially with implementation of industrial robots with feasibility of various dispositions, where safety and risk assessment is considered as most important issues.*

Target setting. *The protection of workers must be at the first place, therefore safety and risk assessment at automated workplaces is most important problematic, which had presented in this article*

Actual scientific researches and issues analysis. *Actual research is much more focused at standard workplaces without industrial robots. So, missing of information from the field of automated workplaces in connection with various dispositions can be considered as added value of article.*

Uninvestigated parts of general matters defining. *Despite to lot of general safety instructions in this area, still is missed clear view only at automated workplace with industrial robots.*

The research objective. *The aim of article is to provide general instructions directly from the field of automated workplaces*

The statement of basic materials. *For success realization of automated workplace is good to have a helping hand and orientation requirements needed for risk assessment at the workplace.*

Conclusions. *The results published in this article increase the awareness and information of such automated workplaces, together with industrial robots. In addition, presented general steps and requirements helps persons for better realization of these types of workplaces, where major role takes an industrial robot. Our proposed solution can be considered as relevant base for risk assessment such workplaces with safety fences or light barriers.*

Key words: *safety; risk assessment; industrial robot.*
Fig.: 5. Table: 1. References: 8.

Introduction. Automation at Slovakia is basically determined in automotive sector with massive production and low variability of manufactured model numbers at automated lines. These characteristics are still the same over the several years without significantly change. Stereotypical working positions at companies lead to fluctuation of employees. Also this contributes to the implementation of robots into the processes that can be considered as suitable answer to cost increasing and qualified employers inability [1]. Over the time, classical and standard working positions are reduced and missing and new highly specified knowledge is necessary. The example of insufficient safety conditions at workplace can be presented at Figure 1, where woman during operation at machine has not protected their eyes.

Fig. 1. Insufficient safety during operation at workplace

The aim of automation in this content consists in sustainability of qualified workers in companies with representative expert and analytical knowledge with potential for creation of added value activities at their automated workplaces. Main field of automation is obviously industrial sphere, but significant space is also in services. As good example, we can remark software robots that can help people in offices, banks and public with daily boring activities (like lot of numbers entering, repetitive information, etc…), but people still must be presented an helped to him. Reasons for robot implementation lay in:

- Decreasing of operational costs (heating of hall, lighting during some operation etc…).
- Better quality of products (stability of their accuracy without distraction, fatigue or monotonous and repeating work).
- Quality of working environment (robots take tasks that are unconformity for people, so they can work on more interesting and complexion tasks in working process).

- Increasing of manufacturing capacity (robots can work almost always with small human supervision).
- Increasing of manufacturing flexibility (adoption to new customer requirements are much faster thanks to offline programming).
- Lower wasting of material (more accuracy = more products = less waste).
- Compliance with safety regulations (robots can take a role that is potential dangerous for people, less ergonomic or lead to illness).
- Lower fluctuation of workers (automation is connected with qualified of workers and interesting jobs that are much more preferred).
- Reduction of capital costs for stocks and incomplete production (manufacturing in term of just in time).
- Better utilization of workspace (robots can be mounted at the walls, roofs and can work in narrow conditions).

In past, industrial robots have not so that major position at working space as in present. They are important because of its parameters like speed, accuracy, flexibility. Its position and role for lean production together with implementation into the automated workplaces that includes specific customer requirements is a target to continuous increasing of product parameters and company prosperity. Robot themselves are not lean, but by their integrating into the automation can rapidly increase to lean concept development [2]. Benefits of robots integration are in:

- Repeatability – robots increase a quality of product, stability for quality level and eliminate a waste.
- Speed – robots can participate at increasing of productivity and decreasing of cycle time.
- Accuracy – robots contribute to decreasing of waste.
- Flexibility – robots decrease a time that is necessary for workers training and reduce time for tools exchange.

Despite to the fact that industrial robot as a whole is considered as relatively safety (regarding to his certification and software control), it does not mean that the same robot is safely during its environment implementation. Especially, in industrial applications are for robots developer impossible to say that any type of robot after his inserting into the application can be safe without risk assessment. Safely robot can be assumed after a risk evaluation and assessment.

Hazard at automated workplace. A reason for hazard presented at the automated workplace is much more than could anybody imagine. Between significant sources of this hazard can be included dangerous work equipment, stress conditions, speed of working, insufficient training of workers, insufficient supervision or absenting of safety procedures and control, Fig. 2. In case of young workers (until 18 years) is injury probability more expected than others workers [3]. As young people, you can be faced to more hazard because of lower skills, protection and OSH solutions that can occur.

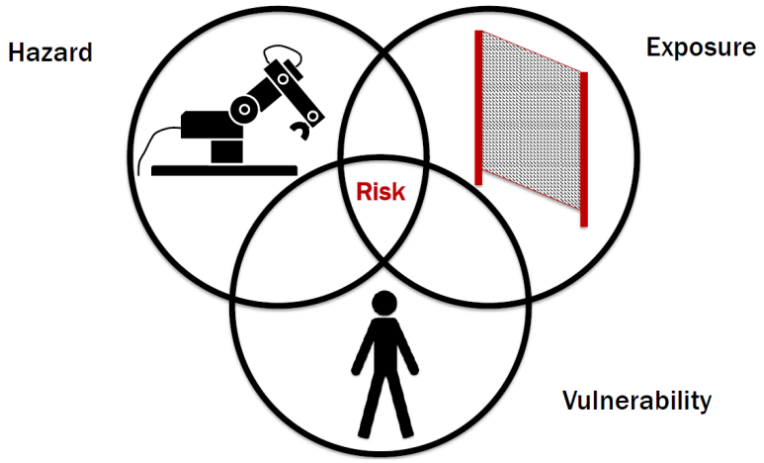

Fig. 2. Factors of risk at automated workplace

Automated workplace can be considered as safely only after risk assessment and repeatedly minimising. Working with robot is generally considered as safely (collaborative robot i.e.) but if the end effectors has sharp shapes, operation is no more safely, at all – despite to the whole developer certifications and protection parts and surfaces. One of the major factors that have impact to hazard is vulnerability. Long and periodic factor lead to human diseases at automated workplace; such is noise and vibration i.e. that is most often from working process. Types of hazard in general can be seen in table.

Table

Hazard in general form

1.	Unequal and slippery surfaces (can lead to fall, slip etc…). Most often reason because of lot of people at the workplace, dust or liquids at surfaces cables or damages.
2.	Moving equipment and machines (insufficient maintenance, missing security equipment, trying to machine repairing)
3.	Moving parts of machines (disconnecting of machines from voltage)
4.	Objects and parts with dangerous surface (sharp, rough etc…)
5.	Hot and cold surfaces, materials etc…
6.	Workplaces at high and places with possibility to fall
7.	Handle tools
8.	High pressure
9.	Electric installation and equipment
10.	Fire
11.	Explosion
12.	Chemical substances (including dust) in air
13.	Noise (higher and long duration can lead to ear damages)
14.	Vibration of hands
15.	Vibration of whole body
16.	Lighting
17.	UV, infrared, laser and microwave radiation
18.	Electromagnetic fields
19.	Hot and cold climate environment (temperature extreme lead to health problems)
20.	Lifting and manipulation with load (unstable and heavy load, missing of lift at a workplace)
21.	Work in contrary position
22.	Biological hazards (viruses, parasites, bacteria's etc…)
23.	Stress, violence, mobbing (as a result of bad work organisation, unclearly responsibilities, etc…)
24.	Others (can be specified…)

Prevention at automated workplace. Knowing how to prevent in the automated workplace is super important, but what's better than that? Of course, it's not possible to completely eliminate accidents, but with a little effort and some foresight, they can be significantly reduced. Tips, how to prevent accidents in the first place can be:

- No tasks can be realised by new worker, only after his regularly training.
- In case of speedily OSH training, try to repeat information from trainer and slow down.
- For new recruited persons is better to stay at desired space in working area (they have low knowledge about whole area of company, hall etc…).
- If you are not sure, firstly ask more skilled worker or your supervisor.
- Do not be afraid to ask for further training.
- Wear and use PPE correctly, his place and carrying about them.
- Be informed about emergency situations.
- Do not ignore early signs of problems, such as headaches, other pains, dizziness, itchy skin or irritated eyes, nose or throat.
- Follow advice and instructions given to you - this applies also breaks the correct setting chairs, wearing personal protective equipment.

Convectional industrial robots are strictly isolated from human operators (by mechanical fences or optical barriers) that serve for immediately stopping of human approaching, Fig. 3. It helps with difficult and routine tasks, manipulation with products [4].

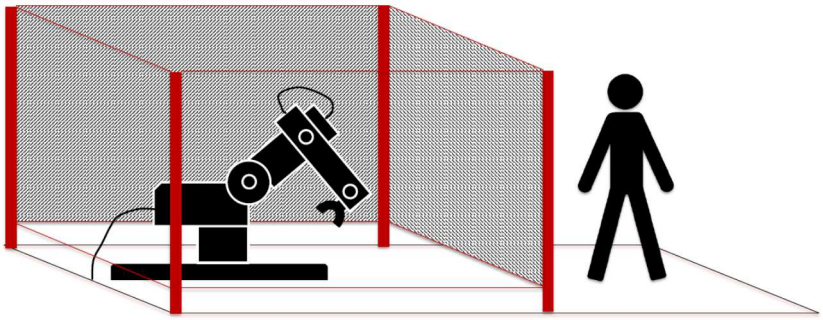

Fig. 3. Prevention by mechanical fences at automated workplace

Creation of prevention plan

All automated workplaces should have prevention plan. Generally, it is not possible to create one universal concept for whole and specific situations [5]. Prevention plan allows to company consider a necessary implementation questions for relevant and equal situations. Consists of fourth phases:

- pre-treatment phase - includes creation of working group, evaluation of needs, commitment, social atmosphere and communication,
- planning and preparing phase – agreement of objectives and tasks, curriculum planning and program selection, preparation of program creation, identification of resources, start of project, key stakeholders,
- sustainable phase – assessing and adapting of program, engaging key stakeholders, assessing of tasks and responsibilities, monitoring of trends and data,
- starting / initiation phase – coordinate of project or project team, regular meeting, agree of key element, leadership

Minimizing of risk

Minimizing of risk is continuous process together with using of security devices. The purpose of these devices is decreasing of injury level to minimum regarding actual standards, directives up to acceptable surface [6]. During minimizing of risk is possible to apply an approach into the followed steps. In first step we try to avoid creation of danger already at design and production of automation workplace phase. Second step can be characterized as decreasing of danger through implementation of several protection devices [7]. In last, third step we try to identify a residual danger. After that, we try to decrease this danger i.e. by informing of employees, additional training etc. It is recommended to minimizing of risk also via health and security examples see Fig. 4.

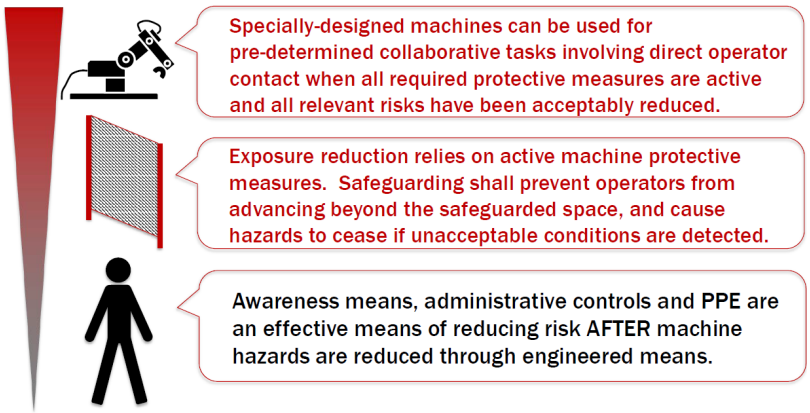

Fig. 4. Minimizing of risk at automated workplace

Risk assessment at automated workplace. Risk assessment can be realized by employer; employees entrusted to employers or by external evaluators or these service providers (if there is a small number of employees) [8]. Generally, evaluators must have all necessary information, training, sources, time and support to realize it. We can follow this procedure:

1. Parameters defining at automated workplace.

Introductory step for risk assessment is defining of all parameters at automated workplace. Is possible to help with several questions, like: Where will be place for robot? What kind of end effector will be used? Which will be the main purpose of the robot? What is the type of manipulated work piece (in case of manipulation task)? By answering at these questions we can obtain a lot of necessary data for precise and detailed risk assessment. In this phase is good to know the type of the robot followed by studying of manufacturer catalogues lists to determining a maximum speed, acceleration, maximum payload etc. After collecting of these information is possible to reach a second step – identification of risk sources.

2. Identification of risk sources.

This step is characterized as identification of whole possible risks. Is needed to know that risk assessment process includes not only operations as manipulations, welding, packaging etc. but also buying of component (at the beginning), it's given from providers until the liquidation of workplace (at the end). Already at the incorrect unloading of heavy robotic arm from car or robot operation starting without qualified persons can be sources for creation of big injuries. Warning to the creation of possible risks during installation may be insignificant, but security experts warn and claim that the process of risk sources identifying is often underestimated, and many times during the installation of robot itself it has become tragic. After a thorough identification, the result should be an analysis that is subsequently needed in the next step to determine level of risk.

3. Determining level of risk.

Exists more and various ways how to monitor and evaluate risk. One of them is under the ISO 13849-1:2006 method. Risk is evaluated by performance level rating (PLr). This analysis uses three parameters: severity of injury – S, frequency of exposure to hazard – F and possibility of avoiding hazard P. Basic principle of risk assessment according to the given method is to gradually move from start to finish to individual parameters and their evaluations, at the end we will find the level of risk from negligible to very high, Fig. 5.

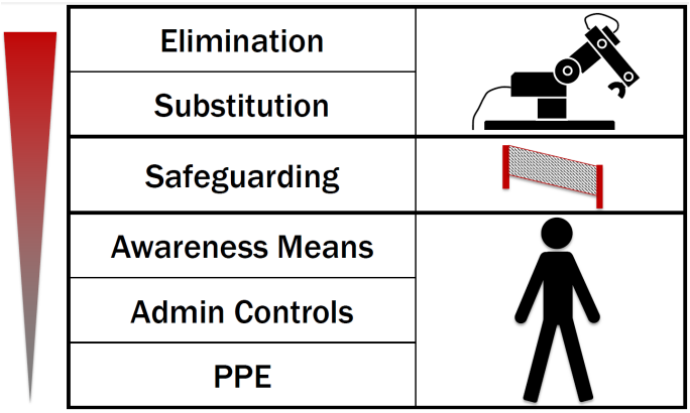

Fig. 5. Risk assessment at automated workplace

Conclusions. During robot integration into the automation processes is major requirement a workers safety, of course. More automated solutions with implementation of industrial robots require safety fences or light barriers. So, robot works in a closed space and thus protects operators. Future safety needs are also important during realisation of these solutions, because they contribute to the increasing of company efficiency and will be grow up together with you. Automation as a whole is not only about less employees at the workplace, but it is also about integration of new security devices and technologies with supporting of workers cooperation.

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ФУНКЦІОНАЛЬНА БЕЗПЕКА ТА ОЦІНКА РИЗИКУ НА АВТОМАТИЗОВАНОМУ РОБОЧОМУ МІСЦІ

Актуальність теми дослідження. *В даний час зростає кількість автоматизованих робочих місць, особливо з впровадженням промислових роботів з можливістю зміни їх розміщення, де функціональна безпека та оцінка ризику розглядаються як найбільш важливі проблеми.*

Постановка проблеми. *Захист працівників має бути на першому місці, тому оцінка безпеки та ризику на автоматизованих робочих місцях є найбільш важливими питаннями, які були представлені в цій статті.*

Аналіз останніх досліджень і публікацій. *Актуальні дослідження більш сфокусовані на стандартних робочих місцях без промислових роботів. Таким чином, відсутність інформації щодо автоматизованих робочих місць у зв'язку з різними диспозиціями може розглядатися як додатковий чинник, що підвищує цінність статті.*

Виділення недосліджених частин загальної проблеми. *Незважаючи на безліч загальних інструкцій із техніки безпеки в цій галузі, досі відсутній чіткий огляд виключно автоматизованих робочих місць із промисловими роботами.*

Постановка завдання. *Метою статті є надання загальних інструкцій безпосередньо в області автоматизованих робочих місць.*

Виклад основного матеріалу. *Для успішної реалізації автоматизованого робочого місця корисно мати додаткову допомогу та перелік вимог, необхідні для оцінки ризику на робочому місці.*

Висновки відповідно до статті. *Результати, опубліковані в цій статті, підвищують обізнаність і інформованість про автоматизацію робочих місць разом із промисловими роботами. Крім того, представлені загальні кроки й вимоги, які допомагають людям краще реалізувати ці типи робочих місць, де основну роль відіграє промисловий робот. Запропоноване рішення може розглядатися як актуальна база для оцінки ризику таких робочих місць із захисними огородженнями або світловими бар'єрами..*

Ключові слова: *функціональна безпека; оцінка ризику; промисловий робот.*
Рис.: 5. Табл.: 1. Бібл.: 8.

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Darina Hroncová

MULTIBODY SYSTEMS AND SIMULATION IN MATLAB

Urgency of the research. *Computer modeling changes the teaching methodology, the way of thinking and the possibilities of applications. It helps to move from external to internal properties and from individual to related properties. The development of the product is accelerated by experimenting with a computer model.*

Target setting. *Kinematic analysis in Matlab and MSC Adams View. The aim is to investigate the rotation of individual members of the robotic system and to determine the spatial movement of the end effector.*

Actual scientific researches and issues analysis. *MSC Adams represents dynamic simulators of virtual prototypes of mechanical systems. Virtual prototypes allow to model, analyze and optimize the future products and to examine their properties before building a real prototype. This approach is suitable for developing miniature mechatronic elements as well as complex systems.*

Uninvestigated parts of general matters defining. *Virtual prototypes represent a suitable resource for testing of control and regulation procedures.*

The research objective. *Compilation of a virtual prototype of a mechanical system that has all the decisive features and is computationally stable.*

The statement of basic materials. *Virtual model is a mathematical representation of real-world structures, simulating all its physical properties virtually.*

Conclusions. *The aim was to determine the kinematic properties and also to evaluate the influence of the parameters of the mechanism which influence these kinematic properties. The matrix method was used. The process of the solution consisted of determining the transformation matrices of the coordinate systems, the kinematic analysis of the industrial robot and the graphical representation of the effector handling space.*

Keywords: *virtual model; open kinematic chain; robotic system; software simulation; end-effector; transformation matrices.*

Fig.: 11. References: 17.

Introduction. The development of technology and mechanization has led to the development of the theory of planar and spatial mechanisms. Spatial mechanisms are used in various production machines, for example, in robots and manipulators. Analytical analysis of mechanisms describes the movement of driven members or some points of these members depending on the known or prescribed movement of the driving members. It means the determination of the position, speed and acceleration of the studied members and points depending on the movement of the driving member. It is possible to use the vector method for kinematic solution of spatial mechanisms, which was described by V. A. Zinovev. This method, however, is quite complicated for scalar notation of vector equations. More suitable is the usage of the matrix notation. The fourth order matrices were introduced by J.Denavit and R.S.Hartenberg. Similarly, G.S.Kalicin solved some problems of planar and spherical mechanisms by the matrix notation. The possibility of using quaternions or biquaternions in kinematics of the rigid bodies was pointed out by J. Novák. General methods of analytical analyses were studied by S.G. Kislicin and J. F. Moroshkin. The czech author V. Brat introduced into practice the usage of a matrix notation in analysis of kinematics of spatial mechanisms. Individual simultaneous movements can be described by matrix equations. There are relationships derived for both simple and simultaneous movements. The suitability and widespread usage of the matrix method is given not only by the possibility to describe the directly the space of the individual members, but it is also appropriate for use in computers with advanced methods of numerical solution of systems of equations.

This paper presents the application of the matrix method in the kinematic analysis of a simple manipulator model. Manipulators are composed of open kinematic chains. Matlab and MSC Adams -View computer programs were used in their analysis.

Model of manipulator with 2 degrees of freedom of movement R-R.

The mechanical system representing the open kinematic chain consists of two members 2 and 3 and the base 1 (Fig. 1). The member 2 with length l_2 rotates around the axis $z_1 \equiv z_2$ by the angle φ_2 and the member 3 with length l_3 rotates around the axis z_3 by the angle φ_3. We investigate the absolute motion of the member 3 and its point M, determine the position