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THE OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT ISSUES IN THE INDUSTRY 4.0

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Abstract: The specificity of the work organization in Industry 4.0 varies depending on the technological development and the level of security of new technology solutions. Employees are required to maintain a key function in working with knowledge, including decentralized decision-making and the safety and quality assessment of the production processes. The results of occupational risk assessment are presented here as a method contributing not only to the improvement of production processes, but also to the improvement of the product quality level. Author presents solutions in the field of occupational health and safety management applied in the chosen production company in the department of repair and anti-corrosion works, which contributed to the product quality level improvement.

Keywords: occupational health and safety, management, work

1. INTRODUCTION

Changes in markets, both local and global, caused by short product life cycles, new technologies, innovations and an increase in individual customer requirements in terms of product functions, increase the level of competitiveness of enterprises. This state of affairs forces manufacturers to look for advanced technologies and solutions that guarantee shortening the production time and unconventional opportunities to reduce costs, while improving the quality of products. Current trend in the production, called as the industry 4.0 means the unification of the real world of production machines with the virtual world of the Internet and information technology (Skrzypek, 2020).

The concept of industry 4.0 can therefore be under-stood as a complex solution created at the interface be-tween engineering, IT and management knowledge. The use of new technologies enables globalization, and thus the unlimited range of activities of the organization. The assumptions of this concept are primarily: reducing costs and improving production efficiency, offering improved and personalized products and services (tailored to the preferences and behaviour of consumers). Their implementation is to be based on the automation of production "based on the use and exchange of data in real time, using artificial intelligence (Gajewski, et al. 2016, Pietraszek, 2020, Ingaldi, and Ulewicz, 2020).

The current methods of production processes management are no longer flexible enough to meet the requirements of today's highly competitive market. Individual orders of contractors make it necessary to retool the means of production with a view to various batches of products (Ulewicz, et al. 2021).

Changes in the industry are accompanied by changes in the work environment, such as (Gralewicz, 2015):

- modifications of work processes due to the introduction of non-standard production (direct design approach to production),
- multi-factor risk due to the complexity of new technologies and work processes,
- machine failures due to the increased degree of multi-functionality of the production process,
- flexible hours and flexible work processes,
- information overload of workers.

Changes in enterprises as part of revolution 4.0 require the implementation of a new concept of intelligent work environment management, which consists in continuous, direct monitoring of the risk and simultaneous management of work safety using new technologies created for the needs of this area. This requires changes in the approach to occupational risk management in the context of using the traditional hierarchy of preventive measures (Łosyk, et al 2019).

The working environment has a large impact on the employee, and therefore he is exposed to the adverse effects of work, i.e. accidents at work and occupational diseases. The probability of occurrence of negative effects of the work occurs in every enterprise, which is why it is so important to carry out occupational risk assessments, to which employers are obliged. In addition, occupational risk assessment also affects the organization of production processes, as well as the quality level of products and services (Ulewicz, 2014; Krynke, 2020; Knop, 2020). As a result of the occupational risk assessment, it is possible to introduce preventive measures that involve making employees aware of potential sources of risk and its size during training in the field of occupational health and safety. They are a mandatory element of proper safety management in the enterprise (Szczerska and Łosyk, 2019). Effective risk analysis is helpful not only in the subsequent definition of procedures for monitoring the health and safety condition in the enterprise, but also contributes to the improvement of the organization of production processes and the quality of products, which is the main goal of the analysis of the results presented in the paper.

2. LITERATURE REVIEW

The abstractness of the safety materializes when con-fronted with threats. A threat to safety can be defined as any phenomenon (process, event) undesirable from the point of view of the undisturbed operation of a social organization as a certain order or order. Thus, safety can be understood as resistance to the emergence of dangerous situations (threats), with attention being focused on the unreliability of the safety of the facility, i.e. its susceptibility to the emergence of dangerous situations and the ability to protect internal values against external and internal threats. This approach to safety coexists with the approach: objective (in which there are conditions for the occurrence of real threats) and subjective (expressing a sense of safety as realized threats). Risk and/or liability are the measure or assessment of the risk (danger) arising either from probable events beyond our control or from the possible consequences of making a decision.

Risk is an indicator of a condition or event that could lead to losses (Maternowska and Pedryc, 2014, Niciejewska and Kiriliuk, 2020).
Occupational risk is the probability of the occurrence of undesirable work-related events that may cause losses, in particular the occurrence of adverse health effects in employees as a result of occupational hazards at work or the manner of performing work (PN-N-18002:2011).
Occupational risk assessment is an important mechanism for the safety and improvement of product quality. It means that a hazard was identified at workplaces, an assessment of the consequences of the related hazardous events for the safety and health of employees was pre-pared, and the probability of occurrence of these events was assessed.
Occupational risk assessment is also the definition and implementation of activities aimed at counteracting threats that affect both employees and the process itself (Băbut, 2018). Occupational risk assessment (ORA) is a process that consists of evaluating, ranking, and classifying the hazards and associated risks arising in any work-place from the viewpoint of occupational health and safe-ty. A significant number of ORA methods, either in quantitative or qualitative/hybrid structures, are in use in the academic and industry environment (Ak, et al., 2021). Fatih Ak, Melih Yucesan and Muhammet Gul (2017) say that an ISO standard of IEC 31,010: 2019 'Risk manage-ment' Risk assessment techniques' includes techniques for eliciting views from stakeholders and experts (brain-storming, Delphi, Nominal group, interviewing), identify-ing risks (checklist, FMEA, HAZOP, scenario analysis, what-if analysis), determining sources, causes and drivers of the risk (fishbone technique), analysing controls (Bow-tie analysis, LOPA), understanding consequences and likelihood (Bayesian Network, ETA, FTA, Markov analysis, Monte-Carlo simulation), analysing dependencies and interactions (causal mapping), including a measure of risk (Value at Risk), evaluating the significance of risk (Frequency-Number diagrams, Pareto charts), selecting be-tween options (cost-benefit analysis, decision trees, Multi-criteria decision making, game theory), and recording and reporting (Consequence/Likelihood matrix, S-curve) (ISO 2019, Ramesh et al., 2017).
Risk assessment can be carried out on the basis of three methods:

- preliminary PHA hazard analysis, which allows for a qualitative determination of the risk by determining the probable losses by the degree of damage and the probability of the occurrence of damage,
- the Risk Score method, which is an indicator method that determines the risk on the basis of three parameters, exposure to a threat, the probability of its occurrence and the consequences of an event,
- methods according to the PN-N-18002 standard, which is a matrix method consisting in determining the probability and severity of the consequences. A five-point or three-point scale is used.
- In accordance with the requirements of the standard (chapter 4), it is recommended to take into account, inter alia, the following rules (Krause, 2016):
- it is recommended to prepare an action plan relating to occupational risk assessment, which may include, inter alia: appointing the right people to carry out the occupational risk assessment, involving representatives of management and employees in the occupational risk assessment, providing occupational risk assessors with access to appropriate information and resources;

- the choice of methods used in the process of occupational risk assessment to identify hazards at workplaces and to assess occupational risk de-pends primarily on the subject of the assessment;
- for workplaces where the risks are well known and easily identifiable, risk assessment can be a very simple process, and hazard identification and risk assessment based on judgments that do not require expertise or complex measurement techniques and computing, e.g. for office work;
- in other cases, in order to carry out an occupational risk assessment, it may be necessary to measure the harmful factors in the work environment.

The RISK SCORE method was chosen in the analysis applied in the research presented in the paper as a qualitative, indicative method of occupational risk assessment, useful especially in the assessment of non-measurable factors of the work environment. It is convenient to use due to the indicators that have been defined in tabular form, and thus allow for the determination of the risk category for individual threats in a transparent manner. Risk Score method is used to estimate the risk of human and material losses that may occur during specific activities realization in determined time set. It is a factor meth-od because the failure and threats levels (values for the risk calculation) are not expressed in the strict manner but by contractual numerical scales. In this method the risk is the product of three parameters (Krause, 2008): exposure for threat, probability of the threat appearance, effects of unfavourable event.

The risk is calculated from formula:

$$R = S \cdot E \cdot P \qquad \text{(PN-N-18002:2011)}$$

where:
R - risk,
S - potential effects of threat,
E - exposure for threat,
P - probability that threat occur.

Occupational risk is closely related to the work environment. Therefore, for the same positions, but under different working conditions, the risks and level of risk may be different. When estimating the degree of harm of a hazard, the greatest possible effect is assumed. It should be remembered that in estimating the probability of con-sequences should take into account the working conditions and events that have occurred in the past, the behaviour of employees, etc. The values of individual factors are estimated according to Tables 1 ÷ 3.

Table 1. Potential effects of threat (S)

Value of the risk	**Estimated losses**	**Human losses**
100	A serious catastrophe	Many fatalities
40	Catastrophe	Several fatalities
15	Very large	One fatality
7	Large	hard injury
3	Average	Absence
1	Small	First aid

Table 2. Exposure for threat (E) - frequency of impact of harmful factors on the employee

Value of the risk	Characteristic
10	constant
6	frequent (daily)
3	occasional (once per week)
2	chance (once per month)
1	minimum (a few times a year)
0.5	insignificant (once a year)

Table 3. Probability that threat occur (P) for worker

Value	Characteristic
10	very probable
6	quite possible
3	practically possible
1	unlikely, but possible
0.5	occasionally possible
0.2	possible to consideration
0.1	theoretically possible

After calculating the risk index R, the occupational risk assessment is carried out according to the scale.

Table 4. R = S x E x P

Value	Characteristic	Actions
R≤20	Acceptable	Recommended control
20<R≤70	Low acceptable	Need of control
70<R≤200	Essential	Need of control
200<R≤400	High	Need immediate control
R>400	Very high	Indication of a work suspension

3. EXPERIMENTAL

The occupational risk assessment was made in the chosen production enterprise that produces modern steel constructions for the coal mining industry. The analysed company has a developed information and IT system, office activities are performed in an integrated modular ERP system. The company has built many kilometres of conveyor routes, many drive and return stations, over-hauls of basic machines, and also has a large number of steel structure renovations. Over the years, the company has specialized in works accompanying mining, in partiCular: anti-corrosion protection, construction and assembly of structures, general construction works, electrical works, mechanical works, treatment and regeneration. There is a quality control office in the analysed company, which has the control and measurement equipment necessary to conduct construction tests at every stage of production and assembly, including: flaw detectors for ultra-sonic tests, flaw detectors for magnetic particle tests, ultrasonic thickness gauges, fiberscope, meters for the assessment of surface roughness, coating thickness gauges, meters for measuring atmospheric conditions, a laser system for aligning machine assemblies and GPS receivers, levels and an electronic tachymeter.

The equipment is systematically supplemented with the latest generation equipment. Quality documentation is prepared from the individual stages of steel structure production, including inspection protocols and data on the control and measurement tests performed.
The subject of the analysis was the work carried out as part of the corrosion protection process of the steel structure of the hall. The process of protecting the structure against corrosion is divided into pre-treatment and proper treatment. The pre-treatment process, which is divided into two stages, includes grinding work, which consists in rounding all sharp edges, as well as removing chips. The second stage of pre-treatment also includes washing the structure with detergent in order to remove dirt and grease. The actual machining is also divided into two stages and the first one is abrasive blasting, which aims to obtain the appropriate cleanliness class of the metal and give it appropriate roughness for better adhesion and penetration of the paint. The second stage of proper pro-cessing is the application of paint coatings in accordance with the specification and documentation of the steel structure. The elements are abrasive blast cleaned to the Sa 2½ cleanliness class, and then undergo a very detailed visual inspection according to PN-EN ISO 8502. After the inspection, the elements of the structure are transported to the paint shop.
At the beginning, each structure is additionally dedusted, and then, in the first stage of painting, hard-to-reach places as well as welds and narrow edges are worked out with a brush, this treatment is necessary in order to obtain similar values of the coating thickness. The structure prepared in this way is painted with a hydrodynamic spraying method with an epoxy primer layer, which has good penetrating properties and is to inhibit the corrosion process in the initial stage of corrosion.
After the primer layer has dried, its thickness is con-trolled, which must meet the specification and usually amounts to 70 μm. There is a possible acceptability of the thickness error that may occur and cannot be lower than 90% of the established thickness and higher than stated in the product data sheet. The next step is to repaint hard-to-reach places as well as welds and narrow edges, and then you can apply an intercoat, which is also an epoxy paint, by hydrodynamic painting. After this painting step, the thickness quality control is also carried out, which also has to meet the specification and is usually 120 μm. The last stage is painting the top layer - polyurethane, which has very good protective properties against moisture and, what is very important, against UV radiation. It is applied by hydrodynamic painting, but with a slightly smaller thickness 50 μm. Over-roughing could cause the topcoat to crack. After final painting, we carry out thickness checks and visual assessment.
The object of the occupational risk assessment was pre-pared for the position of painter-sandblaster with all facilities, rooms and premises of the workplace intended for the performance of described position. Analysed position is situated at enterprise department for renovation and anticorrosion works responsible for the final product performance. RISK SCORE methodology was applied the mentioned assessment.
The first step of the occupational risk assessment is description of the employees task at this position include, among others:

- preparation of the workplace,
- preparation of machines and devices for sand-blasting and shot-blasting of steel elements,
- sandblasting and shot blasting,

- painting,
- taking care of law and order at the workplace,
- performing other activities and tasks specified in the scope of activities,
- carrying out the orders of superiors.

Machines, tools, materials used: sand shed, blasting chamber, compressor with sandblaster, petrol, electric, painting unit, paint sprayer, paint and sand nozzle, paint, sand, pressure hose, abrasive, shot, big bag, paints, thin-ners, other chemical substances - dangerous. Personal protective equipment at the analysed position includes: headgear, working clothes, work footwear, gloves, masks, half masks, hearing protectors, paint, sandblaster suit. Collective protection equipment include: natural, ex-haust, suction - filtering and ventilation ventilation, guards for moving parts.

4. RESULTS AND DISCUSSION

The assessment of hazards and occupational risk in the position of a painter-sander was presented in the table 5.

Analysis of the data presented in Table 5 underline high risk indicator within two tasks:

1. Service of pressure devices (compressor, sandblaster).
2. Construction cleaning by abrasive blasting.

According to the risk assessment, mentioned tasks re-quires essential control, what results from the noting a high level of noise at the work position related to devices used in the analysed process. Applying hearing protective equipment is a crucial solution that has influence on the work conditions comfort for the workers. Analysis of the data in Table 5 shown that crucial task for the occupational risk level that has influence on the process and product quality is abrasive blasting.

Abrasive blasting is a very popular technological pro-cess and widely used in the preparation of surfaces for protective coatings, both for new constructions and those intended for renovation. This treatment is suitable for cleaning virtually any material and can be used anywhere, unless the site has an explosive zone or is particularly exposed to the risk of fire, in which case such treatment must be applied in a water cover. This process consists in cleaning a given surface with abrasive material in a stream of compressed air. The quality and efficiency of cleaning is influenced by factors such as:

1. Compressed air quality and efficiency - compressed air is used not only to impart kinetic energy to the abrasive, but also to the following processes:
   a) generating adequate pressure in the blasting ma-chine tank,
   b) transport of abrasive from the tanks to the nozzle,
   c) giving the abrasive kinetic energy,
   d) powering the operator's helmet, enabling him to breathe,
   e) supplying pneumatic and electro pneumatic automation devices.
2. Equipment quality - including the type of pressure vessel, the quality of hoses and the type and type of nozzles.
3. The type of abrasive and its granulation - apart from its shape and hardness, granulation has an important feature that has a significant impact on the roughness of the obtained surface.

Table 5. The assessment of hazards and occupational risk in the position of a painter-sander

Task		Threat	S	E	P	R	Risk
1	Service of pressure devices (compressor, sandblaster)	Excessive noise	3	6	10	**180**	Essential / Needed control
		Driving over, being hit by a vehicle	7	0,5	0,5	**1,75**	Acceptable / Desirable control
2	Covering the stripper with abrasive	Crushing the worker with a "bag" of abrasive. Amputation, crushing of the upper limbs	7	0,5	0,5	**1,75**	Acceptable / Desirable control
3	Preparation of the workplace (placing machines and devices, stretching the hoses)	Hit by moving vehicles	7	0,5	0,5	**1,75**	Acceptable / Desirable control
		Hovering over with a dragged machine	7	0,5	0,5	**1,75**	Acceptable / Desirable control
		Excessive effort during manual transport, laying hoses (back injuries)	3	1	3	**9**	Acceptable / Desirable control
		Fall, stumble on structure	3	2	6	**36**	Small / Needed control
4	Construction cleaning by abrasive blasting	Noise	3	6	10	**180**	Essential / Needed control
		Fall from a height	3	0,5	6	**9**	Acceptable / Desirable control
		Tripping, falling over the structure	3	2	6	**36**	Small/ Needed control
		Blast with abrasive jet	3	1	3	**9**	Acceptable / Desirable control
5	Painting the structure by the hydrodynamic method	Splashing paint in the eyes	3	1	3	**9**	Acceptable / Desirable control
		Fall from a height	3	0,5	6	**9**	Acceptable / Desirable control
		Impingement with a stream of pressurized liquids (paint, solvents)	3	1	6	**18**	Acceptable / Desirable control
		Poisoning by the respiratory tract	3	1	3	**9**	Acceptable / Desirable control
		Skin diseases (contact with chemical - toxic agents))	3	1	3	**9**	Acceptable / Desirable control
6	Cleaning and maintenance of devices and instruments in use	Mechanical injuries of the upper limbs	3	1	6	**18**	Acceptable / Desirable control
7	Tidying up the workplace; breaks	A fall from a great height	3	1	3	**9**	Acceptable / Desirable control

The other task that requires control within noted occupational risk level is preparation of the workplace (placing machines and devices, stretching the hoses) what can result in the fall, stumble on structure. It requires not only maintaining proper concentration of the workers attention, but there is needed a mapping routes for vehicles.

5. Summary and conclusion

In the result of the occupational risk assessment presented in Table 5 corrective and preventive actions have been proposed as follow:

- using hearing protectors,
- maintaining proper concentration of attention,
- keeping attention,
- mapping routes for vehicles,
- being cautious, using available technical means,
- proper preparation of the workplace,
- current removal of production waste,
- knowledge of the rules of safe work, appropriate on-the job training,
- maintaining attention, selecting appropriate tools,
- being attentive, using protective measures,
- maintaining order in the workplace, ongoing waste disposal.

Applying proper individual protection equipment and appropriate job training at the analysed work position has significant on the final product quality level. Preparation of metal for painting begins with the verification and assessment of the condition of a given structure, which determines further steps taken to adequately protect the elements. The entire protection process consists of a number of activities and they depend on the required effect and the time for which the structure will be protected and under what conditions it will work. Abrasive blasting to the required cleanliness class, i.e. cleaning the sur-face with a strong, directed air stream containing solid particles, e.g. copper slag, requires appropriate preparation. As a result, all loose dirt and the old paint coating are removed from the metal extremely effectively.

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