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Research paper

Estimation of occupational safety risks at energetic sector of Iron and Steel Works

Volodymyr Kukhar [1]*, Nelly Yelistratova [2], Vadym Burko [3], Yulia Nizhelska [4], Olga Aksionova [5]

[1] *Department of Metalforming, Pryazovskyi State Technical University, Mariupol, Ukraine*
[2] *Department of Occupational Safety and Environmental Engineering, Pryazovskyi State Technical University, Mariupol, Ukraine*
[3] *Department of Occupational Safety and Environmental Engineering, Pryazovskyi State Technical University, Mariupol, Ukraine*
[4] *Department of Occupational Safety and Environmental Engineering, Pryazovskyi State Technical University, Mariupol, Ukraine*
[5] *Department of Occupational Safety and Environmental Engineering, Pryazovskyi State Technical University, Mariupol, Ukraine*
**Corresponding author E-mail: kvv.mariupol@gmail.com*

Abstract

Modern methods of estimation of working conditions at the metallurgical enterprise are considered on the occupational safety due to European standards. The main approaches are identified in determination of hazards at work, assessing of technological risks and injuries as an example for one of the Iron and Steel Works, Mariupol, Ukraine. The purpose of this work is to analyze the effectiveness of the introduction of international methods in the field of health safety, assess the effectiveness of the safety management system at an industrial enterprise. The analysis of the process of implementing European standards in the field of the health safety at industrial enterprises is a prerequisite for their further successful application, reducing the level of injuries. The procedures for drawing up the matrix of risk assessment (HAZID method), assessment of working capacity of technological processes (HAZOP method), and safety assessment of works (ISA method) are considered. The analysis of the efficiency of measures to increase of health safety in the energy (gas) sector at the enterprise was carried out. A graph of the dynamics of the decline in industrial injuries in five years is shown. The main statistical indicators that are used to account for industrial injuries at an industrial enterprise are given.

Keywords: *Industrial Injuries; Occupational Safety Studies; Technology Risk Assessment; Accident; International Standards.*

1. Introduction

Industrial enterprises of Ukraine, which adopt the European vector of development, set themselves the task of increasing the effectiveness of the Occupational Safety Management System and Health Safety. Effective schemes to improve the occupational safety are fulfilled through the implementation of an Occupational Health and Safety Assessment Series OHSAS 18000, which combines two standards [1, 2]: OHSAS 18001:2007 "Occupational Health and Safety Management System. Requirements", and OHSAS 18002:2008 "Occupational health and safety management systems. Guidelines for the implementation of OHSAS 18001:2007". The strategy is to improve the occupational safety, reduce injuries and professional diseases of workers, achieved by the introduction of European Union directives [3 – 8] and international standards [9 – 12], as well as approaches based on the best domestic practices [13 – 16]. The process is established by regulatory documents in the field of risk management, containing methodological recommendations on the procedure of risk analysis on the workplace. There rules for attesting workplaces for the working conditions, identifying sources of danger, qualitative and quantitative risk assessment, criteria for their acceptable level are in this list.

The analysis of the process of European standards implementation in the field of occupational safety at the enterprises of Ukraine is necessary for their further successful application, reducing the level of industrial injuries.

Modern scientific and methodological approaches of the managing risks in the system of occupational safety include the following stages: identification of technological problems and problem situations; identification the sources of risks in the field of occupational safety; development of options for eliminating risks or bringing them to the acceptable value; optimal solution of the problem by the criteria of effectiveness, optimality, efficiency [2, 5, 8 – 11]. This methodology corresponds to the order of risk assessment, and the practical approach is based on the international standards ISO 31000:2015 “Risk management – A practical guide for SMEs” (Figure 1) and ISO 31000:2009 “Risk management – Principles and guidelines”.

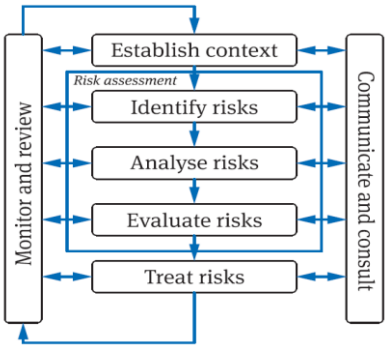


Fig. 1: The ISO 31000:2009 risk management process

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The designation of its harmonized normative standard is ISO 73.2003. The document defines the main terms and concepts in the field of occupational safety.

The principles of the industrial risks are covered in the standard IEC 61882:2016 "Hazard and operability studies (HAZOP studies) – Application guide", with outlining practical recommendations for assessment and accounting using the HAZOP (Hazard Operability) methodology. It contains a procedure of describing the potential hazards of technological systems, as well as their operability and the causes of operational violations. The document has been widely applied and regulates the key stages of quantitative and qualitative risk according to the international methods HAZID (Hazard Identification), determining the scenarios for their development Bow-Tie (Bow-Tie Model), methods for regulating the safe work JSA (Job Safety Analysis), and also identification of the industry impact on the environment using the method ENVID (Environment Impact Identification).

At the present, the HAZID method is used at the stages of design development, planning of various types of industrial activities and reporting procedures of Occupational Safety (OS), Industrial Safety (IS), Environmental Protection (EP); in preparation of a particular type of works [2, 3, 6, 7, 14]. An important advantage of this method is its ability to establish and demonstrate the link between the risks of OS, IS, EP, and risk management activities. Which determine through the analysis of the hazards and risks, based on the description of the process, the process flow diagram, the results of previous risk assessments, the risk register and accident investigation reports [1, 2, 10].

The JSA method – a work safety survey is used to assess and manage the risks of IS, EP, which occur when staffing and non-staff activities are performed to serious consequences [6 – 11]. Risk assessment is an ongoing and systematic process, carried out in stages, taking into account previously identified hazards. Thus, a unified approach at the enterprises is formed to increase occupational safety on the workplaces and determine environmental damage [6 – 11, 14 – 16].

At the same time, there assess of the state and operating modes of the equipment [17 – 19], of the stress-strain state of the treated workpieces [20 – 23] to exclude their destruction and injuries to people is necessary to estimation of the personnel safety at the working conditions in production workshops. Risk assessment methods have been implemented in different countries and in different industries [24 – 32]. However, for the conditions of the metallurgical enterprises of Ukraine, the reduction of occupational injuries requires the introduction of organizational and technical measures, the improvement of the methodology for risk assessment and has not been sufficiently studied to date.

The purpose of this work is to analyze the effectiveness of the introduction international methods of risk estimation in the field of occupational safety, the potency of the safety and health management system, using the example of the of the PJSC "AZOVSTAL" Iron and Steel Works (Mariupol, Ukraine).

2. Methodology

At the present day, several methods of assessing work conditions at workplaces and procedures for determining industrial risks are used at the industrial enterprises of Ukraine. They are divided into: expert methods for auditing the risks of the industrial process; methods with application of risk scenarios analysis and conclusions of industry experts; methods of statistical analysis of accidents or diseases. The first of them received practical use only in recent years.

Thus, the METINVEST Group (a vertically integrated group of steel and mining companies, including the PJSC "AZOVSTAL" Iron and Steel Works) since 2012 has embarked on the implementation of a technological risk management system, developing "Normative and methodological recommendations for identifying of hazards and assessing of production risks in the field of health safety engineering, occupational safety and environmental engineering". This document is based on four international methods: HAZID – Hazard Identification of Occupational Safety; HAZOP – Hazard and Operability Study; ENVID – Environmental Impact Identification; JSA – A Job Safety Analysis. To carry out the procedure for assessing industrial risks was created a working group (WG) of internal experts – specialists in in the field of health safety engineering, occupational safety and environmental engineering with the participation of industrial managers, engineers of technology, and specialists of technique service.

When working according to the HAZID method, experts divide the technological processes or objects into elements and analyze all inherent dangerous and harmful factors. In this regard a "List of specific hazards" was compiled with the assignment of an individual number to each technological element. For example, the area of hazards in the energetic sector includes the entire range of explosive and fire hazardous and poisonous substances: hydrocarbons (H-01), refined hydrocarbons (H-02), other flammable materials (H-03), explosives (H-04), sources hazards that can cause suffocation (H-18), toxic gases and liquids. The list includes objects using: increased pressure, equipment under induced stress, hot surfaces and liquids, refrigerants. Ergonomic hazards are also taken into account (H 05-020).

At the second stage, with the help of the "Risk assessment Matrix of health safety engineering, occupational safety and environmental engineering" (Table 1 and Table 2), for each element, the "Current Risk Level" is established for the three-tier system. The first level of industrial risk is indicated by the color: high – "red", medium – "yellow", low – "green". The second level is a numerical value (from 1 to 5), depending on the severity of the actual or potential consequences. The third level is the score in points (from 1 to 5), determined by the probability of occurrence of the predicted consequences. At its values of less than 5%, the level is one point, with more than 60% – five ones.

The matrix includes analysis by sections: "Humans", "Environment", "Assets", "Reputation". After evaluations are completed, a HAZID table is created for a specific area of the workshop or equipment, for each hazardous or harmful factor in the workplace. At the same time, the forecast of possible ways of development of a dangerous event under the scheme "Danger" – "Events" – "Consequences" is carried out. The analysis is supplemented with the list of "Existing measures" – organizational and technical measures of health safety engineering and occupational safety at this stage. In conclusion, the working group (WG), based on the principles of the ALARP ("As Low As Reasonably Possible") methodology defines measures to reduce the risks of medium and high levels, to an acceptable level, calculates the "residual risk level", establishes the "Responsible parties" of executors and the "Terms of Work Realization".

3. Results and discussion

An example of practical implementation of the methods in question is the "Gas Safety Program". As events, an audit of technological risks was carried out in workplaces with the gas-consuming and gas-producing units, as well as gas pipelines, gas control points and installations. As a result, a list of gas-hazardous jobs and places where gas is available is compiled. This allowed to increase the safety of work in hard-to-reach places, in particular, such as wells of engineering communications. At the same time, normative and technical instructions (based on JSA standards) have been compiled, and changes have been added to the instructions of occupational safety. There are the rules of the mandatory use of personal gas analyzers, provisions for emergency response training, the periodicity of updating personal protective equipment in gas hazardous areas. The realization of the program allowed reducing the number of accidents in the main industry by 30%, in contracting organizations – by 60%. The dynamics of the relative indicators of injuries (injuries ratio) of PJSC "AZOVSTAL" Iron and Steel Works is presented in Figure 2.

Table 1: The basic matrix of the assessment of occupational risks at PJSC "AZOVSTAL" Iron and Steel Works (Part 1)

Risk assessment matrix of occupational safety				Severity of consequences, points/ points
The severity of consequences (actual or potential)				
"Humans"	**"Environmental"**	**"Assets"**	**"Reputation"**	
Death of several humans (group deaths)	Critical over-standard impact on environmental elements. Exceeding the established standards more than 50 times, or the impact, but the standards for the source of impact are not established	Damage, as a result industrial activity or project activity stops for a month or more. Financial costs – more than 100 million UAH	Irreparable damage to reputation, which leads to significant financial and other losses. A long negative PR company at the national and international level	**5**
Death of one person (death). Steady full or partial loss of ability to work of several humans. Professional diseases of several people	Significant over-standard impact on environmental elements. Exceeding the established standards from 15 to 50 times	Damage, as a result industrial activity or project activity stops for a week or more. Financial costs – from 10 to 100 million UAH	A hard-to-recover damage to reputation. Financial and other loses. Negative PR company at the national level and non-long term company at the international level	**4**
Steady full or partial loss of ability to work of one person. Temporary loss of ability (hospital list) to work of several humans. Professional disease of one person	The average of over-standard impact on environmental elements. Exceeding the established standards from 5 to 15 times	Damage, as a result industrial activity or project activity stops for a month or more. Financial costs – from 1 to10 million UAH	Significant damage to reputation. It takes several months to restore the reputation. A negative article in the local and national press	**3**
Temporary loss of ability (hospital list) to work of one person	Low level of over-standard impact on environmental elements. Exceeding the established standards from 2 to 5 times	Damage, as a result industrial activity or project activity stops for a one day or several hours. Financial costs – do not exceed 1 million UAH	Short-term repairable damage to reputation. Negative article in the local press	**2**
Cases without temporary loss of ability to work. Cases of first aid, interventions without hospital list. Cases of temporary transfer to the easy job	Minimal level of over-standard impact on environmental elements. Exceeding the established standards more than 2 times	Damage as a result industrial activity or project activity do not stops. Financial costs are absent or within limit of current budgets	Insignificant impact on the reputation. Negative mention in the local press	**1**

Table 2: The basic matrix of the assessment of occupational risks at PJSC "AZOVSTAL" Iron and Steel Works (Part 2)

Severity of consequences, points/ points	Probability of consequences, %				
	≤5, Very low, most likely not happen	**5-20**, Low, it is unlikely to happen	**21-40**, The average, it is probably what will happen.	**41-60**, High, most likely happen	**≥60**, Very high
5	5-1	5-2	5-3	5-4	5-5
4	4-1	4-2	4-3	4-4	4-5
3	3-1	3-2	3-3	3-4	3-5
2	2-1	2-2	2-3	2-4	2-5
1	1-1	1-2	1-3	1-4	1-5
	1	**2**	**3**	**4**	**5**

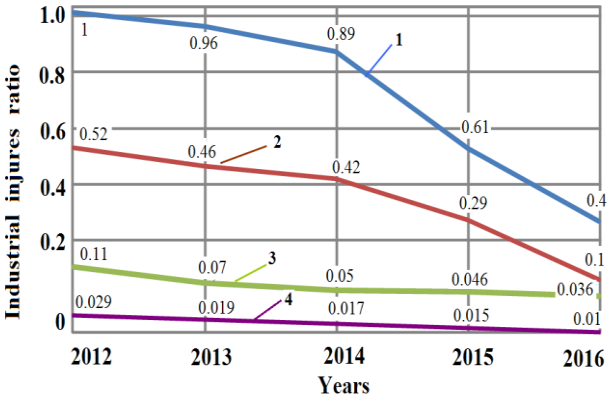


Fig. 2: Dynamics of relative indicators of the level injuries: 1 – Lost Time Injury Frequency Ratio (LTIFR); 2 – Industrial Injures Ratio (IIR); 3 – Fatal-Injury Frequency Ratio (FIFR); 4 – Industrial Death Ratio (IDR)

Sources of occupational risks are including: thermal electric furnaces (3 units), thermal gas furnaces (3 units), shaft furnace, quench tanks, blowing fan, and mechanical equipment. For example, for dangerous index "blast furnace gas – coke oven gas" the current risk level is "red" or 5-4 in points. The introduction of an automatic burner ignition system, the overhaul of exhaust ventilation from furnaces, the installation of safety valves on all ovens with a response to the drop in gas pressure and the flame attenuation on the burners, and the installation of a stationary gas analyzer is allowed to decrease a residual risk to "yellow" level, 5-2 in points.

The calculation of risk index connected with the identified hazard [5, 7, 30] is carried out as:

$$P = \frac{T[(\Pi + BP)]}{2}, \quad (1)$$

where P – industrial risk index; T – severity of consequences; Π – probability of hazard manifestation; BP – frequency of occurrence of a dangerous event.

The frequency of a possible manifestation of a dangerous factor is established on the basis of expert opinions of the working group (WG). Value of BP varies from 1 to 3, which corresponds to the minimum (once a year or less) and to the maximum risk index (daily). For the basic level the values (P) in 2012 – 2013 are adopted. A retrospective analysis of the dynamics of the main risk indices in the shop of rail fastenings is presented in the Table 3.

Researches have shown that technical and organizational measures for health safety engineering and occupational safety for the time from 2012 to 2016 allowed to reduce the level of the total risks index from 121 to 74 points (Figure 3).

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Table 3: The calculation of the risk indices in rail fastenings shop

Risk factor	Risk index, P, points				
	Years				
	2012	2013	2014	2015	2016
Blast-furnace gas	18	18	8	8	8
Open fire	6	6	6	3	3
Infrared radiation	12	12	11	11	11
Asbestos, Cement dust, Sodium salt	9	9	9	3	3
Pendant equipment	9	9	6	6	6
Hot surfaces with t ≥150ºC	4	4	4	4	4
Hot liquids, oil with t ≥900ºC	13	13	10	10	10
Loading equipment	6	6	5	5	5
Heat stress	12	12	12	9	9
Gas furnace No.2	20	20	8	8	8
Exhaust ventilation from furnaces	10	10	10	6	6
Condition of equipment insulation	2	2	1	1	1
The total risk, P_{total}	121	121	90	74	74

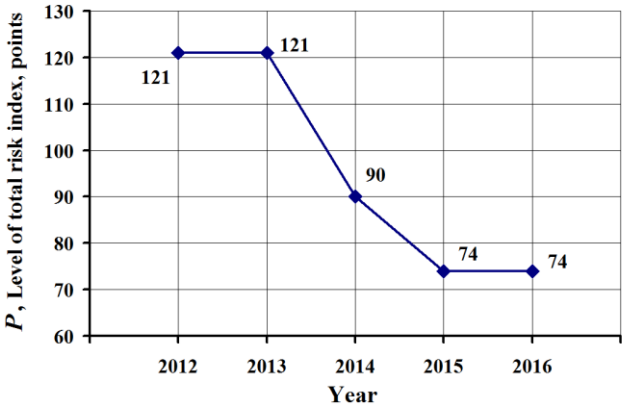


Fig. 3: Dynamics of the total risk index at the rail fastenings shop of PJSC "AZOVSTAL" Iron and Steel Works

Thus, the level of total risk index is reduced by 61%. The residual total risk index is characterized as "substantial and requiring the necessary improvements".

4. Conclusion

It is shown that the introduction of international methods of risks prevention in accordance to the standards for the audit of production risks such as HAZID, HAZOP, JSA, etc. is an effective way to increase the potency of the management system in the field of health safety engineering and occupational safety. A matrix of risk assessment in the field of health safety engineering, occupational safety and environmental engineering was developed and tested using the example of the PJSC "AZOVSTAL" Iron and Steel Works. The new methodology allows assessing of occupational safety risks at the current World level, using international indices. The efficiency of the new risk prevention methodology is confirmed by a 30-60% reduction in injuries ratios that approved in the European Union. Technical and organizational measures to reduce of production risks in the energetic sector of the enterprise's rail fasteners shop allowed to decrease the level of residual total risk by 61% to an "acceptable level" (74 points).

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