Scientific Journal of the Military University of Land Forces
ISSN: 2544-7122 - print, 2545-0719 - online
2018, Volume 50, Number 3(189), Pages 244-252
DOI: 10.5604/01.3001.0012.6241

Original article

Hazards in the production process, characteristics and methods of risk elimination

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INFORMATIONS

Article history:

Submited: 21 February 2018

Accepted: 14 June 2018

Published: 30 September 2018

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ABSTRACT

This article presents the main hazards in the production process on the basis of selected enterprises. Those hazards are mainly related to the safety of workers. The second element of the analysis is the way of elimination of risk factors. The method of risk elimination in each enterprise has been shown, with particular emphasis on the most effective ways of removing threats. The comparative analysis was applied for research purposes.

KEYWORDS

safety, threat, production process, production continuity, risk elimination

Introduction

A manufacturing enterprise is a highly complex system supported by advanced technology. The activities of manufacturing companies are variable and difficult to predict. The engagement of many people is necessary in order to control all the processes in a company. However, manufacturing companies pay the greatest attention to the production process [Krzyzanowski 2011]. All strengths and all the attention are focused on it. Production adds value to a company and it is mainly through this that an organization has an opportunity to exist and to grow.

Not only is the metalworking industry one of the fastest growing sectors of the national economy, but it also faces a significant threat to the manufacturing process. The creation of new entities and workplaces are closely related to the development of this sector of industry.

According to the Polish Language Dictionary, a threat as 'a situation that is hazardous to life or health' [Dunaj 2001, p. 607]. On the other hand, the Polish Standard defines a threat as 'a factor whose influence on a working person leads or may lead to injury' [PN-Z-08052:1980]. The risks associated with the manufacturing process in the metalworking industry relate not only to the health and safety sector, but also to direct fi-

nancial losses and the impairment of company's prestige and reputation. The place of formation of hazards does not necessarily refer to the workplace itself. Risks can also occur in places where no one is working and may be associated with the company's external environment. By dividing threats into the outer and inner, we get the following result [Karczewski and Karczewska 2012]:

External threats:

- severe power failure (no electricity, water, Internet – in the long run),
- natural disasters (flood, fire, earthquake, hurricane, tornado, heavy snowfall, extreme heat or frost in the long term, environmental contamination) [Karczewski and Karczewska 2012],
- economic risks (loss of markets, blockade and economic discrimination, economic crisis, financial speculation, soaring unemployment) [Ciekanowski 2010].

Internal threats:

- failure of machines and equipment,
- employees' errors,
- misuse of machinery and equipment,
- non-compliance with health and safety, also fire safety, provisions as well as the company regulations,
- loss of data and information.

It can be boldly hypothesized that all the major actions take place inside the production process. That is why it is so crucial to get acquainted with existing threats and methods of their elimination as well. The hazards of the metalworking industry in the manufacturing sector, referring to the safety of workers, concern the whole spectrum of side effects, which begin with mild wounds or cuts, and end up with serious injuries to the upper and lower limbs and even death.

1. Hazard characterization

Proper organization management should start with the process of identification and characterization of hazards. Appropriate management of knowledge about existing threats results in improved economic efficiency by suitable controlling of possible losses. The simplest measurability of threats to a company is represented by the potential amount of losses and the probability of an event occurrence. Nowadays, enterprises take into account environmental factors and additional profit [Karczewski and Karczewska 2012].

The production process in the metal industry is based primarily on the metal treatment and manufacturing of a product, whose main operations are:

- cutting,
- bending,
- milling,
- turning,

– drilling,
– reaming,
– pulling and pushing,
– planing and chiseling,
– grinding,
– polishing,
– welding.

All machines and equipment available at work must be certified for safety to be used. Any machine or equipment purchased after 2006 has the CE Declaration of Conformity and a manufacturer's declaration of the machine's conformity with European Union directives and PN-EN standards. Machinery and equipment purchased before 2006 were certified with 'B' Safety Mark. All products that corresponded to the Regulation of the Council of Ministers and became accredited by the Polish Center for Accreditation were subject to such marking. Machinery and equipment that do not have any safety certificate are not allowed for operation [Mac and Leowski 1998, p. 102; Certyfikacja… n.d.; Czym jest… n.d.]. Taking into account the certification of modern machinery and equipment in terms of safety, working with such products should be 100% safe. However, despite significant improvements in the safety of machinery and equipment already in their design phase, hazards still has not been removed. Accidents at work during machine operation have dropped by more than 10% over the past two decades [Wypadki… 2016; Mac and Leowski 1998, p. 102; Typowe zagrozenia…n.d.]. Rigorous guidelines for the manufacture of machinery and equipment are conducive to the safety of workers. However, most accidents related to the work of machines and equipment concern an error on the part of an employee. On the basis of the interview with safety officers, the most common misconducts include:

– inappropriate behavior of an employee during working time,
– an employee's unlawful behavior during working time,
– failure to follow safety instructions,
– improper use of tools,
– misuse of tools,
– unauthorized repair of defects in equipment,
– removal of safety guards,
– improper movement of the limbs in the hazard zone [Wrzesinska 2012, pp. 569-581],
– distraction of an employee and scarcity of focus on work.

Metal industry workers are often exposed to particularly hazardous jobs. The welding of metal parts causes the greatest risk. A worker is exposed to welding fumes, ionizing, visible, ultraviolet and infrared radiations, and to the electromagnetic field as well. Apart from the aforementioned factors, an employee is also exposed to non-natural body postures and the possibility of electric shock and noise. The welder's work is dangerous in so far as even by using appropriate general and local ventilation with appropriate work clothing and personal protective equipment, operating under such condi-

tions can lead to conjunctivitis, cataracts, blindness, various types of burns, pneumoconiosis, skin cancer and spinal injuries [Raczkowski 2005, p. 443-467; Zagrozenia… 2011].

Other hazards appear directly when working with a machine or device; for example an item of clothing caught by moving parts such as drills. The greatest danger when operating a drill is the absence of a transmission belt guard that transfers the drive from an electric motor to a spindle. Another threat concerns working with a lathe. Flying chips and waste cause the most common injuries. Therefore, in addition to the guards, lathe operators should also be equipped with safety goggles. Just as with a drill, the swirling parts of the lathe can also draw in a hand and consequently severely harm an operator. Similarly, hazards occur when working with a milling machine. Not only may a suitable transparent router guard improve worker's safety but also the performance of a machine and its tools. When working with a grinder the greatest hazard comes from a grinding wheel that can be damaged or broken and thus maim a worker. Grinders are equipped with safety guards. Incorrect servicing of a grinder can lead to pulling employee's hands in and cause very serious injuries [Mac and Leowski 1998]. Various types of metal saw also create the danger of pulling in clothing items as well as pulling, catching and injuries to limbs as a result of direct contact with the moving saw [Typowe zagrozenia…n.d.]. A similar situation applies to metal presses and metal benders. Catching an item of clothes can also result in serious injuries. It is enough to inappropriately place employee's limbs in a machine danger zone, and the consequences of such an event can be severe and irreversible for an operator's health.

In addition to risks directly related to work, production processes are also affected by external threats. A very important factor for companies exporting the essential part of their production is the economic situation of a given country [Zolenski 2012] with which the exchange rate is linked. Another significant threat to the manufacturing process and thus to the functioning of the whole enterprise may be the imposition of a ban on imports or exports of certain goods from or to the country concerned [Embargo… 2007]. In present times, a longer power failure may not only cause product downtime but also irreparably damage the machine. The long-term power supply failure may result in damage to machines and equipment and block all manufacturing operations. Furthermore, the unexpected power shutdown may also cause the damage the to control units of machines as well as other production data necessary for the autonomous operation of the machine.

2. Hazard identification based on selected enterprises

Manufacturing companies operating within the metalworking industry should pay attention to the same risks and hazards and eliminate them in a similar way. The aim of this article is a comparative analysis of production enterprises with similar business specificity, in terms of existing hazards and ways of their elimination.

The NR1 Company was established in 1983. It manufactures metal parts and possesses its own galvanizing plant. Currently it employs 81 people. Over the past six years, the

company has suffered from serious work-related accidents and the death of one employee. Light injuries only in the last twelve months amounted to 17.

The NR2 Company was established in 2001. Its main activity is based on the production of specialized steel structures and other metal components. At present 38 workers are employed by the Company. From the beginning of its operations, the Company did not report serious accidents at work. The number of minor injuries in the past twelve months was 7.

The NR3 Company was established in 1997. Its core business is metal parts processing and the production of pallets and steel frames. The Company has its own powder coating plant. It employs 70 people. Over the past six years, there have been 3 serious accidents at work and 37 minor injuries.

Table 1. Basic statistic data on Companies NR1, NR2 and NR3

	Company		
	NR1	**NR2**	**NR3**
Employment [workplaces]	81	38	70
Type of hazard	internal	external	internal
Average age of employees	35	38	34
Type and quantity of machinery	– 3 numerically controlled production lines, – 4 × eccentric presses with a tonnage of 20 tons, – 4 × universal lathes, – 6 × cutting machines, – 3 × welding machines, – 6 × benders, – 6 × bench drilling machines and many other machines and auxiliaries for steel processing	– 3 × universal lathes, – 1 × CNC miller, – 2 × hydraulic press, – 2 × benders, – 2 × CNC cutting machines, – 4 × bench drilling machines, – 4 × grinders, – 10 × maintenance-free automatic welders, – 12 × MIG welders, – 4 × TIG welders, and other machines and auxiliaries	– 1 × CNC lathe, – 4 × universal lathes, – 2 × press brakes, – 1 × plasma plotter, – 1 × mandrel bender, – 2 × three roll benders, – 2 × hydraulic press, – 1 × guillotine, – 8 × MIG welders, – 2 × TIG welders, – 5 × bench drilling machines, – 2 × eccentric press and other machines and auxiliaries
Number of serious accidents at work [72 months]	6	no	3
Number of minor accidents at work [72 months]	73	5	37
Days of work unfitness [72 months]	3200	450	1600
Material losses	PLN 2,500,000.00	PLN 300,000.00	PLN 1,100,000.00
Number of diagnosed occupational diseases	no	no	no

Source: [Own study].

The data on the employees' unfitness for work referenced in Table 1 refer to the total sick leaves submitted by employees in relation to accidents at work. Not every injury or minor injury was related to the absence of an employee at work. On the other hand, a serious accident at work was associated with absence from work from 31 to 180 days. An employee's inability to work due to health detriments gives rise to costs. In the first place, the costs of sick leave and the costs of potential rehabilitation and compensation services must be paid. Another element is the employment of a casual worker as a substitute for a sufferer (depending on the duration of incapacity for work). There may be additional costs involved in repairing a machine or goods. The top management boards of the Companies in question presented the values relating to material losses. The article does not show the exact values associated with the costs of improving health and safety conditions.

In the case of the first NR1 Company, accidents at work are notorious. These are serious accidents, with severe detriments to the employee's health. In one case a person died. All accidents at work were related to the use of old machines with the years of manufacture between 1920 and 1960. Despite many serious accidents at work, the enterprise does not invest in new machines. The losses suffered by the Company as a result of these activities are set at PLN 2,500,000.00. The Company introduced additional safety guards and acoustic sensors at the scene of the incident. Despite additional security measures implemented, hazards are still present.

The NR2 Company, despite a similar production process to the NR1 Company, does not have such a high accident rate. Over the past six years, only 5 minor injuries have occurred on the site. The cause of this state of affairs is undoubtedly a new machine park and properly trained staff. In order to eliminate possible risks, NR2 continues to invest in state-of-the-art technology, machinery and equipment. The biggest threat to the functioning of the company is external factors – currency fluctuations, as the total production is exported to the West. The biggest problem for NR2 is the lack of local customers.

In the NR3 Company three serious work-related accidents have occurred which have left a lasting detriment to workers' health. Those accidents were caused solely by the inattention and incompetence of employees. The Company has a new machine park. Machinery and equipment are provided with all necessary guards and security devices. After the events and the convalescence, the staff changed work stands. The greatest threat to the workers is the lack of a suitable place to operate. Machines are closely spaced and most cuts occur when workers pass them and move various metal pieces from one end of the production hall to the other. The losses are currently valued at PLN 1,100,000.00. The Company has been seeking for the plant extension for three years in order to ensure a decent workplace, but the investment is still blocked by the Company's competition. The present state is directly reflected in the manufacturing process, which is constantly interrupted by the transport of the material to be processed in and out. Due to insufficient space, employees are constantly on the go, moving between machines and devices, which also increases the risk occurrence. The blockage of the production hall expansion can lead to a complete closure of the Company.

Conclusion

Each of the aforementioned Companies suffered the greatest losses through the workers' inability for work. It is not just about the costs of paying compensations and sickness allowances, but above all about the lack of a person at work and a substitute organized for the time of treatment. Every new employee in the workplace must be given enough time to learn new things. Preparing an employee for a new job involves a temporary downtime with initial production of incomplete items.

Despite the similar production characteristics of each Company, the threat to the manufacturing process concerns another element. For the NR1 Company, the primary threat is old machines and lack of willingness and resources to replace them. The NR2 Company determines the threat in the production process as the withdrawal of foreign contractors and the unfavorable exchange rate. On the other hand, the main threat to the last Company is the inability to expand the existing plant, which directly affects the continuity of the manufacturing process.

The analysis carried out shows that new machine parks and modern technological solutions influence the safety of work and continuity of the production process to the greatest extent. Not every enterprise can afford to exchange all machines and equipment for new ones. The best solution is to gradually replace the old machinery and equipment with new ones. It is a costly investment, but provides immediate safety improvements and, above all, the continuity of production. The losses that were estimated in the abovementioned Companies by accidents at work would undoubtedly refund the purchase of at least some of the most important machines or equipment. Regeneration of old machines, by introducing additional protections that do not guarantee significant safety improvements, is only a temporary solution – extremely expensive.

Acknowledgement

No acknowledgement and potential founding was reported by the authors.

Conflict of interests

The author declared no conflict of interests.

Author contributions

All authors contributed to the interpretation of results and writing of the paper. All authors read and approved the final manuscript.

Ethical statement

The research complies with all national and international ethical requirements.

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How to cite this paper

Kulinska, E. and Dendera-Gruszka, M. (2018). Hazards in the production process, characteristics and methods of risk elimination. *Scientific Journal of the Military University of Land Forces*, vol. 50, no. 3(189), pp. 244-252, http://dx.doi.org/10.5604/01.3001.0012.6241