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Hazard analysis and risk assessment in metal cutting process

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INTRODUCTION

Occupational health and safety since 2019 has been covered by standard STN ISO 45001 Occupational health and safety management systems. Requirements with guidance for use. This document specifies the Occupational health and safety (OSH) management systems requirements and provides guidance on their use to enable organizations to provide safe and healthy workplaces to prevent work-related accidents and health deterioration, as well as to proactively improve the performance of their OSH.

Among other changes, the updated version puts more emphasis on risk identification, risk management and action. Under the heading 'Risk and Opportunity Management', manufacturing organizations are required to identify, consider and, if necessary, take steps to address risks and opportunities that may have (positive or negative) impacts on the OSH management system and the achievement of planned results, including increased health protection and occupational safety (Sinay, 2011; Tuker and Bagal, 2018). The purpose of the standard is to make it easier for organizations to manage OSH risks and improve their own OSH performance by preventing injuries and occupational diseases.

The risk management process is the systematic application of management policy, procedures and experience to communication, consultation, contextualization and identification, analysis, evaluation, treatment, monitoring and review of risk (Bujna et al., 2017; Sujová and Čierna, 2018). Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. Risk identification is the process of identifying, identifying and describing risk. Risk analysis is a process containing the nature of the risk and determining the level of risk. Risk evaluation is the process of comparing the results of a risk analysis with risk criteria to determine whether the risk and its magnitude are acceptable or tolerable. Risk can be defined as the effect of uncertainty of intentions (Korenko et al., 2015; STN ISO 31000: 2019).

In general, risk assessment and evaluation refers to the “architecture” (principles, system and processes) of effective risk management. At the same time, risk

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management focuses on the practical use of this architecture for a particular risk. And ISO 31000: 2019 provides the rules that must be followed for risk management to be effective. The standard recommends develop, implement and continuously improve our risk management system. This means that the standard describes the principles, system, process and general guidance on risk management.
The term "machine safety" refers to the ability of a machine to perform its intended function during its life, while reducing the risk accordingly. The most important step in reducing risk is to design a solution to prevent or reduce the risk. This can be achieved by a suitable machine design selection or the relationship of endangered persons and the machine. Applied protective measures constitute a machine characteristic and remain effective throughout the operation of the machine. Experience with the use of the machine shows that even a well-designed device may fail or endanger and that instructions for use may be missing (ISO 12100: 2010).
Metal saws are generally defined as metalworking machines in which the chips are removed by means of a saw circular blade, band or cutting blade. A metal band saw uses a saw blade formed by an endless steel band orbiting between two wheels - the drive and guide wheel. The basic requirement to ensure safety at work with the saw is set by §59 of the Decree. No. 59/1982 Coll., according to which all saws must have an easily adjustable support to support long cut material. And saw blades and circular saw blades must be enclosed in machine structure or have protective guards.
In accordance with other regulations to ensure safety when working with a metal saw, we must respect STN EN ISO 16093: 2017 Machine tools - Safety - Sawing machines for cold metal. This standard specifies the safety requirements and protective measures to be used in the design, manufacture and supply of machines. This standard considers the intended use, the logically foreseeable misuse, the setting up of the machine and the attachment of the cutting, maintenance and cleaning tool. It also assumes access to the machine from all sides, normal work, unexpected or unintended start-up and their impact on operator safety.
The aim of the paper is to determine the level of risk in working activities of employees in a production organization. To assess the risk, we chose to work on a hand-held band saw, which performs one of the basic operations in the machining of the bulk steel (steel profiles). When assessing the risk, we identify hazards, threats and propose safety measures.

MATERIAL AND METHODS

The risk assessment and evaluation was carried out in the production organization MetalTrade, s.r.o. Nitra. The manufacturing organization focuses on machining metal parts for the automotive industry. Operation of the production organization is equipped with modern CNC machining centres as well as machines for material cutting-off. Quality of production is ensured by reliable control instruments with appropriate certificates for measuring instruments, personnel and production process.
We have chosen the Ergonomic 290.250 GAC band saw as the object of our analysis. The machine is most often used in material cutting in production organization. The saw has a hydraulic lift of a vibration-resistant cast iron arm with a powerful industrial motor and a helical gearbox in the oil bath. It is equipped with precise carbide band guide, material feeder and hydraulic vise. Angle cuts up to 45° are possible in automatic mode, up to 60° in semi-automatic mode.

The band saw is shown in figure 1 and its technical data are as follows:
- motor power: 1.1/1.5 KW 400V/50 Hz,
- total installed capacity: 3.4 kVA,
- saw band speed: 40/80 m/min,
- saw band dimensions: 2910 x 27 x 0,9 mm,
- minimum cutting diameter: 5 mm,
- material loading height: 760 mm,
- machine dimensions: 1810 x 1790 x 1200 mm,
- weight: 575 kg.

Fig. 1 Bomar ergonomic 290.250 GAC band saw

We used an extended point method to analyse the risks that result from the manufacturing process and the environment in which the machine is located. For this method of risk assessment, we have chosen an extended risk definition where the risk rate (R) is the product of three parameters, the probability of occurrence of the event (P), the consequence of the event (D) and the impact of occupational safety and health (V). The categorization and risk assessment are presented in Tables 1 and 2

Table 1
Risk categories

Value	Probability categorization "P" - Estimates the possibility of an adverse event occurring.
1	Unlikely
2	Random
3	Probable
4	Very likely
5	Permanent
Value	Categorization of consequence “D” - expresses the severity of the occurrence of an adverse event.
1	Damage to health and work ability
2	Injury with incapacity to work
3	Serious injury requiring hospitalization
4	Severe occupational accident with permanent consequences
5	Fatal occupational accident
Value	Categorization of the impact of occupational health and safety level „V“ - takes into account the levels of management, time of exposure, qualification of employees, level of prevention, condition and age of technical equipment, impact of working environment, etc.
1	Negligible impact on the probability and consequences of injury
2	Low impact on the probability and consequences of injury
3	Significant influence
4	Significant, great influence
5	More significant impacts

Source: STN EN ISO 31 000:2019 Risk management.

Table 2
Evaluation of the risk rate „R“

Risk	Risk category	Point range	Safety assessment	Safety action need
Negligible	I.	1-4	Acceptable safety	No action required
Moderate	II.	5-10	Acceptable risk with increased attention	The system is classified as safe, improvement can be achieved, corrective action planned
Serious	III.	11-50	The risk cannot be accepted without protective measures	Security measures need to be taken
Undesirable	IV.	51-100	Inadequate safety, great possibility of accidents	Immediate corrective or short-term measures should be taken
Unacceptable	V.	101-125	Dangerous system, permanent threat of injury	Necessity of immediate stop of operation

Source: STN EN ISO 31 000:2019 Risk management.

RESULTS AND DISCUSSION

In assessing the level of risk, we first identified the possible hazards of the work itself. Subsequently, we defined the threat and described the causes that may cause the threat. After assessing the level of risk, we have proposed safety measures that need to be applied to the manufacturing organization. Table 3 shows the risk of work-related injury due to electric shock. Tables 4 to 6 indicate the danger of manual material handling, where the division into groups "A, B, C" is only from the perspective of the type of relevant threat. Tables 7 to 9 indicate the danger of manual handling of the cutting blade, where the difference is also only in the characteristic of the threat to the groups "A, B, C". Tables 10 and 11 show the coolant emulsion and the resulting danger as a cause of danger.

Table 3
Risk assessment - electric shock

Hazard: electric parts of machine	**P**	**D**	**V**	**R**
Threat: electric shock from machine parts	2	5	3	30
Risk category III. - serious				
Threat description: – contact of persons directly on the live parts of electrical equipment: ▪ uncovered or insufficiently covered parts, removed covers, insulation, ▪ failure to meet the required distances, e.g. out of reach placement ▪ incorrect placement of hazard warning signs, – contact of persons with inanimate parts, covers with voltage: ▪ damage to the enclosure insulation, ▪ due to internal failure and failure of the machine protection system, ▪ due to incorrect machine connection (driver interchange), ▪ operation of the device by a person not trained in OSH principles.				
Safety measures: – to divide electrical equipment in an organization into equipment to which only qualified staff and equipment where untrained persons have access, – to train persons without electrical qualifications to operate the machine, – to secure parts of the machine to which non-electrically qualified persons have access as specified in the relevant regulation. – to delegate repairs to personnel who are qualified for the type of repair, – to regularly carry out prescribed technical inspections and eliminate faults, – to mark dangerous parts or equipment according to applicable regulations, – to carry out the familiarization, training, and necessary training of persons who will be delegated to operate the machine to the specified extent.				

Table 4
Risk assessment – load handling A

Hazard: manual load handling	P	D	V	R
Threat: backbone injury	2	3	3	18
Risk category III. - serious				
Threat description: – injury of the backbone during repeating lifting and handling of loads in inappropriate position of the backbone: ▪ too heavy and too large, ▪ difficult to grab, ▪ unstable or tending to fall, ▪ at a long distance from the body, thereby shifting the center of gravity of the load towards the body, – the risk of spinal damage may occur if physical load is: ▪ repeating, ▪ reduced only on the certain backbone movement, ▪ executed in inappropriate way, – joint injuries due to uncoordinated movement of the body, long-term wear of joints, muscles, tendons and resulting chronic diseases (arthrosis, inflammation of the carpal tunnel).				
Safety measures: – complex training in heavy loads handling, – ensure that the employee masters the principle of movement when handling a heavy load, – observe the principles of safe and harmless handling, without bent back, – provide sufficient space for safe handling of the load, – ensure that the floor is firm and does not slip, – ensure that the band is stable and strong, – provide the operator with solid and non-slip shoes, – ensure that this work is not performed by an employee who is not 100% physically fit.				

Table 5
Risk assessment – load handling B

Hazard: manual load handling	P	D	V	R
Threat: load fall to the leg	2	1	3	6
Risk category II. – moderate				
Threat description: – Injury of the leg may occur if: ▪ the load is too heavy, ▪ the load is atypical in shape and its edges are too sharp, ▪ the load is carried and lifted at longer distances, ▪ the load is carried on an uneven surface, it is possible to trip over and then fall with the load.				
Safety measures: – when handling heavy loads that are above the carrying capacity, it is necessary to provide a means of transport for transporting the load with atypical shapes and dimensions, – ensure that floors in workshops, warehouses are flat and dry, – ensure that loads are handled at optimum height and distance, – provide employees with suitable steel toe shoes and non-slip sole.				

Table 6
Risk assessment – load handling C

Hazard: manual load handling	P	D	V	R
Threat: hands and fingers crushing and/or cutting	2	1	3	6
Risk category II. – moderate				
Threat description: – pressing the hand against the other load due to incorrect handling, – crushing your fingers when placing the load on the saw band, – cuts of hands, pricks, abrasions, – seizure of the metal chip when handling the cut piece.				
Safety measures: – when handling heavy loads that are above the carrying capacity, it is necessary to provide a means of transport for transporting the load with atypical shapes and dimensions, – to store loads in easily accessible areas where handling is easy; – to warn employees of the danger of slipping or crushing fingers when placing a load on the band; – to perform surface treatment if the semi-finished product is visibly damaged, – wear protective gloves resistant to mechanical wear.				

Table 7
Risk assessment – manual handling of cut sheet A

Hazard: manual handling of cut sheet	P	D	V	R
Threat: cutting on the sheet while handling in the saw work area	1	3	2	6
Risk category II. – moderate				
Threat description: – the employee can be cut if: ▪ worker violates safety regulations and is handling band or products during the sawing, ▪ puts his hands in the saw area during operation to clean chips, ▪ when checking the dimensions of the workpiece during sawing, the worker puts various things into the machine working area that may be caught by the cutting band and subsequently removed from the operator's hands.				
Safety measures: – machine operator must receive basic OSH training, – professional training and instruction of operators on the principles of work in machine operation, – clean, repair, tighten the saw band or otherwise interfere with the work area only after turning off the machine, – wear protective gloves that are resistant to mechanical wear.				

Table 8
Risk assessment – manual handling of cut sheet B

Hazard: manual handling of cut sheet	P	D	V	R
Threat: cut when changing saw band	1	3	2	6
Risk category II. – moderate				
Threat description: – cuts when changing saw bands can occur if: ▪ the employee violates safety principles when changing the cutting band, ▪ the employee is not adequately trained, it may happen that the band is put upside down, this can destroy the cutting band or otherwise damage himself and the machine.				
Safety measures: – machine operator must receive basic OSH training, – professional training and instruction of operators on the principles of work in machine operation, – wear protective gloves that are resistant to mechanical wear.				

Table 9
Risk assessment – manual handling of cut sheet C

Hazard: manual handling of cut sheet	P	D	V	R
Threat: cut when changing saw band	1	2	2	4
Risk category I. – negligible				
Threat description: – burning of the hand on the cutting band of the saw is unlikely, but there may be an error of unknown origin in the cooling system, causing the saw band not to cool and this causes the cutting band to overheat if the operator does not register burns, ▪ when the error is corrected by the employee's lack of attention, ▪ if the cooling tube close to the cutting band is obstructed.				
Safety measures: – wear protective gloves that are resistant to mechanical wear during any manipulation with the saw band – regular maintenance and inspection of all machine parts.				

Table 10
Risk assessment – cooling emulsion A

Hazard: cooling emulsion	P	D	V	R
Threat: the employee slipping on the emulsion when handling the workpiece	2	2	2	8
Risk category II. – moderate				
Threat description: – an employee can fall if: ▪ the machine is not maintained and regular service inspections are not carried out, ▪ the employee does not wear required footwear, ▪ workplace cleanliness is not observed.				
Safety measures: – emphasis should be placed on regular maintenance and servicing of the machine, – ensure employees are equipped with anti-slip shoes, – after every change of stuff, the area around the saw should be thoroughly wiped off with a cloth.				

Table 11
Risk assessment – cooling emulsion B

Hazard: cooling emulsion	P	D	V	R
Threat: cooling emulsion with eye contact	2	2	2	8
Risk category II. – moderate				
Threat description: – threat can occur when: ▪ the operator breaks the safety distance when operating the machine, ▪ the operator violates the principles of safety and health when operating the machine, ▪ the operator does not wear protective glasses or carries the emulsion into his eye by his negligence.				
Safety measures: – ensure that the operator wears safety glasses, – train the OSH operator on the machine properly.				

When assessing the hazard, we identified the risk as serious (Category III.) for two hazards. The highest risk is in case of electric shock, where the risk cannot be accepted without protective measures. We also identified a serious risk in manual material handling in spinal injuries. In both cases, appropriate precautions should also be taken. In other cases of hazard assessment, we have identified the risk as moderate (Category II.) and negligible (Category I.). In risk categories I.-II., safety is satisfactory and risk acceptable where improvement can be achieved by planning precaution with safety measures.

In addition to the threats mentioned above, other hazards may arise that have not been included in the risk assessment. Other hazards associated with the operation of a metal cutting saw include:

- impacts, contusions and other injuries to an employee near the material cutting;
- tripping, knocking over or catching on long material,
- injury from uncleaned chips, cuttings, etc.,
- skin and other infectious diseases in contact with poor quality cutting fluid,
- skin disease with constant intensive contact of liquid with unprotected skin.

The most common types of injuries when using the machine include open wounds, amputations, fractures, dislocations and contusions. In work injuries, the most commonly injured part of the body is the hand from the wrist down, especially the fingers. In addition, injuries to whole hand, head, eyes, body and back injuries are the most common for occupational diseases. In terms of occupational diseases, machine operators are most often affected by long-term, excessive and one-sided musculoskeletal stress, skin diseases, respiratory and lung diseases, and hearing

disorders. (Nováková et al., 2017; Piteľ et al., 2019).
When assessing the hazards in the production organization, we have identified the most common deficiencies in compliance with legal regulations to ensure occupational health and safety when using the saw. These shortcomings directly endangering the safety and health of the employee and can lead to harm to health:
- unauthorized operation of the saw,
- missing, inadequate or broken protective devices;
- use of incorrect, unsafe working procedures;
- improper maintenance of the saw;
- employees ignoring to use personal protective equipment.

These health risks can be prevented by a system of measures planned and implemented in all areas of the employer's activity. Precautions must be aimed at eliminating or reducing the risk and the factors causing the accident at work. Emphasis is put on adherence to the applicable safety regulations as part of an integrated management system in a production organization. It is a universal tool that combines several methodologies and procedures in the process of globalization of management processes. (Dziuba et al., 2016; Ingaldi et al., 2016)
When assessing safety at work, we did not assess the risks arising from transporting the saw to and inside the manufacturing organization. Regarding this threats, the machine may slip off the portable platform or fall (roll over) the saw itself. In case of incorrect positioning of the saw, the employee may be overwhelmed. We considered the saw placed in a suitable place and ideal working conditions. During its operation, all regulations concerning the location, position or setting of the saw according to the manufacturer's instructions are observed.
We did not assess the risk when handling the saw or parts of it that are not part of the employee's work activities. Delivery and assembly of the saw is provided by an external organization, which is obliged to observe the safety regulations for its correct setting. The transportation and arbitrary handling of the saw has been prohibited by the internal safety regulations of the production organization.

CONCLUSION

In business operation we encounter various influences that present some uncertainty regarding to whether and when we will achieve the goals and objectives of the production organization. The positive or negative effects of that these uncertainties resent risks. (Cyprich et al., 2017). We manage risks by identifying, analysing and assessing them. By assessing and categorizing the risk, we determine the level of occupational safety and, at the same time, the necessity to propose certain measures to reduce the risk to employee health.
In order to minimize risk, it is important to use methods of reduction that depend on the objective to be achieved. We have to realize that the results of the analysis have to create conditions for breaking the causal dependence of the occurrence of the negative phenomenon, i.e. eliminate or minimize risk. (Hnilica et al., 2017; Schwarz et al., 2015). The manufacturing organization shall monitor and review individual risks regularly to ensure that the proposed safety measures are effective.
In all cases of the proposed measures there is a progressive correction in the production organization. Emphasis was placed on training the employees in the use and operation of the band saw. Employees were also trained in proper working

procedure and saw operation. Other measures are continuously applied and effects of the risk reduction measures are checked by the authorized employee - the head of the plant. The Chief Operating Officer informed the operators of the results of the risk assessment, including the proposed and adopted measures.

The risk assessment may be applied at any time to the whole production organization, to various machines and equipment, production areas and levels, as well as to its specific functions, projects and activities. A coherent approach to risk management can help to ensure that risk is managed efficiently, effectively and in the whole production organization.

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REFEENCES

Bujna, M., Kotus, M., Čičo, P. (2017). Manažérstvo rizika. Nitra: SPU.

Cyprich, F., et al. (2017). Bezpečné používanie strojov. Košice: NIP.

Dziuba, S.T., Ingaldi, M., Kadlubek, M. (2016). Use of quality management tools for evaluation of the products quality in global economy. In: Globalization and its socio-economic consequences, Žilina: Žilinská univerzita, pp. 425-432.

Hnilica, R., Jankovský, M., Dado, M. Messingerová, V., Schwarz, M., Veverková, D. (2017). Use of the analytic hierarchy process for complex assessment of the work environment. Quality & Quantity, 51(1), pp. 93-101.

Ingaldi, M., Dziuba, S.T., Kadlubek, M. (2016). Integrated management systems as an element of globalization in production management. In: Globalization and its socio-economic consequences, Žilina: Žilinská univerzita, pp. 750-758.

Korenko, M., Bujna, M., Földešiová, D., Dostál, P., Kyselica, P. (2015). Risk analysis at work in manufacturing organization. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 63(5), pp. 1493-1497.

Nováková, R., Pauliková, A., Čekanová, K. (2017). Risk management as a part of a quality management system in woodworking companies. In: More wood, better management, increasing effectiveness: Starting points and perspective, Praha: ČZU, pp. 170-178.

Piteľ, J., Matisková, D., Marasová, D. (2019) A New Approach to Evaluation of the Material Cutting Using the Artificial Neural Networks. TEM Journal – Technology education management informatics, 8(2), pp. 325-332.

STN ISO 31000:2019. Risk management. Guidelines.

STN EN ISO 12100:2010. Safety of machinery. General principles for design. Risk assessment and risk reduction.

STN EN ISO 16093:2017. Machine tools - Safety - Sawing machines for cold metal.

Schwarz, M., Dado, M., Hnilica, R., Veverková, D. (2015). Environmental and Health Aspects of Metalworking Fluid Use. Polish journal of environmental studies. 24(1), pp. 37-45.

Sinay, J. (2011). Bezpečná technika, bezpečné pracoviská – atribúty prosperujúcej spoločnosti. Košice : TU.

Sujová, E., Čierna, H. (2018). Complex evaluation of safety culture determinants in manufacturing companies in Slovakia. Management systems in production enginnering, 26(3), pp. 184-188.

Tureková, I., Bagalová, T. (2018). Knowledge and Experiences of Safety and Health Occupation Risks among Students. International journal of engineering pedagogy, 8(5), pp. 108-120.

Abstract. The paper deals with the issue of occupational health and safety in a metalworking manufacturing organization. Hazard and threat have been defined when cutting metal materials with a band saw. We assessed the risk by an extended point method, where we determined the risk rate values. In most cases of sawmill work, we found a "moderate" or "negligible" risk. The highest, 'serious' risk we found in a possible electric shock. In this case, we have also taken the necessary actions. As a precaution, we have also proposed safety measures for other threats.

Keywords: safety, threat, risk rate, manufacturing plant, band saw