

ASSESSMENT OF TECHNICAL SAFETY OF EMPLOYEES DURING THE OPERATION OF THE LASER CUTTER

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Abstract: The operation of various types of machinery and equipment constituting a material work environment exposes employees to many different hazards (especially mechanical hazards). According to the Polish law, the basic duty of both machine manufacturers and employers is to limit the level of these hazards and to provide employees with broadly understood safety. The article presents the basic issues related to the technical safety of laser cutter operators on the example of a selected industrial plant. Technical and organizational solutions used to reduce the level of risk associated with the use of the selected machine were assessed.

Keywords: technical safety, safety of machinery and equipment use, occupational hazards, mechanical hazards, laser cutter operator

1. INTRODUCTION

Safety of exploitation of machines and devices is inseparably connected with compliance with safety requirements contained in European Union directives regarding the construction and use of machines as well as national regulations. The basic legal act regulating the introduction of minimum safety and health requirements in Europe is Framework Directive 89/391 / EEC. It was aimed at establishing a uniform level of safety and health protection and obliging employers to take appropriate measures to improve working conditions. Pursuant to the aforementioned legal regulation, the employer should prevent threats, assess threats and combat them at source, and treat health and safety at work as one of the elements of a holistic approach to company management (Directive 89/391/EEC).

Directive 2009/104 / EC and Directive 2006/42 / EC are important legal regulations at European level. These regulations differentiate machines into two categories: "*old machines*" and "*new machines*". The first group includes those machines that were placed on the market or put into service in the European Economic Area before May 1, 2004. Similarly, "*new machines*" are those put on the market for the first time or put into service in the EEA after May 1, 2004. "*Old machines*" must meet at least the minimum requirements of Directive 2009/104 / EC, while "*new machines*" must meet

the essential requirements of the Machinery Directive 2006/42 / EC (Directive 2006/42 / EC; Directive 2009/104/EC; Górny, et al., 2009).

Directive 2009/104 / EC sets out minimum safety and health requirements when employees use work equipment. According to this directive, the employer is obliged to implement the necessary measures to adapt work equipment to the proper performance of work and its safe operation, without harming the health and life of employees. Proper selection of work equipment should be preceded by an analysis by the employer of specific working conditions and possible hazards both at the specific workplace and any other hazards arising from the use of work equipment. In a situation where the use of work equipment may expose the employee to danger, the employer must take appropriate measures to minimize this risk. The employer, implementing the minimum requirements in this regard, should take into account the principles of ergonomics, positions taken by employees when using work equipment and the conditions of the workplace (Chinniah et al., 2017; Chinniah et al., 2019; Directive 2009/104/EC; Górny, et al., 2009; Mrugalska and Kawecka-Endler, 2012).

In Poland, one of the elementary legal acts is the Labor Code, which in art. 215 stipulates that the employer is obliged to ensure that the machinery and other technical devices used protect the employee against injuries, hazardous chemical substances, electric shock, excessive noise, mechanical vibrations and radiation as well as harmful and dangerous effects of other factors of the work environment), and also included ergonomic principles. Art. 217 of the Labor Code in art. stresses that all machinery and other technical devices should meet the requirements for conformity assessment as set out in separate regulations. This provision is the Act on the conformity assessment system (Journal of Laws of 2019, item 1040), which aims to eliminate threats from products to the life and health of users and consumers. Pursuant to this legal act, products placed on the market are subject to assessment of compliance with the essential requirements set out in the executive regulations to the Act and separate provisions.

On the other hand, § 51-61 of the Ordinance of the Minister of Labor and Social Policy of 26 September 1997 (Journal of Laws of 2003, No. 169, item 165, with amendments) define detailed requirements for machines, tools and other technical devices as well as their operation. It should be added that also the guidelines of Directive 2009/104 / EC and Directive 2006/42 / EC have been transposed into the Polish legal system. Similarly, they are: the Ordinance of the Minister of Economy of 30 October 2002 on minimum requirements for occupational health and safety in the use of machinery by employees during work (Journal of Laws 2002 No. 191 item 1596) and the Ordinance of the Minister of Economy of 21 October 2008 on the essential requirements for machines (Journal of Laws 2008 No. 199, item 1228).

The guidelines contained in the cited legal provisions are on the one hand aimed at guaranteeing an adequate level of safety and protecting the employee's health in the place and environment of his work, and on the other hand enabling the free circulation of machines on the European market.

The basis for preventing the effects of hazards during work is to eliminate hazardous factors at the source of their occurrence. Therefore, protective measures should be applied in the following order: (Dźwiarek and Latała, 2016; Gałusza, 2014)

- technical measures to eliminate or reduce the hazard at source;
- collective protection measures;

- organizational and procedural measures;
- collective protection measures.

Due to the issues raised in the article, the special importance of technical measures eliminating or organizing the threat at source should be emphasized. This category of protection measures includes all structural solutions used in machines, which include, among others on: (Górny, et al., 2009; Górny, 2012; Dźwiarek and Latała, 2016)

- use of safety distance;
- limiting strength and energy;
- use of covers;
- use of electro-sensitive protective devices designed to detect people (active optoelectronic protective devices, pressure-sensitive protective devices);
- use of safety devices (two-hand control devices, enabling devices, emergency stop devices, etc.);
- use of safe control systems (electromechanical, hydraulic, pneumatic).

The technical measures presented may also be supplemented by such constructional solutions used in the machines that are associated with:

- eliminating contact with surfaces and edges with which the worker may contact (elements with sharp edges, cutting, rough, etc.);
- preventing excessive increase in force, pressure or rotation;
- preventing exceeding the assumed traffic ranges;
- ensuring a collision-free sequence of machine movements or technological processes;
- preventing the emergence of threats related to the disappearance of working media;
- location of the impact zone of a given factor in relation to the human work zone;
- limitation of the kinetic and potential energy of machines and their parts that can move under the influence of gravity or elastic and pressure elements;
- proper location of elements that can create hazardous areas when moving, e.g. cutting off, pulling in.

The foundation for ensuring technical safety during the operation of machinery is analysis, assessment and risk reduction. According to this principle, designers and machine manufacturers are required to identify potential hazards (e.g. mechanical, electrical, thermal, noise hazards or the properties of the materials being processed) and to apply the necessary methods to reduce the specified risk to an acceptable level. Indispensable in this regard is the use by producers of Safety triads, which assume the use of appropriate, safe construction solutions in themselves, appropriate technical protective measures, as well as providing the user with information about residual hazards, by means of documentation and placing the marking directly on the machine. In addition, proper implementation of the production machine, user training, the use of additional technical protective measures, or the employee's equipment with personal protective equipment are also important. The guarantee of the safe operation of machines is also compliance with the rules related to their correct use, i.e. in accordance with their intended purpose (Badri, et al., 2018; Kozirowska and Prucnal, 2019; Suryoputro et al., 2017).

2. SUBJECT OF RESEARCH

The subject of the study was the analysis and assessment of technical security features of the TRUMPF laser cutter, as well as organizational measures recommended for use by the company. Selected technical parameters of the machine are described in Table 1.

Table 1
Technical parameters of the laser cutter

Parameter	Value
cutting time	16524 h
time to turn on the machine	28498 h
work area (X, Y, Z)	3000 x 1500 x 115 mm
maximum weight of the processed sheet	710 kg
positioning speed parallel to the axis	60 m/min.
positioning speed	85 m/min.
accuracy - the smallest programmable step:	0,001 mm
simultaneously (axes X and Y)	+0,10 mm
positioning error	+0,03
average positioning deviation	73 kVA
Power Connection	24 V
control voltage	3 x 125 A
necessary security	7-10 bar
compressed air connection	30 bar
N2 nitrogen connection	20 bar
O2 oxygen connection	9300 x 4600 x 2000 mm
dimensions of the laser (length x width x height)	11500 kg

Source: Internal materials of the examined enterprise

The review of protective measures applied on the laser cutter was carried out on the basis of information contained in the instructions provided by the machine manufacturer and provided by the selected company operating the machine.

3. RESULTS

The danger zone associated with the operation of the machine has been secured by means of appropriate devices. The basic ones include:

- protective photocell;
- protective cabin;
- laser device cover;
- main switch;
- shock EMERGENCY STOP button;
- FEED STOP function;
- switch with a key to block the beam;
- key switch on the laser device;
- suction function from the work area
- laser status light;
- laser device warning lamp.

The individual safety devices are characterized below.

Protective photocell

The laser cutting machine is supplied with a double beam light curtain as standard to protect the danger zone. The photocell rays run 400 mm and 900 mm above the floor. If the light beam is interrupted during the operation of the machine (e.g. by the appearance of a person in the danger zone), it triggers the FEED STOP function. Then all machine movements are stopped automatically.

Protective cabin

The machine was placed in a closed protective cabin, with one or several protective doors, which were electronically secured and monitored by the control system. The protective cabin is made of sheet steel, and in the field of view it is equipped with windows protecting against laser radiation. In addition, the protective booth is also equipped with an opening roof to prevent reflected laser radiation or scattered radiation from propagating to the top. The laser beam is only excited when the protective booth is tight, i.e. all protective doors as well as the open roof and flap in the pallet entry area are closed. If the machine door was opened during processing, then the FEED STOP function will be activated. It is forbidden to climb onto the roof of the protective booth.

Laser device cover

Lasers (i.e. radiation generators) are protected by specialized shields, which are monitored by a safety switch. They can only be opened using suitable tools and by qualified personnel.

Main switch

The main switch is used to turn the machine on and off (interruption and induce the machine to supply electricity). This switch can be secured against accidental use with a padlock.

Shock EMERGENCY STOP button

This function causes:

- interruption of the machine's power supply (24 V control voltage is maintained);
- turning off laser radiation; in case of deviations from the standard setting and in the case of laser devices equipped with more than one output, the laser is not turned off, but the radiation is led to the absorber;
- blockage of the closing clutch of an optically installed radius path (LLK);
- interruption of treatment gas supply;
- stop all axis movements;
- disconnecting all drives from the power supply;
- disconnection of the hydraulic aggregate, collecting filter and longitudinal and transverse conveyor.

STOP FEED

The indicated function causes:

- stop all axis movements;
- beam hold for an installed optical path of a light beam;
- disconnection of the longitudinal and transverse conveyor belt.

Switch with a key to lock the beam

The switch with the RADIUS LOCK key is located on the control panel. The switch can be switched to two positions. When the switch is in the left position, the beam lock is inactive and the closing clutch of the optically installed beam path is released.

However, the position of the switch on the right causes that the beam lock is active, the closing clutch of the installed beam path is released and the key can be safely removed.

Dust extraction from the work area

In order to increase the operational safety of the machine, its working bar is ventilated by means of suitable devices. Depending on the machine configuration, ventilation is carried out using the following techniques:

- flap channels connected to the suction bowl;
- extraction connection (for stationary extraction of space);
- mobile space extraction;
- suction channel with ventilation grilles;
- suction channel under the laser cutting head.

The extraction and filtration systems presented above are designed to remove all types of dust and aerosols that accumulate during operation of the machine.

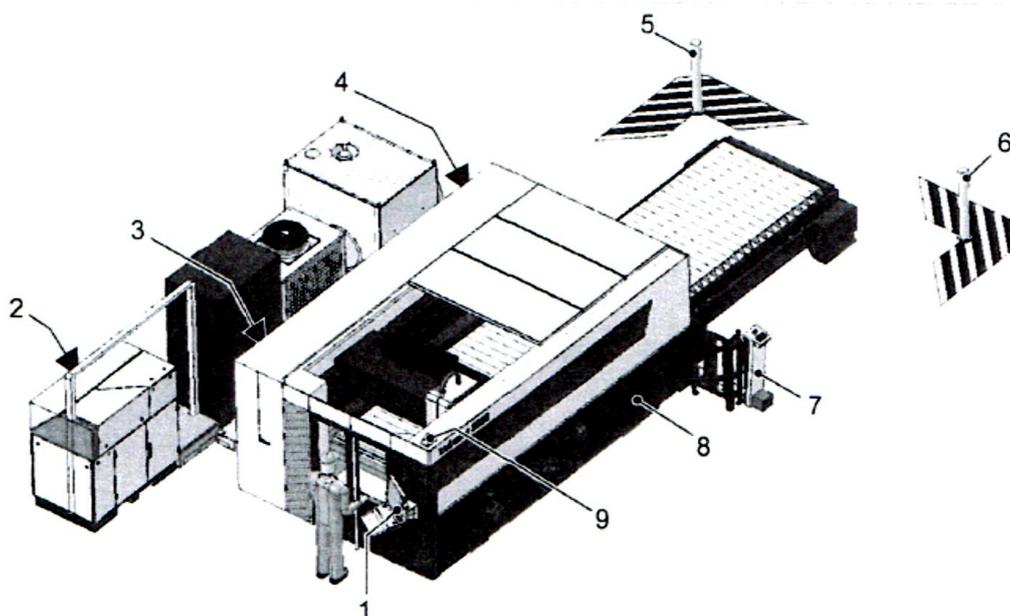
Laser status light

The laser status light is intended to indicate that the laser device has been connected to the machine or that laser radiation escapes from the optical processing system.

Laser device warning lamp

The warning lights on the laser device indicate that the laser light is available at the processing site and the laser is ready to emit light, even if the light is not yet emitted.

The arrangement of individual protections on the machine is shown in Fig. 1.



Mark:

1. Shock emergency button
2. EMERGENCY STOP impact button on the laser in the standard setting
3. Main switch
4. Mirror post with transmitter

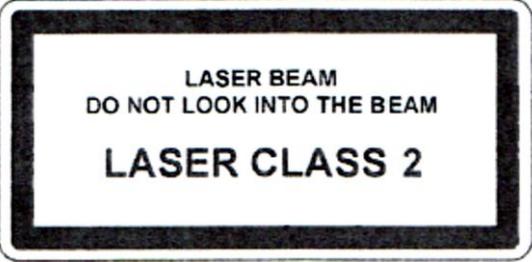
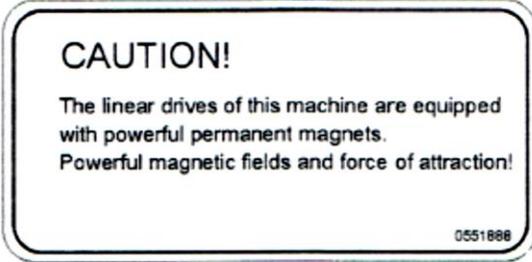
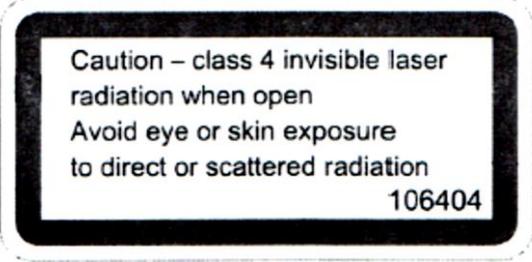
5. Mirror post
6. Mirror post
7. Starting pole with receiver and the EMERGENCY STOP push button
8. Protective cabin
9. Laser warning light

Fig. 1. The arrangement of individual protections on the machine

Source: Internal materials of the examined enterprise

The machine is also equipped with a set of warning signs that are intended to inform the employee about the danger and the need to exercise caution when operating the machine. The appearance of the plates with their general description is presented in Table 2.

Table 2
Warning signs on the machine

Warning sign	Meaning
 <p>LASER BEAM DO NOT LOOK INTO THE BEAM LASER CLASS 2</p>	<p>Laser radiation. Do not look into the laser beam.</p> <p>Class 2 laser</p>
 <p>CAUTION! The linear drives of this machine are equipped with powerful permanent magnets. Powerful magnetic fields and force of attraction! 0551888</p>	<p>Warning: the linear drives of this machine are equipped with strong permanent magnets - strong magnetic field + high magnetic attraction force</p>
 <p>Caution - class 4 invisible laser radiation when open Avoid eye or skin exposure to direct or scattered radiation 106404</p>	<p>Warning: Class 4 invisible laser radiation when the visor is open.</p> <p>Avoid irradiation of eyes or skin with direct or diffused radiation</p>
	<p>Warning - laser beam!</p>
	<p>Warning - electric current!</p>
	<p>Warning - hot surface!</p>
	<p>Danger due to magnetic field</p>

Warning sign	Meaning
	No access for people with pacemakers or implanted defibrillators
	No entry (nozzle changer)
	No entry

Source: Internal materials of the examined enterprise

An inseparable element of work safety during machine operation are all kinds of organizational security measures, which are the responsibility of the employer. Personnel before working with the machine should be trained by the employer in the proper operation of the machine and work with the laser, the need to use personal protective equipment. An example may be protective glasses for working with laser, which should meet the requirements of IEC / EN 60825 or EN 207. In addition, the employer should inform employees about hazards at the workplace and the security measures implemented. An important element of employee education is also familiarizing them with the rules of conduct in the event of an accident at work. It should also be noted that all types of repair and maintenance works should be performed only by qualified personnel who know the rules of dealing with laser radiation, using specialized equipment and appropriate tools.

Ensuring an adequate level of safety when working with a laser also involves employees maintaining due diligence and caution when using the machine. Before each use of the machine, operators must ensure that no bystanders or colleagues are in the danger zone. Personnel may only operate the machine with properly installed safety devices. Workers may not disable or remove safety devices unless they are necessary for repair and maintenance work. After the indicated work has been carried out, the safety devices must be reinstalled or switched on.

Before starting the working day, the operator should:

- check the operation of safety photocells and light barrier;
- check the safety booth, sight glasses, safety fences and maintenance doors for damage; do not start the machine if the sight glass is damaged (i.e. there are deep penetrations, holes, cracks, etc.).

Safe use of the machine also requires ensuring its proper technical condition. To this end, the employer is obliged to:

- setting up and installing the machine in accordance with the assembly plan and assembly conditions specified by the manufacturer;
- ensure that only qualified personnel work on the machine;
- replacement of damaged or missing warning signs on the machine;
- maintaining the machine in perfect condition (also by authorized employees);
- ensure cleanliness and good visibility at the operator's workplace;

- ensure a sufficient supply of fresh air to the work rooms.

In turn, the operator should:

- immediately report to the employer or supervisor any changes in the operation of the machine;
- at least once during the work shift check for external perceptible deficiencies and damages;
- immediately use the EMERGENCY STOP impact button if the sight glass is damaged during laser operation.

The technical condition of the machine is also affected by the use of appropriate consumables, in particular lubricants and cleaning agents. The European directive 1907/2006 REACH indicates to pay attention to:

- chemical properties;
- physical properties and technical specifications;
- transport information;
- security, storage and handling measures;
- rules of conduct in the event of an accident or fire;
- information on toxicity and ecology;
- waste codes with information on the correct disposal of the material.

4. CONCLUSION

Based on the analysis of the literature and own research, the following conclusions and final statements can be formulated:

1. One of the employer's basic duties in the field of health and safety is to ensure safe and hygienic working conditions with appropriate use of scientific and technical achievements. It is inseparably connected with properly selected machines adapted to the performed work and other working means. The basic requirements for machine safety are regulated in European and national legal regulations.
2. The use of machines involves exposing the employee to a number of hazards, including mechanical hazards, which may be caused by elements of the workplace equipment with which the employee directly or indirectly comes into contact in the work process. These hazards can cause injury (e.g., cutting, puncturing, bruising, cutting off, impact, crushing, fracturing, etc.) or even the death of an employee.
3. Ensuring the safety of machine operation requires the use of a number of technical measures (e.g. covers, housings, light curtains, two-hand control devices, and undertaking organizational and procedural measures.
4. An important element of preventive measures is to inform employees about potential hazards associated with the operation of machinery in the workplace. Therefore, the employer is obliged to provide employees with current health and safety instructions. These instructions should contain information on hazards at the workplace and how to use machines and other technical devices.
5. The laser cutter analyzed in this work is equipped with many different types of technical protections, thus meeting the highest safety standards of its users. Thanks to the use of technical measures such as protection, blockades, safety covers preventing the machine from starting, it was possible to reduce the risk

associated with even laser radiation (characteristic of this type of equipment) to an acceptable level.

6. In addition, to increase the level of employee safety, each machine operator is equipped with specialized glasses and work clothes to protect his eyes and skin against possible damage (e.g. in the event of a breakdown).
7. An important element of safety is also appropriate marking of danger zones with the help of safety signs. The markings used on the machine are intended to inform and warn the employee about situations directly threatening their safety and life. In addition, only personnel trained in the proper operation of the machine are permitted to work with the machine.
8. An important element in ensuring safe and hygienic working conditions in the case of the audited enterprise is maintaining the proper condition of the technical infrastructure, conducting periodic inspections and undertaking immediate reaction to any symptoms indicating the possibility of deterioration of the machine's safety condition.

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