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INTRODUCTION

The aim of this article is to present solutions aimed at improving work safety for employees entrusted with tasks performed within Autonomous Maintenance (AM). This article discusses legal aspects related to workplace safety pertaining to employers' and employees' obligations, as well as those concerning safety during the use of machines. The statistical data served as a basis for the identification of the most common causes of accidents during the use, repair and maintenance of machines and equipment in 2015-2018. Moreover, the individual activities performed by employees at the time of the accident were indicated. This highlights the essence of the problem which lies in the ability to identify hazards and take appropriate actions to eliminate them, in particular in the case of operators performing tasks within AM. The article proposes solutions that should be considered by manufacturing companies that implement Autonomous Maintenance, including: Visual Management, 5S method, TWI program, as well as the Lockout-Tagout system.

LEGAL ASPECTS OF WORK SAFETY

The provision of safe and hygienic conditions of work is the legal and social responsibility of every employer. Conscious management of the occupational safety and health area in the company cannot be reduced to the mere prevention of accidents at work and occupational diseases (Chojnicki and Jaroszewicz, 2019). It is in fact an inherent feature of the development of the enterprise and responsible business in which an adequate level of the culture of safety perceived as a factor affecting the attitudes and behavior of the staff in terms of health and safety is ensured (Krupa et al., 2018).

Occupational safety and health is defined as "all legal rules and research, organizational and technical measures aimed at creating such conditions for employees as to enable them to perform work productively without exposing them to the unreasonable risk of accident or occupational disease and excessive physical and mental stress" (Kowalski, 1999).

The basic legal act that guarantees the right to safe and hygienic conditions of work is the Polish Constitution (Art. 66) (The Constitution, 1997). The method of

exercising this right is specified in the Labor Code (The Labor Code, 1974), and the basic regulations in the field of OSH are contained in Division Ten of the Code.

Employers' and employees' obligations

Employers' basic obligations in the field of OSH are specified in the Labor Code and the implementing rules issued on its basis, including the Ordinance on General Occupational Safety and Health Provisions of the Minister of Labor and Social Policy (Rozporządzenie MPiPS, 1997).

Pursuant to Art. 207 § 2 of the Labor Code (The Labor Code, 1974), an employer shall protect the health and life of employees by ensuring safe and hygienic conditions of work, whilst making proper use of the advancements in science and technology. In particular, an employer shall:

- organize work in a manner ensuring safe and hygienic conditions of work,
- ensure observance of the provisions and rules of occupational safety and health at the work establishment,
- respond to the needs in the area of OSH, adapt measures aimed at improving the existing level of protection of employees' health and life,
- ensure the development of policies pursued in the field of the prevention of accidents at work and occupational diseases, taking into account technical issues, work organization, conditions of work, social relations and the impact of work environment factors.

Employers shall also be required to provide employees with information on hazards to human health and life in particular workstations and during performed work (including rules on how to handle a breakdown). Employers shall inform employees of the protective and preventive actions taken to eliminate or reduce the hazards, as well as on the staff assigned to administer first aid.

In turn, the prime responsibility of employees (defined in Art. 211 of The Labor Code) is to observe the provisions and rules on occupational safety and health (The Labor Code, 1974). In particular, an employee shall:

- be familiar with the provisions and rules on OSH, participate in training activities on OSH, perform work in a manner consistent with the provisions and rules on OSH,
- ensure that the machines, equipment and tools are in a proper state as well as ensure that the workplace is in order,
- apply collective and individual protection measures,
- immediately notify the superior of any accident or hazard to human life or health and warn others in the endangered area of any such hazard.

Legal regulations regarding the safety of the use of machines

The legal regulations regarding the safety of the use of machines are of crucial importance in the context of work safety. Manufacturers of machinery and its users (employers) should take measures to improve workplace safety, which in

turn contributes to the reduction of the number of accidents that ultimately generate serious social and economic costs for enterprises (Małysa and Pawlak, 2017).

The principal element within the scope of work safety during the use, repair and maintenance of machines lies in the fulfilment of legal requirements by the machines in use as well as in compliance with the OSH provisions and rules by the employees of the enterprise. The legal regulations lay down different safety requirements for machines. The concept formulated in the European Union rests on two pillars that relate to (Małysa, 2019):

- minimum requirements relating to so-called old machinery operated in enterprises before Poland's accession to the EU which are set out in Directive 2009/104/EC of the European Parliament and of the Council concerning the minimum safety and health requirements for the use of work equipment by workers at work (Directive, 2009);
- essential requirements concerning so-called new machinery placed on the market or put into service after Poland's accession to the EU which are specified in Directive 2006/42/EC of the European Parliament and of the Council on machinery (Directive, 2006).

The minimum requirements apply to broadly understood work equipment (machines, tools, technological installations) and are directed at employers. The equipment should therefore meet safety requirements throughout the period of use (The Labor Code, 1974; Rozporządzenie MG, 2002; Rozporządzenie MPiPS, 1997). The Ordinance of the Minister of Economy of 2002 points to specific areas to be addressed during the adaptation works – they concern: machine controls, machine control system, starting and stopping of the machine, protection against hazards caused by ejection of objects and gas, vapor, dust or liquid emission, protection against elements in movement, lighting of places, workstations and maintenance work station, warning devices, intended use of the machine, machinery maintenance, disconnection from the electricity supply, safe access to different places in connection with the use of a machine, protection against fire, explosion, electric shock. In view of the fact that the above areas constitute a potential risk of accidents, consideration should be given during adaptation work to whether the undertaken measures have contributed to the reduction of the likelihood of occurrence of adverse events related to the performed work.

The essential requirements are directed at manufacturers, importers and distributors that place machines on the EU market. The essential requirements are intended to guarantee users a higher level of safety than the minimum requirements and manufacturers are therefore under an obligation to limit the risks associated with machinery operation (Małysa and Pawlak, 2017).

When organizing working conditions, employers must bear in mind that accidents at work occur most commonly in the workplace during the use, repair or maintenance of machines and equipment. Pursuant Art. 215. § 1 of the Labor Code, employers shall be obliged to ensure that machines and other technical

devices operated in the enterprise comply with the safe and hygienic conditions of work, and above all, protect employees against: injuries, effects of hazardous chemical agents, excessive noise, electric shock, harmful shocks, effects of vibrations and radiation and harmful and hazardous effects of other factors of the working environment. Moreover, the machines and technical devices used should take into account the ergonomic requirements (The Labor Code, 1974).

CAUSES OF ACCIDENTS DURING THE USE, REPAIR AND MAINTENANCE OF MACHINES

The identification and analysis of the causes of accidents during the use, repair and maintenance of machines makes it possible to take actions aimed at the reduction or elimination of such events. As is shown by the data released by Statistics Poland, operators and assemblers of machines and devices are a professional group (alongside workers and craftsmen) that is most often affected by accidents at work. In 2018, they constituted 16.5% of all the injured persons, as in previous years. More than half of the accidents at work in all professional groups in 2015-2018 were caused by inappropriate behavior of employees, which continues to be a serious problem in various work establishments. That cause is mainly associated with: insufficient concentration of attention, surprise by a sudden event, ignorance of hazards or lack of experience. Other important causes of accidents included improper organization of work and workstation as well as improper condition of the material agent and improper use of the material agent (Table 1).

Table 1 Main causes of accidents at work in 2015-2018

Causes of accidents	2015	2016	2017	2018
Inappropriate behavior of employees	59.2%	60.1%	60.8%	60.8%
Improper organisation of work and workstation	9.9%	9.7%	9.7%	9.5%
Improper condition of a material agent (construction defects, incorrect technical and ergonomic solution, improper exploitation)	8.6%	8.4%	8.4%	8.5%
Lack or improper use of a material agent by an employee	7.5%	7.4%	7.3%	7.2%
Other	14.8%	14.4%	13.8%	14%

Source: (own elaboration based on Statistics Poland)

A data analysis made it possible to identify activities during which accidents at work occurred most often in 2015-2018 (Fig. 1). These were primarily activities related to the movement of employees (i.e. walking, climbing, descending, running) – the total cumulative share of such activities in accidents involving the use, repair and maintenance of machines amounted to 29.3% (Fig. 2). The movement of employees was followed by work with hand tools and handling of objects – the average cumulative share of these activities in accidents was 24.5% and 19.5%, respectively (Fig. 2).

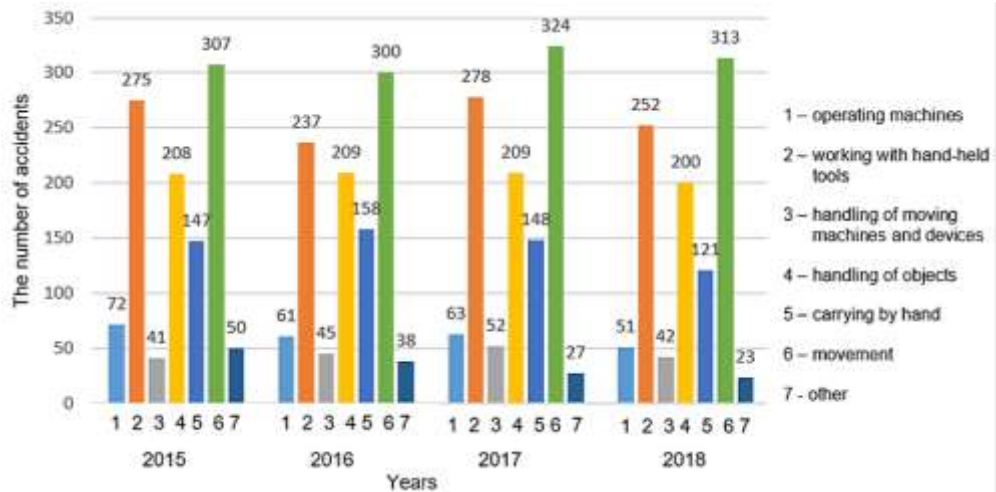


Fig. 1 The number of accidents at work by activities performed by workers at the time of the accident in 2015-2018

Source: (own elaboration based on Statistics Poland)

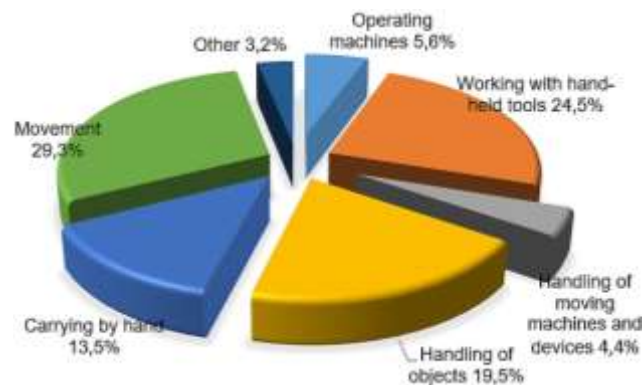


Fig. 2 The average cumulative share of activities in accidents during the use, repair and maintenance of machines and devices in 2015-2018

Source: (own elaboration based on Statistics Poland)

The presented data on the causes of accidents during the use, repair and maintenance of machines indicate areas where safety problems occur, which calls for the adoption of measures aimed at reducing or eliminating such events. This appears to be of particular importance in the case of tasks performed by operators as part of Autonomous Maintenance.

WORK SAFETY WITHIN AUTONOMOUS MAINTENANCE

Autonomous Maintenance is one of the essential elements underpinning the TPM system, which is defined as a continuous process of the operation of machines and equipment implemented within the entire enterprise by all the operators and the maintenance department staff (Furman and Kuczyńska-Chałada, 2016). It includes a set of activities that aim to involve operators in the upkeep and maintenance of the machines they operate, independently from the maintenance department, i.e. inspections, lubrication, replacement of parts, simple repairs, detection of irregularities, control of precision. AM provides for conducting trainings for machine operators to allow them to play a major role in

the prevention of irregularities thanks to daily maintenance. AM's basic goals include (Furman and Matysa, 2015):

- identification and elimination of the causes of variation in productivity,
- increase in the participation of operators in the maintenance of the machines they use,
- making operators more accountable for the technical state of machines,
- improvement of the quality of the workstation and increasing operators' skills.

The implementation of Autonomous Maintenance is carried out in seven steps (Fig. 3), which allows operators to develop the appropriate skills and makes it possible to identify precisely what expectations are placed on operators.

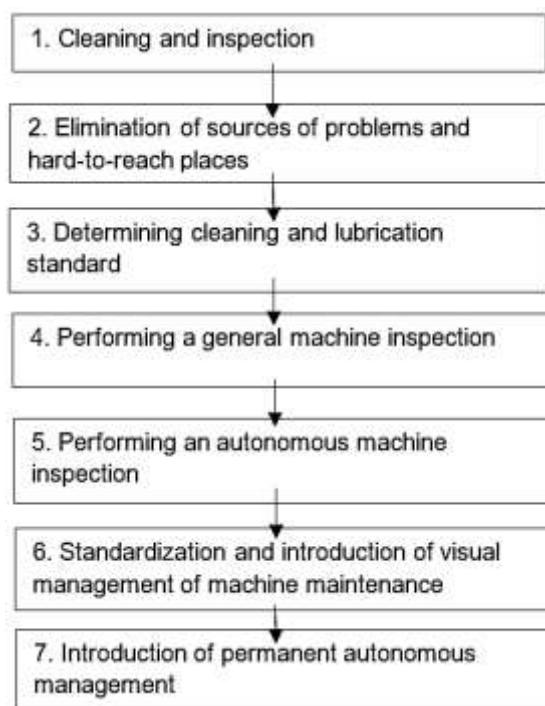


Fig. 3 Stages of Autonomous Maintenance

The first five steps include activities aimed at keeping machines in good condition and preventing their excessive wear, as well as activities related to the development of standards for cleaning, lubrication, tightening of fixings, and inspection. The sixth step focuses on aspects related to the ordering, standardization and visual management of machine maintenance. The last step consists in the activities carried out independently by operators in their workstations (The Productivity Press Development Team, 2012).

Particular attention should be paid during the introduction of AM in the workplace to the degree of compliance of the machines with the legal requirements – minimum, essential – given that the work within Autonomous Maintenance may also be dependent on the type of fulfilled requirements. It is only then that the next step of involving operators in the upkeep and maintenance of machines may be taken.

An employee entrusted with tasks within AM performs activities that may constitute a potential source of an accident. It should be noted that the occupational risk assessment plays a dominant role in the process of supervision over the workstation and it provides the necessary information for planning activities aimed at improving conditions of work. An occupational risk assessment should be carried out again when the scope of the employee's duties includes activities within AM (Furman and Małysa, 2015). The provision of information to the employee by the employer concerning the hazards (as prescribed by the Labor Code) does not limit the accident risk. The employer should provide operators with protective equipment and, where possible, apply solutions that eliminate that risk.

PROPOSED SOLUTIONS FOR IMPROVING WORK SAFETY WITHIN AUTONOMOUS MAINTENANCE

Enterprises can use various solutions to improve the safety of employees performing activities within AM. Given that the most common causes of accidents during the use, maintenance and repair of machines in recent years have been inappropriate employee behavior, improper work and workstation organization as well as improper handling of the material agent, enterprises can apply the following:

- implementation of visual management in the workstation,
- implementation of the 5S/6S principles connected with the workplace organization,
- implementation of the LOTO (Lockout-Tagout) system in the work establishment,
- use of the TWI program as an instructional tool for employees.

Visual Management (VM) is a set of practices that facilitate the management of the production process by quick detection of irregularities. It includes any communication tool used in the work environment that makes it possible to determine how to perform a particular task and whether the method of its implementation deviates from the established standard (Furman, 2019). The use of VM in the workstation area is intended to support the employee in connection with his tasks. The use of visualization makes it possible to organize the work area in such a manner that problems can easily be identified (everything is described, marked and ordered). The use of specific signs understandable for employees can facilitate the perception of specific events and consequently shorten the operator's response time to the incident. The forms of VM – boards, monitors, schedules, standards, instructions, horizontal signs, light and sound signals – should improve the way in which relevant information is conveyed (e.g. the method of performing activities within AM) and make any irregularities immediately apparent. Then corrective action can be taken without delay.

The use of the 5S/6S method enables proper organization of the work area through the implementation of five or six steps of actions that make it possible to accomplish order and improve work safety (Furman et al., 2017). This is of utmost importance, particularly as the improper organization of the workstation is one of main causes of accidents at work. Within the scope of activities carried out as part of AM, the 5S method supports the process of the identification of any irregularities. The standardization of activities within 5S is of particular importance – it aims to ensure the safety of machinery connected with maintenance (e.g. development of a lubrication standard or inspection of safety devices). The introduction of the 5S principles and the maintenance of appropriate conditions at the workstation is closely related to the 6th stage of AM (i.e. standardization and introduction of visual management of machine maintenance). The aim is to eliminate hazardous conditions at the workplace and operators' unsafe behavior.

Another solution is the LOTO system. Its purpose is to protect employees against unexpected switching-on of the power supply or start of the machine/device by releasing hazardous energy during service, regulation or maintenance works (elimination of the human factor as the cause of a dangerous event – accident or breakdown). Maintenance technicians and machine operators are exposed to accidents related to the performed work during which the following may occur: accidental and unplanned switching-on of the power supply, unexpected start of the machine or release of stored energy. The LOTO system includes locking devices with a descriptive label referring to the hazard and the person who blocked the energy. One of the elements of the implementation of the system is the development of a procedure for placing properly marked energy blocking or cutting-off devices that will prevent unexpected start of the machine during repair and maintenance works. Moreover, proper operation of the LOTO system requires adequate staff training (Lis et al., 2016). Visual Management principles may also be used as part of that solution.

TWI (Training Within Industry) program is the last of the solutions proposed to improve work safety within AM. It facilitates the development of managerial skills among experienced operational staff and lower- and middle-level superiors. Its structure is based on three main modules: Job Instruction (JI), Job Methods (JM), Job Relation (JR) and an additional module based on job safety – (JS). As regards the improvement of work safety within AM, consideration may be given in work establishments to the introduction of TWI-JI and TWI-JS modules. TWI-JI is an effective means of instructing the staff on how to perform their tasks properly, consciously and safely. Supervisors can train new employees quickly and effectively, which should lead to the elimination of mistakes, an increase in efficiency and improvement of safety. The scope of this method covers the time of the on-the-job training, the stage of preparing an employee for the training and supervision exercised over him when he performs work independently. As is recommended in the TWI-IP principles, a set of working instructions (forming

the basis for the training) is developed and it is subsequently divided into main steps, instructions and reasons for the instructions. Such a division of work describes the method of work through the main steps and how to do the work through instructions along with their reasons. An explanation of the instructions and the reasons for their existence in the set of working instructions leads to an elimination of human errors. Trainees learn a given activity when they learn how to perform it (instructions) and why such a method is the best (reasons). It is of crucial importance during the AM implementation where maintenance is a new responsibility for the operators.

The TWI-JS module focuses on work safety. It provides superiors with a framework for engaging employees in the identification of potential hazards and elimination of such hazards in connection with training and knowledge of the OSH provisions. The program teaches superiors how to analyze the chain of events leading to accidents and dangerous situations (root causes are identified and removed to "break the chain") (Furman, 2019; Misurek, 2016). The activities performed under TWI-JS result in instructions and work standards which take into account the principles of occupational safety and health. The use of the TWI program can significantly improve the safety of operators performing activities within AM. Table 2 presents examples of the application of the proposed solutions.

Table 2 Examples of the application of the proposed solutions aimed at the improvement of work safety within Autonomous Maintenance

Proposed solution	Example of the application
Visual Management	<ul style="list-style-type: none"> • color marking of switches on the machines • marking of measuring devices • visual (pictograms) and sound (alarms) signaling at work stations • One Point Lesson (OPL) – to provide information to operators in short time (training tool) • cleaning, lubrication and inspection instructions • action boards – to provide information • competence matrix for task planning and autonomous maintenance
5S/6S method	<ul style="list-style-type: none"> • Red Tags – to identify and eliminate problems • standardization of actions within AM
Lockout-Tagout system	<ul style="list-style-type: none"> • Lockout – safety in the form of locks (covers, security padlocks, chains, locking covers) – in visible colors • Tagout – safety in the form of tag (as a warning sign) • instructions, procedures
TWI-Job Instruction TWI-Job Safety	<ul style="list-style-type: none"> • work instructions in line with TWI

Source: (own elaboration)

CONCLUSION

Humans play a prominent role in every process because they are responsible for its proper functioning and safety. The aspect of work safety is an important element of the improvement of the process – the introduced improvements

should include safe conditions of work and reduce the number of potential accidents (Małysa et al., 2016; Małysa et al., 2017). The problem of accidents at work is of crucial importance given the social and economic effects generated by such events. Machine operators and maintenance workers are a professional group which very often sustains accidents during the use, maintenance and repair of machines. Operators who are entrusted with new obligations resulting from the implementation of Autonomous Maintenance at the work establishment are among the most vulnerable. Therefore, the ability to identify hazards and take actions that will reduce or eliminate the risk of an accident assumes a particular significance. Solutions that can improve the safety of operators' work are proposed here and enterprises should consider the possibilities of their application.

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Abstract: Employers are under a legal obligation to provide employees with safe and hygienic conditions of work. These conditions are created by environmental factors that depend on the specifics of the enterprise, production technology and used machinery and equipment. A large number of the risks to which employees are exposed is associated with the use of machinery, equipment and working tools (as confirmed by Statistics Poland). Numerous manufacturing companies increasingly use the practice of involving operators, independently from the maintenance department, in the upkeep and maintenance of machinery and equipment in order to increase efficiency. These activities are undertaken within the scope of Autonomous Maintenance (AM), which is one of the essential elements underpinning the TPM system. The activities performed by operators within AM, such as daily inspections, lubrication or simple repairs, reduce the number of machinery breakdowns. Nonetheless, they could be a potential source of risk for employees. Companies applying the traditional division of tasks entrust the performance of such activities to qualified maintenance staff, so the proper identification of risks that takes into account the specificity of the activities performed by operators and the provision of training in the safe organization of work represent a significant feature of safety improvement. Enterprises may adopt multiple solutions in this regard, including the tools and techniques of the concept of Lean Manufacturing.

Keywords: work safety, accidents, Autonomous Maintenance, Lean Manufacturing