

MAINTENANCE MANAGEMENT AND OCCUPATIONAL SAFETY IN MANUFACTURING ORGANIZATIONS

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Abstract: Maintaining, repairing and installing machines and devices are some of the basic processes being run within the frameworks of broadly comprehended technological process management in manufacturing companies. The purpose of this paper is to identify the level of accident occurrence risk, to determine trends in frequency indicators of total, fatal, major and minor accidents as well as to analyse basic actions being performed at the time of accident and basic reasons for accidents while maintaining, repairing and installing machines and devices.

Keywords: occupational safety, accidents, maintenance, manufacturing

Introduction

The performance and competitiveness of manufacturing companies is dependent on the reliability and productivity of their production facilities (Madu, 2000; Demeter, 2000). This need to improve the production system's performance that has brought the maintenance functions into the limelight. Equipment maintenance and system reliability are important factors that affect organization's ability to provide quality and timely services to customers and to be ahead of competition (Cooke, 2000). Therefore, maintenance management is vital for sustainable performance of any manufacturing plant.

Maintenance and Safety

Maintenance is defined as a combination of all technical and organizational activities required to keep equipment, installations and other physical assets in the desired operating condition or restore them to this condition (Pintelon and VanPuyvelde, 2006). According to Visser and Pretorius, (2003) maintenance objectives are related to attainment of production target at required quality, and within the constraints of the system condition and safety. The maintenance management objectives can be summarized as follows (BSI, 1984):

- Ensuring system function,
- Ensuring system life,
- Ensuring safety, and
- Ensuring human well-being.

Further, maintenance resources are utilised so that the manufacturing equipment are in good condition, the plant achieves its design life, the safety standards are met, the energy use and raw material consumption are optimised among other

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factors (Dekker, 1996; Faccio et al., 2014). The maintenance process adds to customer value in terms of profit, quality, time and service (Zhu et al., 2002). Without well-maintained equipment, a plant will be at a disadvantage in a market that requires low-cost products of high quality to be delivered quickly (Swanson, 2003).

The competence of human resources in the maintenance departments is considered as important factor in a successful maintenance processes (Kelly, 2006). Competence can be described as a combination of knowledge, skills, ability, willingness, interest and personal characteristic, and must be adequate to identified needs (Tsang, 2002). The qualifications of the maintenance operators and the level of training and human resources development are considered to be among the critical characteristics of maintenance resources (Alsyouf, 2007).

Most accidents involving machines and devices in plants are connected with running basic manufacturing activities – 56% of total accidents. In the further sequence, with preparation of production and with providing for smooth production flow – maintenance, repairing, adjusting, cleaning, installing, preparing and dismantling machines – 25% altogether (PIP-GIP, 2011).

Studies on the structure of reasons for accidents at work over the years 2004-2010, which resulted from improper condition of the material object, indicate that a significant increase occurred in the share of reasons associated with improper operation of machines and devices (Tabor, 2011). This means that in order to improve safety of work with the use of machines and devices, problems of excessive exploitation, insufficient maintenance and inappropriate repairs and overhauls must be solved, e.g. with used the Risk Management System (Grabara et al., 2011).

The notion of repair is understood as a set of organisational and technical actions, which are aimed at bringing back a machine (or a facility) being repaired to the state of usable fitness. Each usable unfitness of a machine results in its being transferred into the technical maintenance subsystem, the objective of which is either to remove its unfitness or to perform some strictly necessary maintenance operations (as recommended by the manufacturer) (Żółtowski and Wilczarska, 2010). In other words, a repair is a process that consists in transferring a machine from the state of unfitness into the state of fitness. On the physical side, a repair may consist in replacing components of a damaged machine, adjusting or regenerating it, or in a number of other operations. Repair of a machine may be periodical or ad hoc in nature. The objective of the periodical repair is to bring back the machine to the state of fitness after some determined time of its operation, its total work hours, the volume of work it has done, or based upon results of diagnostics assessment of its technical condition. The machine's technical condition is found to be improper when excessive fall is observed in its technical parameters or economic indicators. Taking into account the scope of periodical repairs, we can distinguish between day-to-day repairs, medium repairs, and overhauls, whereas the ad hoc repair is a repair that is aimed at bringing back the

machine to the state of fitness, which was lost due to some mishap, such as an emergency damage, an accident, etc. It is the so called post-failure repair.

Maintenance, on the other hand, is a process, the objective of which is to cut down on the wear-out dynamics of mechanisms, subassemblies or other components of a machine. Basic maintenance operations include: initial cleaning, general external visual inspection, checking the machine's technical condition, its anticorrosive protection, lubricating its parts and mechanisms in line with relative instructions. Maintenance operations are carried out during technical maintenance, technical inspections and repairs. Using the criterion of time, we can distinguish between short-term maintenance (up to 1 year) and long-term maintenance (more than 1 year). The scope and frequency of conducting technical treatments and/ or technical maintenance operations are prescribed in relative provisions for each type of maintenance (*Leksykon...*, 1996).

On the other hand, installing machines and devices covers such operations as: transporting them (internal transport, manoeuvring), placing on their base plates, fixing, cabling, piping, adjusting, making trial runs and checking the machine's operation with no load. Apart from installing machines or facilities, we also have to do here with de-installing them before they are relocated to another site or scrapped.

The problem of assurance of safety of work with the use of machines and devices, including in the aspect of repairing, maintaining and installing them, has been reflected especially in the provisions of the following two documents: the Ordinance by the Minister of the Economy of 21 October 2008 upon essential requirements for machines (Ordinance, 2008) (implementing the European Parliament and European Union Council's Directive 2006/42/EC called the "Machinery Directive") and the Ordinance by the Minister of the Economy of 30 October 2002 upon minimum work health and safety requirements concerning using machines by employees at work (Ordinance, 2002).

It was stipulated in the introduction the European Parliament and European Union Council's Directive of 17 May 2006 that social costs of high occurrence of accidents caused directly by using machines may be cut down by designing and manufacturing machines which are safe by definition, and by properly installing and maintaining them (Directive, 2006).

Pursuant to one of the comprehensive safety rules as referred to both in the Machinery Directive and in the Ordinance that implements the Machinery Directive, the machine should be designed and manufactured in such a way that it can perform its prescribed functions, and that it could be operated, adjusted and maintained without posing any threat towards persons who perform these operations, not only under intended conditions but also in cases when it is possible to foresee that it can be used in an improper way. Risk elimination measures should be used over the entire expected lifetime of a machine, including its transport, assembly, dismantling, stoppage, and scrapping stages.

In his machine operation manual, the machine manufacturer should indicate types and schedules of inspections and maintenance operations required for safety reasons, as well as indicate wearable parts and describe such parts replacement criteria (Dima et al., 2011). These parts should be produced in such a way that they can be removed and replaced with new ones in easy and safe manners. They must be accessible so as to make it possible to replace them using necessary technical measures compliant with the determined method of action.

Furthermore, in order to provide for safety, adjustment and maintenance points should be located outside hazard zones. Machine manufacturers should provide for a possibility to carry out adjustment, maintenance, repairing, cleaning, and other operations while the machine is at standstill. In case of automatic machines, and, if required, in case of other machines too, their manufacturers must provide for connection points for diagnostic equipment used to detect the machine's defects.

Company Management runs its machinery operation policies that consist in controlling machinery fitness in such a way as to achieve optimum effects (Naidu, 2011, Djordjevic, 2013). The most frequently used optimisation criterion of activities in this respect is machine operation cost understood as the total sum of expenses spent on machinery operation and maintenance. Hence, increasingly often, a tendency is observed to use external companies for the purpose of repairing and maintaining machines and devices. Outsourced services may also cover diagnosing, maintenance, and transport processes. Apart from the fact that outsourced services offer some economic benefits, they are also a risk management activity in case maintenance operations are carried out on machines or facilities that are particularly hazardous.

Accident occurrence rate is the basic and the most frequently used reactive measure of the safety of work. Most often, accidents happen for many different reasons, and therefore classification of reasons for accidents may be different too. The classification that is most frequently used in practice is the one that distinguishes between technical, organisational and human reasons.

With reference to actions consisting in maintaining, repairing and installing machines and devices, technical reasons may cover such problems as: lack of or improper safeties, improper repairs and overhauls of material objects, insufficient maintenance of a material object, hidden material defects of a material object, construction defects of a material object, improper control elements, lack of or improper collective protection measures, excessive exploitation of a material object, improper strength of a material object, lack of or improper hazard signalling systems, and failure to meet required technical parameters.

On the other hand, organisational reasons may relate to such problems as: supervisors tolerating deviations from work health and safety rules and regulations, lack of material object operation manuals, lack of supervision, lack of or improper work health and safety training, performing operations without having removed the hazard, employees using their hands or legs improperly in the hazard zone, employees' insufficient occupational preparedness, improper grip or hold of

a material object, putting a material object into operation without having conducted required controls or inspections, entry into the hazard zone without having made sure that there is no danger, and improper material object safeguarding.

The last but statistically the most important group of reasons, i.e. human reasons, may cover such problems as: neglecting hazards (recklessness, brinkmanship), insufficient concentration of attention on the action being performed, getting startled by an unexpected event, being unaware of hazards, lack of experience, improper pace of work, not knowing work health and safety rules and regulations, drinking alcohol or taking drugs or psychotropic substances.

It is very important to know the most important reasons for accidents while maintaining, repairing and installing machines and devices in order to be able to take effective preventive actions and to run appropriate policies in the area of improving conditions of work with this respect.

Testing methodology

The essential objective of the studies conducted by us was to analyse and assess occupational safety while maintaining, repairing and installing machines and devices. Therefore:

- frequency indicators of total, fatal, major and minor accidents were tracked and analysed,
- basic actions being performed at the time of accident were identified; and
- basic reasons for accidents while repairing, maintaining and installing machines and devices were identified.

In our studies, we used statistical data for years 2009-2013 (GUS, 2010-2014) gathered by the Central Statistical Office based upon the Statistical Accident Chart. In the Statistical Accident Chart, among other things, all reasons for accident occurrence and actions performed at the time of accident are enumerated in the encoded form. The Statistical Accident at Work Chart is compiled by an accident investigation team in line with the specimen that constitutes Attachment to the Ordinance by the Minister of Labour and Social Policies of 8 November 2010 upon Statistical Accident at Work Chart (Ordinance, 2012). The Statistical Accident Chart is based upon the so called statistical accident model (introduced by EUROSTAT), which takes into account three groups of reasons for accidents, i.e.: technical, organisational and human reasons. The way the Statistical Accident Chart form is constructed makes it possible to specify, among other things, a single action performed by the victim at the time of accident, and several reasons behind it.

Occupational Safety while maintaining, repairing and installing machines and devices

Table 1 lists data concerning the number of victims of accidents at work and frequency indicators of accidents over the years 2009-2013 for maintaining, repairing and installing machines and devices.

Table 1. Frequency indicators of accidents at work while maintaining, repairing and installing machines and devices over the years 2009-2013 (Own work based upon GUS annual information)

	Frequency rate					
	2009	2010	2011	2012	2013	Average
of total accidents	10.90	10.94	10.80	10.91	9.48	10.61
of fatal accidents	0.055	0.057	0.037	0.028	0.061	0.048
of serious accidents	0.09	0.11	0.06	0.10	0.10	0.09
of lighter accidents	10.76	10.77	10.70	10.78	9.32	10.47

What follows from our analysis is that, over the studied years 2009-2013, a statistically significant fall was observed in the frequency rate of total accidents (from 10.90 in 2009 to 9.48 in 2013), but a higher in serious (from 0.09 to 0.10) and fatal accidents (from 0.055 to 0.061).

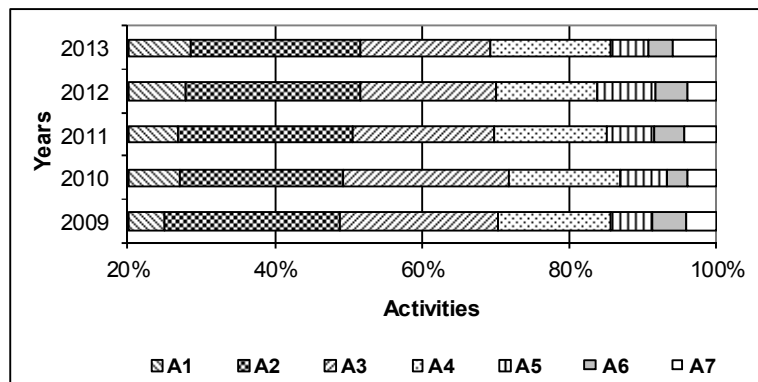
Actions being performed at the time of accident while maintaining, repairing and installing machines and devices

In line with clarifications upon the Statistical Accident Chart form, the action performed by a victim at the time of accident is the action that had been performed intentionally, just before the accident happened. It mainly covers such operations as: operating machines, works using hand tools, driving vehicles or being driven in them, operating rotary or moving machines and devices, handling objects, manual transport, and people moving around the plant.

Figure 1 shows data concerning basic actions being performed by victims at the time of accident while maintaining, repairing and installing machines and devices over the years 2009-2013.

Based upon the analysis of data juxtaposed for the type of action performed at the time of accident occurrence, a statistically significant fall was observed in the share of reasons connected with the manual transport (from 21.60% in 2009 to 17.67% in 2013), and a higher share in case of moving at the time of accident occurrence (from 24.88% in 2009 to 28.68% in 2013).

The Figure 1 shows that in the years 2009-2013, the most frequent actions that were performed at the time of accident were: people moving around the plant (Average: 22.56%), works using hand tools (Average: 23.28%) and manual transport (Average: 19.90%).



A1- Movement (22.56%); A2- Working with handheld tools (23.28%); A3- Carrying by hand (19.90%); A4- Handling of objects (15.13%); A5- Operating machine (6.34%); A6- Handling equipment (3.86%); A7- Presence / Other activity / No information (4.43%).

Figure 1. Victims of accidents while maintaining, repairing and installing machines and devices in relation to actions performed at the time of accident at work, over the years 2009-2013 (Own work based upon GUS annual information)

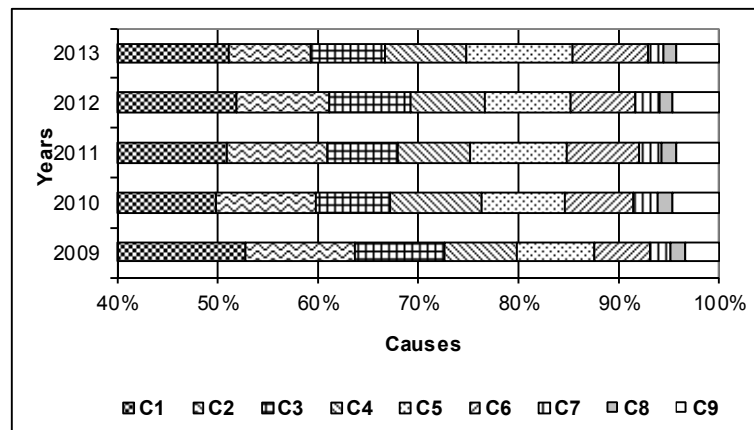
Reasons for accidents while repairing, maintaining and installing machines and devices

In clarifications upon the Statistical Accident Chart form, reasons for accidents are all kinds of shortcomings or irregularities, which, directly or indirectly, have contributed to the occurrence of an accident connected with material (technical) objects, with general organization of work in the company or with organization of the workplace, or connected with the employee.

Over the analysed period 2009-2013, the most frequent reason for accidents while maintaining, repairing and installing machines and devices was incorrect employee action (52.93% in 2009 and 51.25% in 2013) – Figure 2.

The concept of “incorrect employee actions” covers such problems as: being unaware of a given hazard, not knowing work health and safety rules and regulations, neglecting hazards, neglecting commands received from one’s superiors, insufficient concentration on what the employee is doing, getting startled by an unexpected event, and lack of experience.

The second most frequently indicated reason for accidents was absence of or improper use of a material object (a machine, a device or a tool). This includes the issues of using a material object that is unsuitable for a given kind of work, doing some work by hand rather than using tools, using a material object while unauthorised persons are present in the hazard zone, improper safeguarding of a machine or device, using a machine or device contrary to its intended use, improper grip, wrong installation, fixing, suspension, etc.



C1 - Incorrect employee action (51.43%); C2- Absence or inappropriate of the material object (9.65%); C3- Inappropriate organization of workplace (7.74%); C4- Inappropriate organization of work (7.82%); C5- Inappropriate condition of material agent (9.03%); C6- Inappropriate wilful employee action (6.67%); C7- Not using protective equipment (2.14%); C8- Inappropriate mental-physical condition of employee (1.41%); C9- Other causes (4.11%).

Figure 2. Reasons of accidents while maintaining, repairing and installing machines and devices over the years 2009-2013 (Own work based upon GUS annual information)

Summary

The efficiency and effectiveness of the maintenance system play an important role in the organization's success and development. Maintenance and safety are sometimes treated as separate and independent sets of activities (Raouf, 2004). However, part of the accidents in manufacturing environments is caused by poor maintenance as well as while maintenance activities. The analysis of statistical data, which we have carried out for years 2009-2013 regarding the values that describe the occupational safety while maintaining, repairing and installing machines and devices, made it possible for us to draw the following conclusions:

- over the analysed period, the frequency indicator of fatal accidents while maintaining, repairing and installing machines and devices adopted values that were significantly higher in 2013 than in 2009, which resulted in the higher accident occurrence risk category with this respect;
- the most frequent actions performed at the time of accident were: people moving around the plant, works using hand tools, and manual transport;
- inappropriate employee action was the basic reason for accidents while maintaining, repairing and installing machines and devices.

An integrated approach is the appropriate approach for optimizing plant capacity, as safety and maintenance are not mutually exclusive functions (Liyanage, 2007). Being aware of the values that characterise safety of work should be considered as a basis to take preventive actions and to conduct proper policies in the area of

improving conditions of work. Therefore, within the frameworks of works connected with maintaining, repairing and installing machines and devices, it would be advisable to pay greater attention towards proper behaviour of employees who perform works using hand tools and manual transport operations, especially towards employees' higher awareness of the hazards that may be associated with these operations.

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ZARZĄDZANIE UTRZYMANIEM RUCHU A BEZPIECZEŃSTWO PRACY W PRZEDSIĘBIORSTWACH WYTWÓRCZYCH

Streszczenie: Konserwacja, naprawa i instalowanie maszyn i urządzeń są jednymi z podstawowych procesów realizowanych w ramach szeroko rozumianego zarządzania technologią w przedsiębiorstwach produkcyjnych. Celem tego artykułu jest zidentyfikowanie poziomu ryzyka wypadkowego, określenie kształtowania się wskaźników częstości wypadków ogółem, śmiertelnych, ciężkich i lekkich a także przeanalizowanie podstawowych czynności wykonywanych w chwili wypadku oraz podstawowych przyczyn wypadków przy wykonywaniu konserwacji, napraw i instalowaniu maszyn i urządzeń.

Słowa kluczowe: bezpieczeństwo pracy, wypadki, konserwacja, wytwarzanie

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摘要：維護，維修和安裝機械設備是一些製造企業中廣泛定義的技術管理實施的基本流程。本文的目的是確定事故的風險，確定總的事故，是致命的，重鏈和輕的發病率的水平，以及要分析的基本操作在事故和事故的主要原因中的維護，維修和安裝的機械和設備的性能的時候進行的。

關鍵詞：安全，事故，維修，生產