PREVENTIVE MAINTENANCE AND OCCUPATIONAL RISKS: CASE STUDY IN AN INDUSTRIAL PRODUCTION COMPANY

ROLAND IOSIF MORARU[*1]

Abstract: In maintenance activities, contrary to normal operation, the direct contact between worker and machine cannot be substantially reduced. Maintenance generally include both disassembly and reassembly, often involving complicated technical equipment. These can be associated with an increased risk of human error, increasing the risk of accidents. From this perspective, this article presents a case study that analyzes the preventive - corrective maintenance system applied in an automatic gearbox manufacturing company, in the context of challenges related to the safety and health of workers exposed to specific risks, providing an example of good practices for specialists in the country.

Keywords: preventive maintenance, occupational health and safety, risk at work, automatic gearbox, prevention and protection.

1. INTRODUCTION

The need for maintenance arises naturally to oppose the forces of degradation and may be the result of an intervention that follows a maintenance or repair plan for the equipment [1]. Cost reduction and the profitability of the industrial process can only be achieved by combining various factors: increasing the reliability of the machine, increasing the safety in operation, decreasing the operating costs, all leading to a total cost efficiency [2]. For decades, industrial companies have largely focused their attention on production, generally ignoring the maintenance function, viewed only as a necessary evil. Recently, a change of attitude has been observed in the way general managers of corporate organizations consider the maintenance function [3].

One of the most important factors that contributed majorly to this change was that maintenance departments became centers of interest in cost evaluation within these organizations [4]. General operating costs usually fluctuate from year to year, but there is potential for significant savings in maintenance departments, which deserves the full

[1] *Prof. Ph.D. Eng., University of Petroşani, roland_moraru@yahoo.com*

attention of any organization's management. [5]. Maintenance is a generic term for a variety of operations in extremely different sectors and in all types of work environments [6]. Maintenance is essential to ensure the continuity of production, to manufacture superior quality products and to maintain the competitiveness of the company, with an impact also on safety and health at work [7]. For companies that have not implemented a preventive maintenance procedure, the costs of operating production equipment can exceed by up to 10 times the costs of a company that has such a well-established preventive maintenance procedure [8].

The advantages of preventive maintenance include a significant increase in the level of safety of work equipment, and thus drastically reduce the incidence of accidents, reduction of losses in the production process, fewer unexpected breakdowns of essential equipment for production and reduced costs regarding possible emergency repairs [9]. However, preventive maintenance also involves a number of disadvantages, including the possibility of excessive preventive maintenance, high implementation costs, the need for more resources in terms of time pieces and personnel [10]. Even in this case, weighing the advantages and disadvantages of implementing a preventive maintenance system, it can be concluded that, in terms of development and long-term and safe operation, it can bring very important benefits [11].

The lack of equipment maintenance, or their improper maintenance, can lead to some particularly dangerous situations, work accidents and even health problems [12]. One of the requirements of a proper management system at the level of an organization is that the maintenance process starts from the planning stage of a work equipment, before the personnel trained in this sense are present at the workplace [13]. Maintenance operations necessarily require the implementation of appropriate risk assessment procedures, as well as the adoption of preventive measures to ensure the safety and health of workers involved in maintenance activities [14], [15].

At the completion of the maintenance activities undertaken on a work equipment, special checks and tests must be carried out, to ensure the proper performance of the maintenance and the avoidance of new risks. Throughout the process, proper maintenance management must ensure that maintenance is properly planned, coordinated and carried out according to plan and that the equipment or workplace is left in a safe condition for continued operation. Even though maintenance operations can be dangerous to the workers who perform them, with the worst workplace accidents involving maintenance personnel, the absence of maintenance activities can expose many more workers to risk. Some of the major causes of occupational accidents and diseases are poor maintenance activities and unsuitable working environments [16].

2. RELEVANT ASPECTS CONCERNING THE MAINTENANCE ACTIVITY

2.1 Types of maintenance and their correlation

Maintenance represents the set of associated technical and organizational actions that are performed in order to maintain or restore a system in a state to perform its specific functions [17]. Its purpose is to restore the system to working order in the shortest possible time by replacing, repairing or adjusting the component or components that caused the interruption of operation. In another, more comprehensive sense, several types of maintenance are recognized [18]:

i. ***Preventive maintenance*** is the set of all actions performed at well-determined time intervals, in order to reduce the probability of failure or the degradation of a system's performance. The main purpose of preventive maintenance is to reduce the risk of a sudden failure.
ii. ***Corrective maintenance*** is the maintenance carried out after the occurrence of a failure, in order to restore the working state of a system. The main purpose of corrective maintenance is to eliminate malfunctions or sudden failures (breakdowns) that occur untimely.
iii. ***Maintenance by system status*** requires partial or total monitoring of machine operation and intervention by maintenance actions only when the monitoring system indicates this. It is an expensive system but lends itself very well to systems of major importance or vital components in a piece of equipment.
iv. ***Proactive maintenance*** is based on establishing the causes that cause systems to fail and paying more attention to that side.
v. ***Reliability-centered maintenance*** involves the inclusion in maintenance programs of actions on critical components, in the sense of preventing their reliability level from falling below a well-established threshold. It also aims to lower the lifetime cost of the equipment.

Presented in another form, maintenance is expressed by:

- times for repairs, revisions and downtime, for carrying out preventive or corrective maintenance actions;
- the number and level of qualification of the personnel required to carry out the maintenance actions;
- detailed instructions, such as user manuals or technical books, which guide the detection of a fault, the algorithm of its search, as well as the performance of maintenance actions;
- ***work safety instructions***, necessary to be taken into account during maintenance actions;
- the general organization of maintenance activities, recognized according to the situation and as service activities.

Of great economic importance, for the correct exploitation and maintenance of products, is the organization of service units, which ensure their systematic maintenance.

2.2. Maintenance strategies and influencing factors

The maintenance activity of a technical system must be organized in such a way as to obtain the highest possible availability of it, with the lowest possible maintenance costs. In this sense, the adopted maintenance strategy is of particular importance [19]. Within the maintenance strategy it must be established [20]:

- the frequency of preventive maintenance actions (time interval between actions);
- the operations to be performed within the preventive maintenance action;
- the time allocated to the maintenance action.

The most effective maintenance strategy is the one that ensures the shortest periods of immobilization of technological installations, for restorations with minimal expenses. In current practice, several maintenance systems are applied, the most important being:

- the corrective maintenance system;
- the preventive-planned maintenance system;
- complex maintenance system;
- the palliative maintenance system.

The factors influencing the maintenance of technical systems are [21]:

a. Accessibility for maintenance
b. Dismantability
c. Interchangeability
d. Standardization and typification
e*. **Safety at work***

Workers performing maintenance activities may be at risk of:

- ***musculoskeletal disorders*** (MSD's), when performing tasks that require bending and awkward positions, sometimes in difficult environmental conditions (for example, cold);
- ***respiratory problems*** related to exposure to asbestos – in the maintenance activities of buildings or old industrial facilities;
- ***skin and respiratory diseases*** caused by contact with hazardous substances – fats, solvents, corrosive substances and dusts, including carcinogenic wood dusts;
- ***asphyxiation in closed spaces;***
- ***diseases caused by exposure to biological risks*** – hepatitis A, legionella.

Workers are also exposed to many types of injury risks, including falls from height or hits caused by a component of a machine, electrocution, falling from the same level, etc.

2.3. The preventive-planned functional maintenance system

The preventive-planned periodic functional maintenance system, whose objectives are summarized in table 1, is interposed, in certain situations, for certain aggregates and installations, between the current functional maintenance system and that of technical revisions and repairs. The system is based on the prevention of failures with a certain probability, which allows knowing, before the occurrence of failures, the parts that need to be replaced [21].

Table 1. **Preventive-planned maintenance system**

Objectives of the preventive-planned functional system	**The fulfillment of the objectives is done through:**
Avoiding the aging of productive fixed assets and extending their life span.	Periodic checks and the introduction of functional restrictions. Partial and general revisions with the replacement of worn parts. Lubrication on time, of quality and according to requirements. Correct and permanent operation of all devices, indicators, limiters, etc. The effective establishment of the RK period depending on the technical condition of the productive fixed funds and the anticipated preparation
Maintaining the yield of productive fixed funds at the parameters given by the builder.	The mechanization of the work of fastening and loosening the parts, their transport, their handling, etc. The automation of some operations, the indication of some control, signaling and shutdown parameters.
Elimination of accidental stops.	Adjustments, checks, revisions, replacement of worn parts, devices, indicators and blocked limiters.
Reduction of repair costs of productive fixed assets from the endowment.	Refurbishment, repair and reuse of used parts. Carrying out border operations and works, but on time. Introducing the preventive work system through detection, deduction, replacement of parts before breakdowns. Maintenance of all mechanisms in working condition, reducing the number of parts to be replaced during repairs.
Continuity in operation of productive fixed funds.	Through early preparations and quick interventions. Sole, direct and material responsibility. The production link of the electromechanic and the locksmith-mechanic (part of the same team).
Increasing the quality of production.	Maintaining working parameters by adjusting, checking, replacing defective devices. Training of service personnel.
Increasing the safety in operation of productive fixed funds.	By adjusting the parameters of all mechanisms. Adjustment of drives, automatics, limiters. Through self-endowment of specific AMCs.
Creating limit stocks of spare parts, avoiding slow-moving or non-moving stocks	By knowing the parts on machine groups that have fast, medium and slow wear. By making the spare parts according to the wear schedule.
The creation of strong parts reconditioning sectors and their profitability after reconditioning.	By sorting used parts. The choice of reconditioning technology. The actual refurbishment. Entering warehouses as good parts
Reducing the consumption of energy, fuels and lubricants.	By establishing consumption per equipment. Their judicious management. Eliminating any form of waste or extra consumption .
Balanced use of labor in the maintenance bases.	By nominating concrete tasks to be solved. By increasing responsibility due to the individualization of work. By applying incentive forms of remuneration. By integrating each person into directly productive work formations.

3. RELIABILITY CENTERED MAINTENANCE

Reliability-centered maintenance (RCM) has been applied for more than two decades, first in the aviation industry and later in the nuclear, defense, oil and gas, and many other industries. Experiences from these industries show significant reductions in preventive maintenance costs while maintaining or even increasing system availability [22].

Some researchers consider reliability-centered maintenance the final stage of the complex maintenance program, which integrates all types of maintenance: preventive, predictive and proactive, with all the responsibilities that arise at each stage. All three types of maintenance (preventive, predictive and proactive) must be exploited to the maximum for the integrated system to become fully functional [23].

The main steps of an RCM analysis are as follows:

Stage 1. Analysis preparation: before starting an RCM analysis, the analysis group must be established which can be made up of: manager, operator supervisor, engineering supervisor, external specialist (technical or process) and 1-2 helpers (operator, tradesman). In the first stage, the objectives and purpose of the analysis must be defined and clarified.

Step 2. System selection and definition: in principle all systems can benefit from an RCM analysis. But given the usually limited resources, priorities are set. It will start with the systems that will benefit the most from RCM analysis. Systems can be divided into subsystems, etc.

Stage 3. Analysis of functional decline: the objectives of this stage are:

- identify and describe the functions required by the system;
- describe the input interfaces required for the system to work;
- identify how the system might not work.

Step 4. Selection of critical elements: the objective of this step is to identify the analysis points that are potentially critical in relation to the functional failures identified in step 3. These analysis points are called important functional elements.

Step 5. Data Collection and Analysis: reliability data includes:

- average operating time until failure or between failures (MTTF or MTBF);
- average repair time (MTR);
- fall rate $\lambda(t)$.

Several random variable distribution models are available, such as: Weibull, normal, exponential, lognormal, etc. The most used model is the Weibull.

Stage 6. Failure Mode, Effects and Criticality Analysis (FMEA/FMECA): the objective of this stage is to identify the dominant failure modes of the maintenance of significant elements, identified in stage 4.

Step 7. Selection of maintenance actions: This step is the most novel compared to other maintenance planning techniques. A logical decision is used to guide the analyst through the question-answer principle. The input to the RCM logic decision is the dominant failure mode from the FMECA in stage 6. For each dominant failure mode it is decided whether preventive maintenance work is applicable and effective, or whether it is better to deliberately let the element operate until failure and then carry out corrective maintenance work. Figure 1 shows a model of a decision logic diagram.

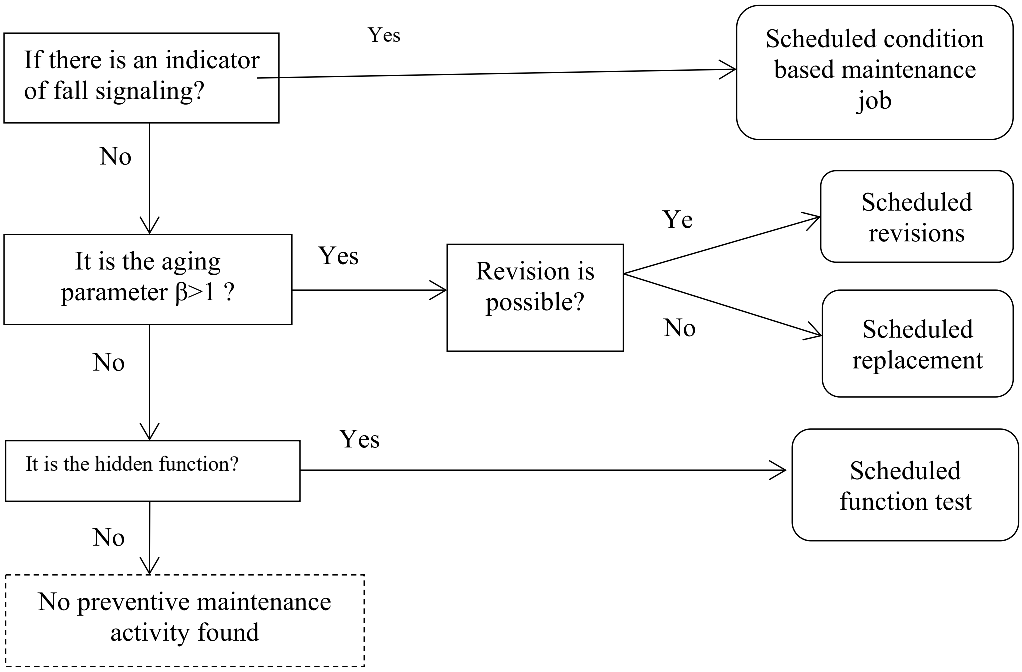

Fig. 1. Allocation of maintenance work/logical decision making

Step 8. Determine maintenance intervals: Many of the preventive maintenance jobs should be at regular intervals. In practice different maintenance works should be grouped into repair packages that are executed at the same time or in a specific sequence.

Step 9. Comparative analysis of preventive maintenance: each selected work must meet two requirements:

- must be applicable;
- must be effective.

Applicability means that the work is applicable in relation to our knowledge of reliability and in relation to the consequences of falling.

Stage 10. Handling the maintenance of insignificant elements: in stage 4, the critical elements were selected for analysis. There is the problem of what to do with the elements that are not analyzed. A maintenance program already exists at plant level, so a cost estimate can be executed.

Step 11. Implementation: experience shows that many accidents occur either during maintenance or due to poor maintenance. When the implementation of a maintenance program is of ***vital importance consider the risk associated*** with various maintenance works.

Step 12. Collect and update data: reliability access data at the start of the analysis may be scant or non-existent. The full benefit of the technique is achieved when operating experience and maintenance are fed back into the analysis process.

4. FAULT DETECTION TECHNIQUES, TECHNOLOGICAL SELECTION AND RISKS/HAZARDS RELATED TO MAINTENANCE IN INDUSTRIAL WORK ENVIRONMENTS

The key factors for successful health monitoring and repair intervention are:

- Selection of appropriate technology;
- Monitoring the causes of the breakdown and its symptoms;
- Establishing an appropriate monitoring frequency;
- Ability to understand results and trends;
- Methods and programs for storing and analyzing information;
- Establishing appropriate limits and alarms;
- Technology update;
- Integrating technology within the organization;
- Quantification of program benefits;
- Education and professional certification in order to apply the adopted, appropriate program.

Vibration analysis: is one of the most used methods for detecting and diagnosing defects in electromechanical systems. With this method, the vibrations of the system are measured, usually with an accelerometer, after which the generated frequency spectrum is examined in order to identify the significant frequencies from the point of view of the state of the machine. Certain frequencies are specific to the system in normal operation. Changing the amplitude of certain harmonics, for example, can mean the presence of a defect. Data can be collected periodically, using a portable system, or continuously, installing a continuous monitoring system. Through vibrations, defects can be detected such as: imbalances, bearing problems, structural resonance, rotor defects in electric machines, eccentricities. The measurements are fast and non-invasive, the operation of the tested system not being disturbed.

Temperature: is an important indicator of the mechanical, electrical conditions or the load applied to a certain component. For example, friction in a bearing causes the temperature to rise. By installing thermocouples in the bearing housing and measuring the temperature changes, the presence of problems can be determined. Maintenance can be scheduled to avoid a more serious problem.

Thermography: is the use of an infrared camera to visualize and measure the thermal energy emitted by an object. Thermal energy is a part of the electromagnetic spectrum that cannot be detected by the human eye, but is perceived as heat.

Lubricating fluid analysis: can be used to determine mechanical wear conditions, lubrication conditions or fluid condition. The presence of metallic particles in the lubricating fluid suggests the existence of wear, their analysis providing information on the part subject to wear. Acidity of the fluid shows either oxidation due to high working temperatures, or contamination with water particles or its long use.

Viscosity is also an important parameter and must be in accordance with that specified in the manufacturer's data. Alkalinity or its loss proves that the fluid is in contact with inorganic acids such as sulfuric or nitric acid.

Ultrasonic noise detection: can be used to determine liquid or gas leaks. When a fluid passes from an area of high pressure to one of low pressure, ultrasonic noise is produced due to turbulent flow. The detector converts the ultrasonic noise into noise in the audible range. Inspections are usually done semi-annually or annually. The measurement of the complex impedance, the insulation resistance, the harmonic spectrum analysis of the phase current, or the leakage flux, are some methods used in the diagnosis of electric drive systems. The main defects that can occur in electric drive systems refer to problems related to the bearings of electric machines, short circuits of the windings, broken bars, inhomogeneous cores, etc..

The technology depends on several factors that must be followed: the type of equipment, the way of diagnosing the defect and the value of the investment. The maintenance technology in a centralized, general form can be found below, in table 2. (*Maintenance algorithm*), from which the executor must adapt the appropriate maintenance technology. The need for maintenance arises naturally to oppose the forces of degradation and can be the result of an intervention that follows a plan of maintenance or repair of the equipment. Cost reduction and the profitability of the industrial process can only be achieved by combining various factors: increasing the reliability of the machine, increasing the safety in operation, decreasing the operating costs, all leading to a total cost efficiency.

Table 2. **Maintenance algorithm**

0	Operating periods	Management of information/results/checks	Human resource calculation procedures	Finding and fixing defects/extending resources
	Number of starts			
	Operating faults			
	Normal maintenance			
Engine performance	Engine parameters		Calculation procedures and comparisons	
	Atmospheric conditions			
Operating parameters	Evolutions over time		Comparisons settings	
Transitory regimes	Diagram of evolutions over time		Comparative analyses	
Engine vibration	Global values		Correlations and interpretations	
	Vibration spectra			
Oil quality	Metallic residue			
	Chemical analysis			
Engine systems	Wear of elements		Resource calculation procedure, settings	
	The level of displacements			
	Gear resources			
	Functionality			
Air intake	Pumping limits		Comparisons	

Inner integrity	Boroscopies		Interpretations and comparisons	
	X-rays			
	Feedback (response control)			
Internal movements	Direct measurements		Comparisons	
	Using specific tools			
Local overheating	Thermography		Interpretations and comparisons	
	Oil cooling in bearings			
	Flue gas temperature field			
Quality of combustion gasses	Checking the spraying of the injectors		Interpretations and comparisons	
	Chemical composition of combustion gases			
Overall engine integrity	External visual inspection		Analysis interpretations and comparisons	
	Manual rotation			
	Spectrum and noise level			

Maintenance activities can cause injury to workers and other employees in three main situations: during maintenance, an accident/injury can occur – for example, workers repairing a machine can be injured if the machine is accidentally started, in if they are exposed to hazardous substances or have to work in uncomfortable positions; improper maintenance work, for example, when using unsuitable spare parts for replacement or repair, can lead to serious accidents; failure to carry out maintenance work can not only shorten the life of equipment or buildings, but also cause accidents – for example, unrepaired damage to a warehouse floor can cause an accident involving a forklift, injuring the worker(s) and, at the same time, property damage.

Maintenance work is undertaken in all sectors and by almost any employee – it is not the exclusive domain of maintenance technicians and engineers. For this reason, workers who perform maintenance work are exposed to numerous dangers – chemical, physical, biological or psychosocial (fig. 2). They may be at risk of:

- musculoskeletal disorders, when working in uncomfortable positions, sometimes also in unfavorable environmental conditions (for example, cold);
- exposure to asbestos – in the maintenance activities of buildings or old industrial installations;
- asphyxiation in closed spaces;
- exposure to chemical agents (eg grease, solvents, corrosive substances);
- exposure to biological hazards – hepatitis A, Legionella;
- exposure to dust, including carcinogenic wood dust;
- accidents (of any type, including falls or detachments from a point, as well as blows caused by a component of a machine).

Fig. 2. Improper maintenance work

The maintenance process begins with the design and planning stage, of which they are key aspects:

- allocating a ***sufficient time*** interval ***and*** sufficient ***resources*** for the maintenance work;
- ensuring the ***training and skills of the maintenance staff***;
- ***introducing safe work systems based on a proper risk assessment***.

Guidelines must also be followed and records must be kept. After the completion of the maintenance work, special checks (inspections and tests) must be carried out to ensure the appropriateness of the maintenance work undertaken and the safety of the equipment or the workplace for continued operation.

The development of monitoring and diagnosis techniques and their implementation on industrial systems ensures their safe and high-performance operation, with positive effects on reliability, productivity and labor protection. Through the method of vibration analysis, it is possible to identify various defects that may appear in the gears of the machine tools. If the parallelism or perpendicularity of two machine parts is mounted differently, during operation, time-varying tensions appear, which will produce vibrations. During the operation of the gears, they wear differently, thus the surface in contact changes, the force is distributed differently in space and time and vibrations are produced.

5. CASE STUDY: STRUCTURED PREVENTION APPROACH AT AUTOMATIC GEARBOX LLC

5.1. Description of Automatic Gearbox LLC

The company Automatic Gearbox LLC has been operating since 2010, being registered with CAEN code 2815 - *Manufacture of bearings, gears, gearboxes and mechanical transmission elements*. The main field of activity is the assembly of gearboxes for cars, being an international supplier of components for the automotive industry. Currently, the company owns 2 production halls, where gearboxes are assembled over an area of 3 hectares. The total number of employees working in the company is 500. The company has outsourced its logistics processes, so that 2 external companies also work within it. Being in continuous development, in one of the production halls, a number of 4 external suppliers, with a total of 80 employees, are also working, responsible for the implementation of a new project. Their activities include the assembly of new production lines.

Within the already existing projects, the work equipment was ordered based on specifications, which include all the applicable safety at work standards and the machinery directive. The equipment is new, and at their reception, managers from each department participated, including OSH managers. The work equipment used is organized in the form of production lines, which include manual stations, semi-automatic stations and automatic stations. All equipment is equipped with protective devices, according to the risk assessment prepared by the supplier, and the safety concepts defined in the specifications. The protective devices are checked periodically, according to the maintenance plans recommended by the suppliers. According to the internal organizational chart, the company's employees work in 4 departments: *Assembly, Maintenance, Quality, Building Maintenance*, plus the *TESA* departments.

Regarding the organization of the Health and Safety at Work department, it is directly subordinated to the employer. At the company level, an Internal Prevention and Protection Service is formed, with a service coordinator and 2 designated workers. Health surveillance activities are carried out on the basis of a contract with a service provider, which provides occupational medicine services on the company site.

Within the company, 11 jobs were identified, as follows:

- Assembly;
- Robotic station;
- Final assembly and verification;
- Product sorting;
- ***Electrical maintenance;***
- ***Mechanical maintenance***;
- Logistics;
- Quality audit;
- Quality control and complaints;
- Building maintenance;
- TESA.

For each workplace, risk assessments and prevention and protection plans were drawn up, according to the legislative norms in force. They are updated whenever necessary. The general risk level for the company is 3.23. Also, for each workplace, separate occupational health and safety instructions were drawn up. They are used in staff training, which takes place according to the annual training schedule. Periodic trainings are scheduled 4 times a year for direct and indirect productive staff, and 1 time a year for TESA staff.

5.2 . Maintenance operations at Automatic Gearbox LLC

Machinery and equipment maintenance is carried out in accordance with the maintenance manual specific to each individual intervention. Preventive maintenance is carried out: weekly, monthly, quarterly, half-yearly and annually. Maintenance activities will be performed only in accordance with the provisions mentioned in the technical book of the equipment and the internal rules. The necessary operations are carried out in safe work conditions, knowing the risks of exposure to accidents. Preventive maintenance includes the periodic check of the safety elements that the equipment is equipped with (emergency buttons, interlocks, doors/windows/protective covers, optical barriers, etc.).

➢ **Preventive maintenance**

The first step in carrying out the maintenance activity will be that of appropriate signaling, by marking the perimeter with the help of signaling poles and using the pictograms of the type of intervention (fig. 3).

Fig. 3. Maintenance intervention icons

Work equipment and personal protective equipment will be worn.

The weekly preventive maintenance steps for the Baumann Automatic Fuse Insertion Cell are:

- ➢ Checking the safety elements of the equipment;
- ➢ Restart computers serving the line;
- ➢ The cell as a whole is checked to detect major faults;
- ➢ Check the pneumatic elements that make repeated movements (cylinders, grippers), clean and grease the guides of the pneumatic cylinders only with special lubricants (fig. 4);

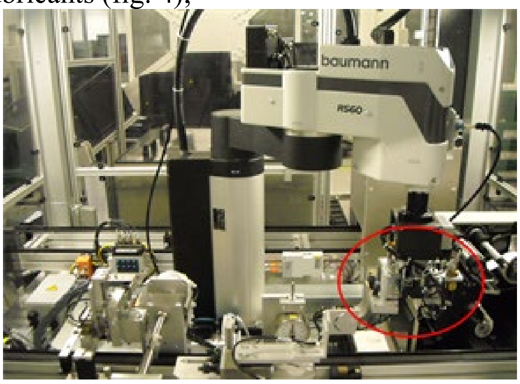

Fig. 4. Check pneumatic elements

- The condition of the sensors is checked (fig. 5);

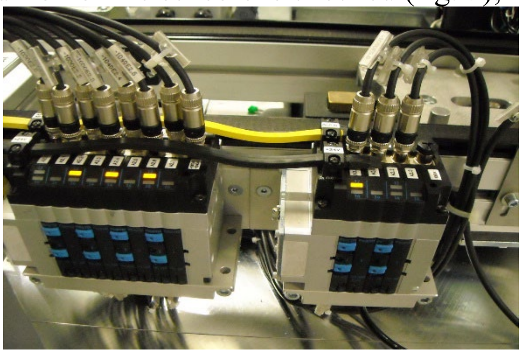

Fig. 5. Sensors check

- Screws that show wear or that do not correspond to the profile are replaced;
- The filters of the air conditioner are checked and they will be cleaned/changed if necessary;
- Check the condition of the belts on the conveyors and grease the bearings on the moving rollers;
- Dust and possible residues resulting from the production and maintenance process are vacuumed.

The stages of monthly preventive maintenance are:

- All weekly maintenance operations are completed;
- Change the worn rollers from the conveyors and change the worn bearings (fig. 6);

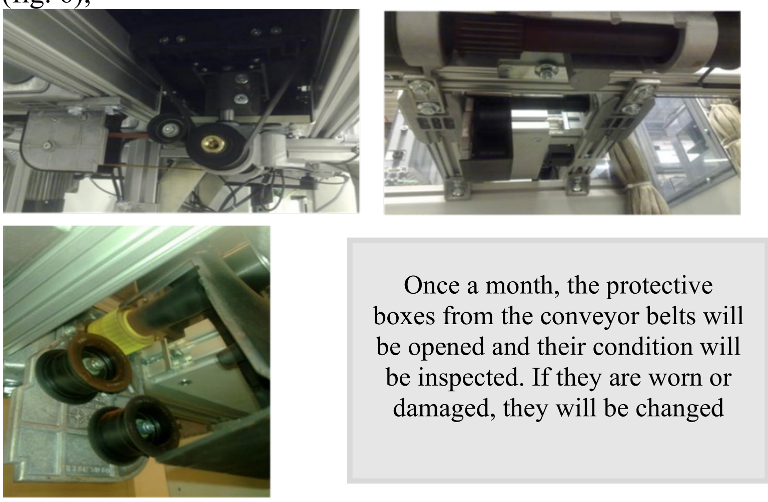

Fig. 6. Change conveyor rollers and worn bearings

- Conveyor motors and worm wheel system are checked;
- All air filters are cleaned;
- Change the air filter from the general valve;

- Optical sensors and scanners are cleaned;
- All indicator lights are checked.

The stages of quarterly preventive maintenance are:

- All monthly maintenance operations are completed;
- Open the protective covers and clean all the conveyor belts (fig. 7);
- The bearings will be changed in case of wear;
- The speed reducing mechanisms will be wrong (the worm wheel -worm system).

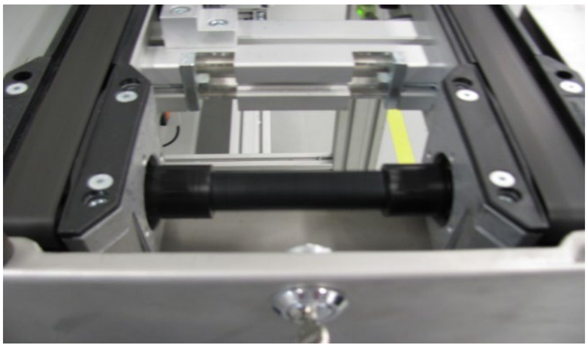

Fig. 7. Cleaning conveyor belts

For the ***half-yearly maintenance***, all quarterly maintenance operations will be performed.

The stages of ***annual maintenance*** are:

- Se parcurg toate operațiile mentenanței semestriale;
- Damaged air ducts are changed;
- Damaged electrical cables are changed;
- The pneumatic cylinders are checked and replaced;
- Linear guides and linear bearings are replaced;
- Unfold the robot arm and lubricate the guides and pistons (fig. 8);

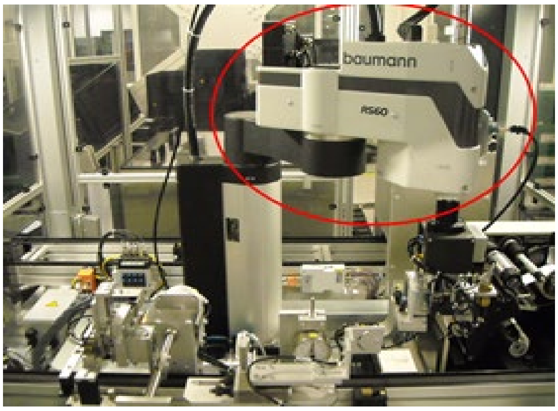

Fig. 8. Lubrication of guides and pistons of the robot arm

- Check the communication of the sensors with the PLC and the PC (fig. 9).

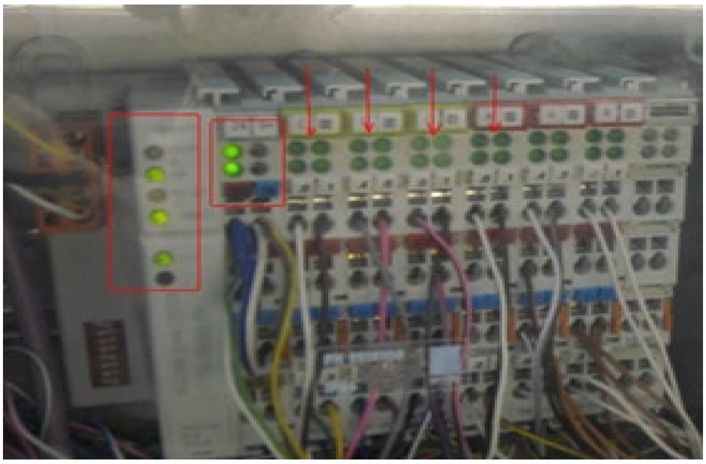

Fig. 9. Checking sensors with PLC and PC

6. CONCLUSIONS

Accident prevention is a multidisciplinary field that must consider all components of work and apply different sciences such as organizational sciences, engineering and human sciences. Through the importance they have for the productive flow, through the consequences they can generate on the health and safety of workers as well as through the substantial financial value, industrial equipment represents one of the basic elements of any work system. In an industrial company, maintenance has direct and indirect objectives of supporting production and management processes. Maintenance improves the safety of the entire production by preventing production interruptions and by helping to control the impact on the environment so that the components and parts of the technical system maintain their normal performance. An error in maintenance operations can jeopardize all these benefits and become a source of injury, hazardous to human health, production and/or the environment.

Maintenance influences the safety and health of workers. Apart from the risks associated with any work environment, maintenance operations involve some specific risks. These include working near an ongoing process and in direct contact with technical equipment. During normal operation, automation generally reduces the likelihood of human error that can lead to accidents. In maintenance activities, contrary to normal operation, direct contact between worker and machine cannot be substantially reduced - maintenance is an activity in which workers must be in contact with processes.

Maintenance involves special works, the activities it involves are often out of the routine and is sometimes carried out under exceptional conditions. Maintenance operations generally include both disassembly and reassembly, often involving complicated technical equipment. These can be associated with an increased risk of human error, increasing the risk of accidents. Maintenance also implies a frequent change of operations and work environment. Working under time pressure is also typical of maintenance operations, especially when outages or priority repairs are involved.

Maintenance workers are much more exposed than other categories of workers to a wide range of hazards – chemical, physical, biological and psychosocial. The effects on their health can be acute or chronic and can include occupational disease, serious injury or death. The risk of occupational accidents during maintenance activities is high. Many of the work accidents are caused by maintenance activities of work equipment and installations. Typical accidents associated with maintenance include falls from height, electrocution, amputations, crushes, accidents involving falling objects and sometimes even death.

In order to manage the sources of accidents in maintenance operations, they must be identified based on potential and materialized accident sources and possible chains of events. Relevant information can be collected through risk assessment, accident or risk data. When assessing risks in industrial maintenance, holistic attention must be paid to variations in tasks, human performance and the work environment including the system being maintained.

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