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The practical application of the machinery management

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ABSTRACT

Purpose: In the paper the problems of equipments and machines management in the automotive company are analyzed based on Total Productive Maintenance and World Class Manufacturing Methodology (in particular Early Equipment Management, Autonomous Maintenance and Professional Maintenance) and PN-EN ISO 9001:2009 norm and also ISO/TS 16949. Benefits of infrastructure management are submitted. The creation of a new procedure for the management of machines was the purpose of this article.

Design/methodology/approach: A new procedure of equipment/machines management was elaborated based on analysis of norms requirements and the practical application of the TPM and WCM methodology. Selected infrastructure management methodologies are presented for specific work, losses and failures resulting from the use of machines and equipment in automotive company.

Findings: The analysis of obtained results in the project management methodology (Total Productive Management, World Class Manufacturing: Early Equipment Management/ Professional Maintenance/Autonomous Maintenance) and selected points of norms (ISO 9001 and TS 16949) in relation to machines and equipment allowed to elaborate the procedure of equipment and machines management in order to prevent losses, deficiencies and failures in the automotive company.

Practical implications: The practical application of TPM methodology, selected pillars of World Class Manufacturing, requirements of ISO 9001 norm allowed to improve the quality of machine and allowed to provide the reliability machines and equipment for uninterrupted production, resulting in reduced manufacturing costs.

Originality/value: In the paper was created a new procedure, which was used in automotive company.

Keywords: Management systems; WCM; Automotive company; TPM; Machines; Equipment; Product technology

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MANUFACTURING AND PROCESSING

1. Introduction

XXI century is a period of global competition increase in the global industry, especially in investment products group like machines, devices or complete installations. Competitive actions among companies are and still will be carried in a global manner. Studies indicate that in the near future the competition will still grow up in products and services segment. The present economic development is considered as an innovation era. Dynamic change of customers requirements is increasing. This leads to necessity of effective competing in each aspect of business and this needs changes also in the area of infrastructure (machines and equipment). Changes form the strongest element in management process. Changes are absolutely bound with innovation, which can be related to four basic types of management shown in the Figure 1 [1,2].

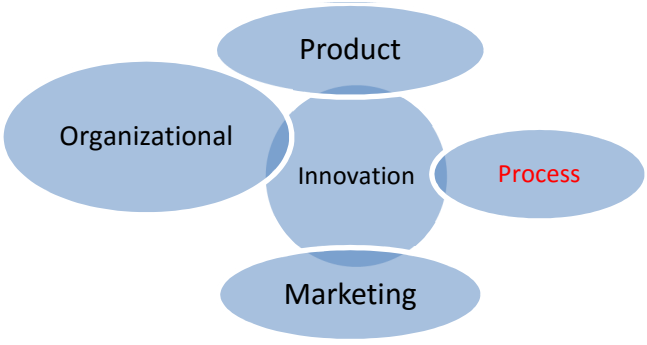

Fig. 1. Types of innovation [1]

One of innovations is technology innovation. It is the change in methods and production techniques used by the company. Changes can concern equipment, machines or production organization. They could be connection of those both kind of changes or could be the result of usage of new method, tool or production technique. The purpose of those changes is increasing of productions efficiency and effectiveness. An example of process innovation could be usage of new method or production technology, i.e. automatization of production line [1,2].

J. Penc defines the innovation as a creation or modifying the techniques and action methods except processes and products [3]. Those innovations are considered by the companies as a new and progressive action which leads to increase effectiveness of company's resources usage. In order to assure significant increase of innovation the companies must implement appropriate infrastructure management methods [2].

2. Assuring the continuity of production management

Assuring the continuity of production process is very important aspect in respect of modern requirements of market competitiveness and penalties for delays due to lack of punctuality in products deliveries to the end-user.

The company which wants to be competitive on the market has to manage the production process in well-considered way, both in range of internal solutions related to resources and processes management and considering the company as one of the links in production chain [2,4].

In range of internal aspects of production continuity management the most important are [2]:

- human resources management – ensuring of adequate number of employees for ensuring required action effectiveness in company, fluctuation analysis/absence, in practice this issue is realized weakly and it is limited to the personnel rotation model on workstations and it doesn't solve the problem,
- infrastructure management, in particular this which is related to production processes and this with influence on products quality, production load scheduling, if it forms important data for calculate production cycle and company's production ability, this definition of planned services, revisions or servicing actions regarding machines and equipment is very important criterion in company's resources management. Very important aspect in this range is data acquisition about machines and equipment breakdowns which has the purpose of taking appropriate preventive actions,
- management system, allows to determine suitable behavior procedures in resources management range and to minimize probable production process discontinuity.

Each production line downtime is connected with cost bearing. Only those downtimes are accepted which are results of planned actions including preventive actions.

Production process continuity management is fully related to appropriate resources management regulations.

The criteria related to production process continuity can be characterized as follow [2,4]:

- time – time-consumption of operation decides about processes efficiency, it comes out of technical abilities also in operational manner, operation time range needed for production readiness,
- cost – machines maintenance costs, breakdowns costs, improper infrastructure management costs, machines and equipment maintenance training costs, requirements fulfilling costs in range of machines and equipment

maintenance safety as well as environment requirements regulations,
- quality – number of lacks generated by certain machine in relation to loss of metrologic characteristics, level of offered realized operation's quality including product's quality forming.

3. Resources management

The company is the set of resources. Efficient and effective operation is conditioned by appropriate resources control focused on designated targets achievement.

Resources functions in company are related to [5]:
- support and goods/services production,
- changes in resources, they inform about production processes.

Company's resources coordination allows to achieve designated targets. Resources use by company can be divided into 5 types shown in Figure 2 [5]:

Fig. 2. General distribution of resources [5]

Human – organization's employees, crucial meaning has [6]:
- employment structure (sex, age, professional qualifications, seniority, education),
- personality (experience, expectations, contacts, intelligence level, values, creative abilities,
- motivation, needs, preferences.

People unlike other resources can't be the company's property. Human resource becomes company's intellectual capital [6]. This resource has a special meaning in infrastructure management, because this is related to trainings and gaining of new qualifications and abilities by the employees.

Financial – financial capital is used by the company for current operation and for the future development. One can distinguish [5]:
- cash,
- credits,
- deposits,
- shares,
- profits.

Financial fluency of companies and capitalization of profits is one of the most important criteria, allowing to investments in range of infrastructure.

Material – fixed assets of the company, infrastructure [5]:
- buildings, rooms, halls, warehouses,
- machines and equipments,
- transport,
- materials and resources,
- surrounding infrastructure.

Infrastructure maintenance of the company is one of the most important criteria allowing to keep status quo of its activity.

Organizational – resources related to process and technology and company's management system [5]:
- tools, methods and management techniques,
- planning system,
- communication system,
- control, evaluation and motivation system.

In range of organizational's resources it is important to separate Maintenance Department which is going to supervise the infrastructure process management.

Informative – numerical and qualitative data from external and internal surrounding of the company, used in decision process regarding management [5].

On company's scale, resources can be divided into [5]:
- fixed assets – machines and devices supporting production process,
- current production – engaged factors into unfinished production,
- resources stock,
- goods stock,
- financial reserves.

One of the most important resources in the company are fixed assets. Management of the fixed assets starts from determining the need, then the project, technological study, manufacturing and use. During managing the fixed assets one should use such solutions which allow cost reduction along with minimum consumption. It is important to manage the fixed assets by reproduction of used fixed assets,

modernization, systematic inspections and repairs as well as taking care about modernity of existing machines and equipment [7,8].

Fixed assets managing process is connected with machine or equipment life cycle along with taking into consideration each stage from purchase, through usage, withdrawing and liquidation. Fixed assets management allows to systematic adaptation of company to changes in technology, organizational and production process as well as to market requirements [7,8].

4. Requirement of the infrastructure management

Infrastructure management is related to acceptance of appropriate criteria and their fulfillment. In that case companies can fulfill the requirements of the ISO 9001 norm [9].

Basic assumptions are related to efficient use of resources and influence of resources on quality of realized processes and as a result delivered goods and services. In range of infrastructure management one should point out the relationship between infrastructure management - machine park and the manufactured goods [9].

Chapter 6 of the ISO 9001 norm defines requirements applied directly to infrastructure - point 6.3. Those requirements are relating to define the requirements' range by the company. Norm determines that the infrastructure management is first of all related to planning, machines and equipment maintenance assuring which have influence on quality of offered product [9]. Requirements related to infrastructure taking part in production process are mentioned in point 7.5.1 of ISO 9001 norm, which describes the requirement of appropriate equipment usage in production process. That guarantees getting defined quality parameters of the product which is related to assuring the required machines' metrological characteristic [9].

In technical specification of ISO TS 16949 intended for automotive industry the requirement range has been particularized [10].

Each process realized in the company should characterize a specified efficiency. This is related to support processes including infrastructure management, described in point 5.1.1 of the ISO/TS specification.

ISO TS describes many requirements related to infrastructure management [10]:

- at planning stage – point 6.3.1 Planning the facility, machines and equipment. Determined obligations for organization in range of study the facility plans, including layouts which should optimize the media transport, product treatment and usage of production area as an added value, allowing the synchronized flow of the materials. Organization should have elaborated and implemented evaluation methods and effectiveness monitoring of existing operations. This solutions should base on so called lean manufacturing approach (Lean manufacturing) as well on connection with effective quality management system. During the planning stage organization should have emergency action plans in case of unexpected occurrence like breakdown of key equipment to guarantee the fulfillment of production process requirements – ISO TS 6.3.2.

  Emergency action plans [10]:
- in range of infrastructure and machines and equipment safety usage the organization is obliged to minimize the risk according to point 6.4.1 of the ISO TS. Accidents have influence on production process breakdowns as well as cleanliness maintenance which in other hand has influence on machines lifetime, risk minimalization. Specification in point 6.4.2 applies to repairs aspect,
- in range of machines and equipment repairs – organization should, according to point 7.5.1.4 of the ISO TS, carry the identification of the key equipment for running the process and to assure resources for machines and equipment repair and elaborate effective system for full preventive repairs, including access for spare parts for the key production equipment,
- in range of production instrumentation management the standard requires in point 7.5.1 that the organization should assure the resources for actions include project, manufacturing and verification of instrumentation and measurement equipment.

Detailed solutions in order to guarantee production continuity have to focus on building the effective process of management infrastructure. Effectiveness guarantees the production continuity. Effectiveness is a measure of infrastructure usage [10].

5. TPM and WCM methodology

5.1. Total productive maintenance

An example of internal process innovation is total productive maintenance (TPM). This methodology allows for maximum and effective use of machines in the company. TPM is used in many international companies and in particular in automotive companies. The purpose of TPM

implementation is reduction to minimum of breakdowns, lacks and unexpected downtimes of production lines [1,11,12].

TPM methodology has been founded in 1970s of XX century in Japan. The first automotive companies which used this conception were Nippon Denso and Toyota [1,13]. The usage of TPM conception improves financial indexes of the company. Improvement of the quality management approach and increasing the production abilities lead to not only maintenance costs reduction but also the operative costs [13].

Proper implementation and usage of TPM allow to develop safer and better organized workstation [1,11].

Implementation of TPM concept contains three phases [1,11,12]:

1. **Phase one – depends on building the program structures allowing to work on changing employees' way of think.**

Phase I – changing the employees' way of think. The first step is to inform all employees about intention of TPM implementation. It is necessary to organize a meeting about all information regarding TPM concept, its meaning in particular company and its advantages.

The second step is about evaluation of present company's situation and determination of point of reference according to implementation of changes for example machines efficiency measurement, numbers of breakdowns and damages, quality level or rearming time. It is also necessary to evaluate the employees involvement. Next step, third, those are informative trainings for top and medium level management, on which the essence of TPM should be presented as well as employees motivation for active participation in implemented changes. Fourth step is about structure creation of TPM. Typical structure includes control committee and TPM cell which includes trainers. The purpose of the control committee is to determine [1,7]: the strategy, policy, targets, measures, marketing, resources, implementation time.

The trainers task it to train the employees, work with teams and active participation during implementation of TPM principles.

Very often TPM cells include maintenance employees who support trainers with their knowledge about machines and equipment. In bigger companies a leader is hired and his task is implementation of TPM concept [1,6].

2. **Phase two – depends on organizing the collective work and to employ the 5S method.**

Phase II – making the teams and employing the 5S tool. Actions in that phase include production. It is important, like in the previous phase, to train managers in the first place and later on the employees. Management should give an example and foresee changes. The first step in this phase is to choose standard area and create teams and use the 5S tool along with it. The number of people in the team depends on company's size but shouldn't exceed several dozen of employees. In turn, each team along with its leader is trained and then they implement 5S method. Motivation for employees could be competition between teams thanks to the mark which determines the usage of 5S on a workstation. First significant results should be noticeable in the first months of usage.

Implementation of TPM program has influence of employees' continuous and to be the complement of priority actions of the company [1,12].

3. **Phase three – depends on tool usage which delivers profits: focused improvement, autonomous maintenance and planned maintenance.**

Phase III – implementation and usage of methods and management tools. The choice of appropriate tool of management methods depends on character of particular company. Often, one chooses several pilot equipment from area in which 5S has been used and then provides trainings for maintenance teams. The first step is about introduction of programs which allows to remove problems which cause defects, damages and lacks which occur in machines or equipment i.e SMED or DMAIC [1].

Methods related to management:

- SMED,
- DMAIC.

SMED (single minute exchange of die) – this method shortens the re-arming time. It is the tool exchange within the one-digit number of minutes. An example of SMED usage is shown in Figure 3 [14].

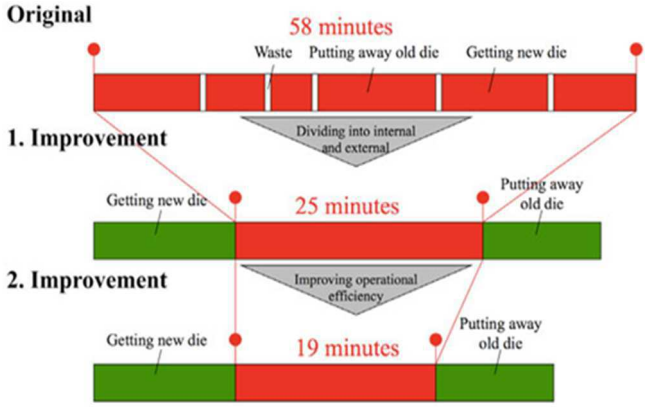

Fig. 3. SMED usage [14]

DMAIC (define – measure – analyze – improve – control) – process improving method and cost reduction. This method of process improving is based on Deming's cycle (Fig. 4). It is systematized and rigorous approach to process improvement consisting of 5 phases. Each phase is logically connected with previous and next phase which is shown in Table 1 [15].

Fig. 4. DMAIC Cycle [15]

Table 1.
DMAIC Cycle [15]

Phase	Typical actions for cycle phase of DMAIC
D	*Defining the problem and starting the project which leads to its solution* • Project plan • Process evidence • Identification, analysis and requirements ranking
M	*Measurement of process performance* • Choice of sizes which have to be measured • Measure plan • Result evaluation
A	*Data analysis and identification of improvement abilities* • Data analysis with use of FMEA, Pareto analysis, Taguchi experiment
I	*Process improvement* • Elaborating and implementation of improvement solutions
C	*Control* • Effects maintenance obtained in result of improvement actions

The next step of phase III of TPM concept is 7-stage autonomous maintenance application. It is based on implementation of new trainings which show teams the targets of next phase and regular machines control. The part of responsibilities is moved to production in range of autonomous maintenance. On the beginning, internal and external general cleaning of machines or equipment takes part with presence of management. Maintenance employees are trained with pilot machines to know how to handle work systematic in their department. Planned maintenance helps the operators conduct the machines to ideal state as well as find the reasons of breakdowns and their elimination, manage preventively with help of data base and to organize the spare part stock. In moment of gaining the experience with pilot machines copying of the same procedure in other company's department takes place [1,11].

TPM provides a life cycle approach to equipment management that minimizes equipment and machines failures, production defects and accidents. It involves everyone in the organization, from top-level management to production mechanics, and production support groups outside suppliers [7,16].

The eight pillar of TPM implementation plan is depicted in Figure 5.

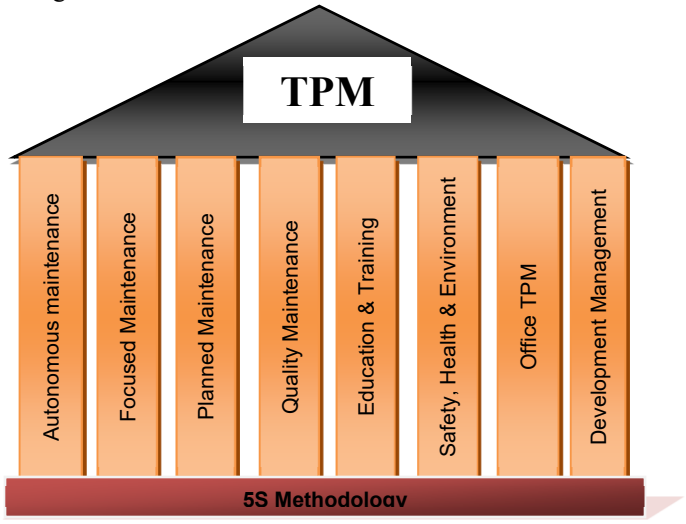

Fig. 5. Eight pillars approach for TPM implementation [16]

Autonomous maintenance [16,17]:

- fostering operator ownership,
- perform cleaning, lubricating, tightening, adjustment, inspection, readjustment on production equipment and machines.

Focused improvement [16,17]:

- systematic identification and elimination of losses,
- working out loss structure and loss mitigration through structured Why-Why, FMEA analysis,
- achieve improved system efficiency,
- improved OEE on production systems.

Planned maintenance [16,17]:

- planning efficient and effective PM system over equipment life cycle,

- establishing PM check sheets,
- improving MTBF and MTTR.

Quality maintenance [16,17]:

- achieving zero defects,
- tracking and addressing equipment problems and root causes,
- setting 3M (machine/man/material) conditions.

Education and training [16,17]:

- imparting technological, quality control, interpersonal skills,
- multi-skilling of employees,
- periodic skill evaluation and updating,
- creation goals with employees.

Safety, health and environment [16,17]:

- implementation standard operating procedures,
- ensure safe working environment,
- eliminate incidents of injuries and accidents.

Office TPM [16,17]:

- apply 5S in office and workstations,
- remove procedural problems,
- improve synergy between various business functions.

Development management [16,17]:

- maintenance improvement initiatives,
- minimal problems and running in time on new machines and equipments.

Implementation and usage of TPM is great undertaking for every company but it brings big profits and effects in company which were not able to get with use of Kaizen or SMED only.

The success of implementation and usage of TPM depend on all employees and particularly on management involvement. If realistic plan of implementation is created, resources and time for implementation are intended. In terms of success management along with employees will actively participate in process improvement actions of implementation. Implementation time should last approximately 3 years. Actions are focused on improvements of existing systems. It is important not to resign from structures nor the trainings and improvement actions because this might lead back to starting point [18,19].

Profits from TPM implementation [1,16]:

- increase of effectiveness during machines and equipment usage,
- change the way of thinking and perceive of employees,
- decreasing number of breakdowns and awareness which cause unplanned breaks in production thanks to regular review of machines and equipment.

5.2. World Class Manufacturing

World Class Manufacturing, (WCM), is a method which assumes the purpose of improvement on a perfect level of company's organizational system operation, to achieve global level of competitiveness.

This is possible only through expansion of qualification and organization able to [14]:

- estimate with wastes and losses,
- engage of all the people who act on each organization level,
- rigorous usage of methodologies and tools,
- spread and standardization achieved results.

Production system evolution assuring, directed on strengthen the competitiveness allow to achieve [14]:

- zero accidents,
- zero defects,
- zero awareness,

which means zero losses in all carried processes.

Necessary elements with WCM implementation [14]:

- knowledge to improve needs and eliminate losses,
- employees engagement who have motivation to solve problems,
- knowledge in WCM scope which has to be processed into particular actions,
- appropriate choice of people and good cooperation is the way to achieve common targets.

WCM is based on 10 technical pillars as shown in Figure 6 [14].

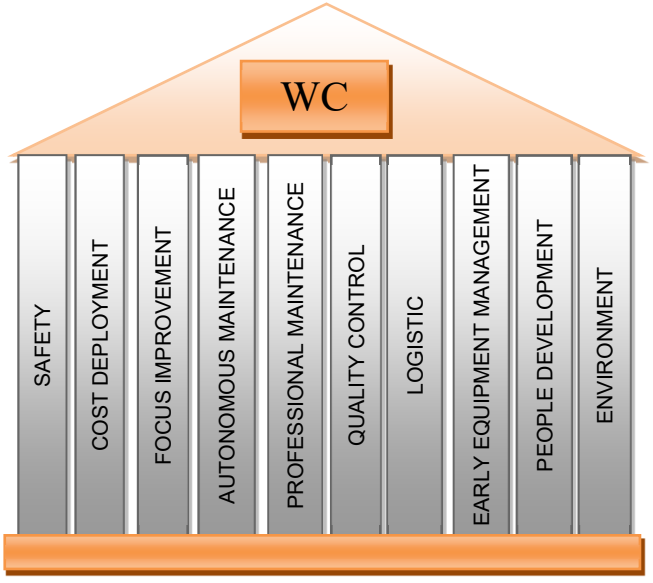

Fig. 6. Technical pillars of World Class Manufacturing [14]

Pillars which correspond to machines and equipment management are:

- Early Equipment Management,
- Autonomous Maintenance,
- Professional Maintenance.

5.2.1. Early Equipment Management

Machines and equipment management in the company creates many problems [14]:

- difficulties in production,
- difficulties in maintenance,
- creation of quality defects which cause the need of repair,
- the need of specialized competence for work with machines/devices,
- safety requirements not always easy to manage.

Those problems cause cost increase, like [14]:

- initial costs and machines' operation costs,
- workmanship costs,
- maintenance costs,
- lack of appropriate quality,
- losses caused by breakdowns.

The purpose of EEM pillar is to create the machines and devices more competitive from continuous improvement point of view and through ability of foreseeing problems which could occur in those machines or devices.

That is possible in moment of designing the new machines/devices thanks to experience gained during the start-up phase and operation of previous or current machines and devices [14].

New base of information of existing devices in particular company should be created. This base of information should be used during designing process of the new devices. Such action leads to problem solving with advance and before start-up the production and in order to shorten the start-up time to minimum.

In short, the EEM purpose is [14]:

- limitation of life cycle cost of device,
- to create reliable device,
- to create device easy to use,
- to create safe device,
- quick start-up of new devices,
- high quality of product.

In order to regularize actions to achieve three basic EEM elements (quality assuring, maintenance and cost reduction), EEM project is realized in 7 steps.

Step 1 – Planning:

- determining the main parameters and product performance,
- project classification,
- main assumptions of production process,
- control according to check-list,
- star-up schedule.

Step 2 – Scheduling:

- determine the LCC (Life Cycle Cost),
- elaborate process' FMEA,
- elaborate the lay-out,
- elaborate device's technical conditions,
- production ability control.

Step 3 – Design:

- detailed elaborate of lay out,
- information analysis from maintenance prevention,
- testing of various equipment variants.

Step 4 – Manufacture:

- taking part in initial acceptance,
- documentation analysis related to Autonomous Maintenance i Professional Maintenance,
- elaborating of spare parts list,
- detection and removing of breakdowns at machine's construction stage.

Step 5 – Installation:

- lay-out control,
- installation quality control,
- control or power supply,
- operator's training and maintenance.

Step 6 – Trial production:

- equipment efficiency control,
- quality ability control,
- control of Autonomous Maintenance standards,
- safety measures control.

Step 7 – Initial flow:

- control of initial production in order to achieving certain rate of production ability,
- lacks' level control,
- equipment awareness,
- general efficiency of production process.

5.2.2. Autonomous Maintenance

It is possible to separate two kinds of autonomous actions [14]:

- Autonomous Maintenance which focuses on lines, that is areas with high density of machines;

- Workplace Organization which focuses on workstations, that is area where the handwork is mostly done.

Autonomous Maintenance is a part of actions which has the purpose of breakdowns prevention of machines and micro-breakdowns.

In the first place Autonomous Maintenance has to be understood and used by the employees who make their work on production and operate different machines.

Knowledge and operators' competences are the basis. Often 5 sensed and basic tools like brushes for removing dirt or plastic covers for machines are used.

Typical actions of Autonomous Maintenance are [14]:

- cleaning,
- lubrication,
- control of small fixings,
- control of temperature,
- noise and vibration control,
- small repairs,
- small improvements.

Autonomous Maintenance is not a specialized action like Professional Maintenance. It is systematic behaviour of company's technical system improvement which has in purpose detection by the production staff, managing in the autonomous way of actions like: control, restore correct state of machine. It is carried out thanks to rigorous maintenance standards and continuous improvement.

One of the Autonomous Maintenance elements is prevention from machine's deterioration. Why do machines deteriorate? Cause of deterioration could be wear, overload, loss of basic conditions, human errors or bad design.

Wearing occurs when there's ineffective maintenance. It doesn't take into consideration maintaining the basic conditions due to lack of operators' qualifications, who don't do recommended inspections.

Increasing load and excessive stress during machine's work are caused by errors during particular work (lack of operators' qualification), repairs or work conditions aren't observed by the operators in rigorous way.

Lack of sufficient strength of the machine is a result of errors or bad machine's design or its components, production's or installation's errors.

To avoid wearing it is necessary to guarantee the maintaining of basic conditions by the preventive maintenance which are included into pillars of autonomous and special maintenance.

To avoid errors caused by the operators or maintenance personnel, proper trainings are carried out.

The purpose of Autonomous Maintenance in the first phase is to maintain the basic conditions of production lines and machines. It is possible to do thanks to assuring the proper machine's usage, cleaning and keeping the safety.

The last element of Autonomous Maintenance is stabilization of machines' conditions, improvement of their reliability and obtaining results of these actions of lengthen their operation period.

Very important factor of Autonomous Maintenance is qualification increase of the operators in range of devices knowledge and improve of quality result visible in the product.

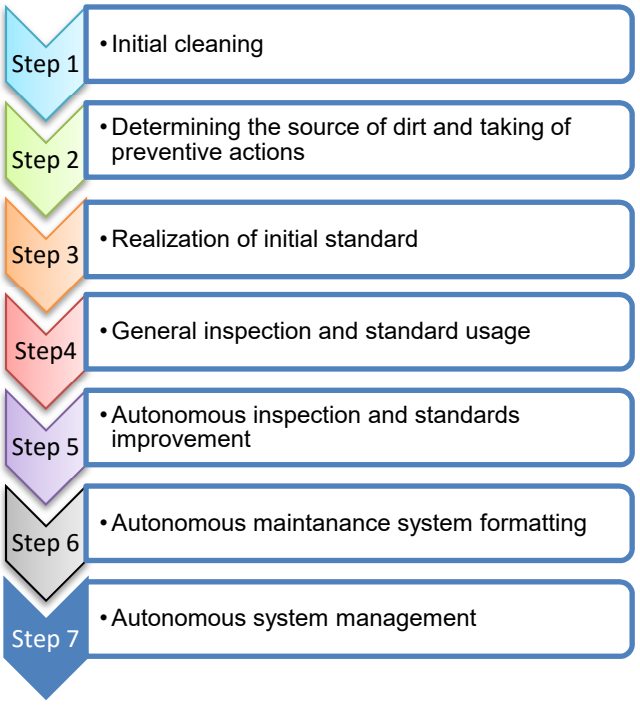

Fig. 7. Seven steps of Autonomous Maintenance [14]

Realization process of autonomous maintenance (Fig. 7) should assume [14]:

- bringing the line to basic conditions (step 1),
- separation of dirt sources and implementation of appropriate preventive measures (step 2),
- prevention of excessive wear thanks to optimization of the first standard of autonomous maintenance (step 3),
- the search of such machine state which assures appropriate quality product and improvement of current standards of autonomous maintenance to be more efficient (step 4 and 5),
- introduction of new principles by the personnel causes the personnel to be more independent during realization of autonomous maintenance actions (step 6 and 7).

5.2.3. Professional Maintenance

Technical pillar of Professional Maintenance has the purpose of creation maintenance and conservation able to reducing breakdowns and micro-breakdowns to zero as well as to get savings in terms of extended machines lifetime through usage of maintenance and conservation practices based on ability of lifetime extension of components i.e. forecast and correction maintenance.

Professional maintenance is a part of process of continuous technical system improvement of the company which consist of Focused Improvement, Autonomous and Professional maintenance actions as well as actions related to beforehand maintenance of development of new devices (EEM pillar) [14].

Maintenance can intervene with instant breakdown repair and in that case this action is not planned but it is reaction on the machine's error. Such actions can be planned as well. Maintenance actions in case of breakdown set the device or component on the level of maximum stress which they can stand, that means level which can cause decreasing of their condition which is the cause of breakdown [14].

Professional Maintenance consists of seven steps [14]:

Step 1 – Rapid wear (elimination and prevention). The purpose of this step is to decrease average time of repair, MTTR, through increasing the operator's qualifications, improvement of management, improvement of spare parts management, improvement of access to devices, usage of 5S within working area.

Step 2 – Breakdowns analysis. The purpose of this step is to prevent the repeating of breakdowns and reducing the frequency of micro-breakdowns, improving the process in range of losses caused by breakdowns, defects reduction and products anomalies caused by device's condition and developed techniques of breakdowns analysis by precisely result documentation.

Step 3 – Definition of standards of periodic maintenance. The purpose of periodic maintenance it to perform planned actions on machine or component including exchange, lubrication, inspection, setting, control, testing, calibration or mechanical inspection i.e. electric or hydraulic. The purpose of above mentioned is to prevent the breakdown.

Step 4 – Countermeasures execution in case of weak points of the machine and extension the device's lifetime. The purpose of this step is to extension the machine's lifetime through correction maintenance actions.

Step 5 – Creating the preventive maintenance system. On the basis of maintenance standard, defined in step 3 and its application, the purpose of this step is to improve work continuity, management, control and machine safety.

Step 6 – Creating the forecast maintenance system CBM and quality maintenance QM. The purpose of this step is ability to forecast the life cycle of components through logging important data which give indications about machine's condition. The purpose is to act before the breakdown occurs. This is based on data analysis which allows to collect information about breakdown occurrence.

Step 7 – Maintenance system formalization and cost maintenance management. The purpose of this step is realization of full usage of devices through maintenance system formalization and cost maintenance management.

The purpose of Professional Maintenance is [14]:

- to maximize the machine's reliability and economic costs,
- to minimize losses caused by safety and quality problems through reliability improvement,
- to reduce actions of maintenance which were not planned and moving them only to those devices with lower priority level,
- to increase percentage weight of correction, forecast and improvement maintenance.

6. The infrastructure management

Infrastructure management can be realized on the basis of process approach. In that case the company should elaborate the management in range of infrastructure control. The purpose of this procedure is to minimize breakdowns of machines and devices in all possible aspects. This refers to unreliability, quality, machines wear and tear, work safety and environment protection. General approach in this range is shown in Figure 8, where:

Input – machine's and device's base, information related to range of required control actions in range machine's and device's operation.

Output – control plan, inspection of machines and devices, preventive actions, investment plans.

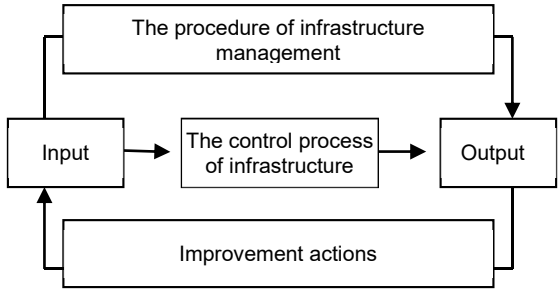

Fig. 8 Process approach in the management of infrastructure

The infrastructure procedure management must form effective diagnostic tool of hazards and their minimalization in all possible aspects in which the infrastructure management might have influence on production process continuity.

In result of problem analysis and industrial experience below questionnaire is shown. This is proposition of questions needed for internal audit in range of infrastructure management process. 8 parts has been separated where each of them relates to most important problems in infrastructure management.

A. Machines meaning in production process

1. Is there production process machine importance analysis carried out?
2. Is there machine compatibility with production line and influence of internal transport operation on its functionality analysed?
3. Is there compatibility of machines park with kind of manufactured products, including outsourcing abilities in range of possibility of machines breakdown analysed?
4. Is personnel aware of importance of keeping the machines in perfect condition?

B. Prevention action plan

1. Is breakdown risk determined?
2. Have the correction action plan in case of machine/ device breakdown been prepared?
3. Are machine breakdown analysis carried out?
3.1. Is the cause of breakdown determined?
3.2. Is multiplicity of machine breakdown causes analysed?

C. Machine quality ability

1. Is indicator of machine quality ability determined?
2. Are number of lacks due to used machines analysed?

D. Metrology in range of machines maintenance

1. Are analysis of determining the scope of machines' control carried out?
2. Are analysis of machines' calibration requirements carried out
3. Are scope of machines' maintenance analysis carried out?

E. Eco and energy operation

1. Are analysis of machines' energy consumption carried out?
1.1. Are possibilities of improving the machines' energetic efficiency analysed?
2. Are analysis of machine's eco-influence carried out?
2.1. Is the number of used media per unit of processed material on certain machine analysed?
3. Is possibility of mounting the additional equipment in order to minimize media usage analysed?

F. Machines wear and tear

1. Is the wear and tear level of machine analysed?
1.1. Are analysis of spare parts wearing carried out?
1.2. Are analysis of unexchangeable machines' parts wearing carried out?
2. Is the level of workstation load analysed?
3. Is awareness action plan according to machines' repairs determined?

G. Machines control

1. Is possibility of machine's control function efficiency analysed?
2. Is control stability analysed?
3. Is system control plan of machines' control determined?

H. Safety of usage and environment protection

1. Is the danger related to machines usage with influence on employees health and life, according to regulations, analysed?
2. Is environmental danger due to local law and regulations analysed?

Below is shown the usage of above mentioned approach of infrastructure management in given company.

In result of infrastructure management process audit in analysed company and with use of before mentioned question list in chapter E following areas have been defined.

Shown results are related to project which purpose was reducing of hydraulic oil usage thanks to new solutions and machine park modernization. Project was realized in production plant of cast production for automotive industry.

Within the framework of supervision, significant leak of oil has been defined. The machine oil leakage is related to environmental danger – oil was present in facility's wastes. In range of infrastructure management responsible departments had to diagnose hydraulic oil leakage and to reduce number of refilling.

Reduction of hydraulic oil is related to industrial wastes reduction and in the same time to savings for the company. In 2011 the amount of hydraulic oil leaks due to hydraulic systems damage or due to obsolete technology and machines was 25 kg/t of production. Actions for the machine park modernization were taken. New machines were bought what significantly influenced on hydraulic oil usage. High effectiveness in operation was obtain thanks to the technical

personnel training in define, set up and control process parameters.

The procedure of daily checking of hydraulic oil leaks in the machines along with status reporting to Maintenance Director has been implemented.

Old engines, valves, blocks with mechanical pressure regulators were not so efficient thus they were changed to new ones with simpler and more efficient hydraulic control thus decreasing the usage of operational liquids (Fig .9).

a)

b)

Fig. 9. The example of machines a) mechanical pressure regulator, b) hydraulic pressure regulator

Actions taken by the company in range of determining and implementation of standardized approach to infrastructure management, based on Total Productive Maintenance assumptions have influence on significant decrease of hydraulic oil usage as well as on decreasing the number of industrial wastes and savings.

Actions taken to solve above mentioned problem let to reduce hydraulic oil usage from 25 kg/t in 2011 to 8,29 kg/t in 2012 (annual average value) – Fig. 10.

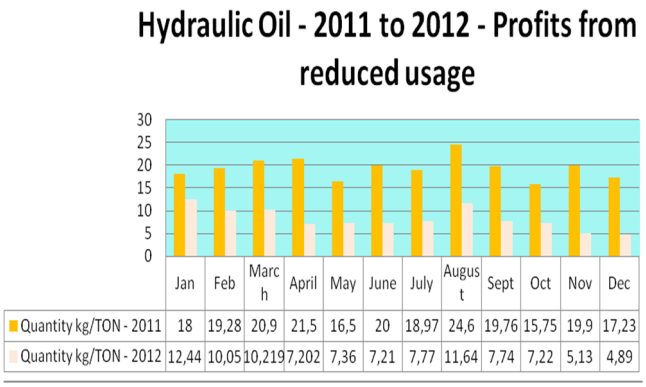

Fig. 10. Analysis of hydraulic oil usage

Conclusion

Implementation of Total Productive Maintenance (TPM) is a way to improve economics of whole organization.

Presented analysis results of TPM approach usage in company are related to oil leakage reduction in machines. Used improvements and modernization of machines' park allowed to achieve the TPM target.

Efficient and effective implementation of TPM principles is based on including all company's employees into improvement actions which lead to achievement of zero breakdowns, zero production defects and zero accidents.

In analysed company the TPM concept was based on following methodology:

- elimination of big losses through work of multifunction team - Focused Improvement, the result of this team work was determination of oil leakage problem,
- formal inclusion of production employees into help in maintenance – Autonomous Maintenance, was related to employees involvement into diagnose the oil leakage sources and their control,
- building the planned inspection system, preventive and maintenance – Planned Maintenance, maintenance system of new control devices in range of oil management was determined,
- gaining new knowledge and qualifications by the operators and employees of Maintenance Department through specialized trainings – consciousness trainings in range of media management savings were conducted,
- building the system to assure designing and purchase easy to use equipment – Early Equipment Management – in frames of conducted works criteria of purchase of new machines and devices were determined. The purpose of this was to minimize the oil leakage.

Elaborated questions questionnaire, used to evaluation the problem of infrastructure management was useful in mentioned case and particularly in range E.

Eco- and energy- operation - in result of carried audit of infrastructure management the change of thinking about infrastructure management was conducted. This allowed to define the main losses.

Problems with infrastructure management are the key element in company management and require of appropriate operation.

Additional information

Selected issues related to this paper are planned to be presented at the 22nd Winter International Scientific Conference on Achievements in Mechanical and Materials Engineering Winter-AMME'2015 in the framework of the Bidisciplinary Occasional Scientific Session BOSS'2015 celebrating the 10th anniversary of the foundation of the Association of Computational Materials Science and Surface Engineering and the World Academy of Materials and Manufacturing Engineering and of the foundation of the Worldwide Journal of Achievements in Materials and Manufacturing Engineering.

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