APPLICATION OF TOTAL PRODUCTIVE MAINTENANCE PRINCIPLES IN METALLURGICAL PROCESSES

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Abstract
Blast furnace process is one of the most demanding production processes both in terms of energy and in terms of required management efficiency. Great demands are posed when the regulation of the process flow, but also the amount of used human capacity to ensure an efficient workflow are taken into consideration. The global economic crisis has significantly affected the production of iron and steel. Dramatic increase of prices of all energy sources has meant substantial interference with the cost part of the production processes. In the field of metallurgical processes, the fundamental cost items also include maintenance of production units and all activities related to it. The utilization of the Total Productive Maintenance system represents an interesting alternative in the sphere of cost reduction for maintenance of production equipment. This system tries to remove the traditional division of workers to those who work on the given equipment and those who perform maintenance. The main reason is the fact that the worker operating the production equipment is the first one who is able to detect the functional abnormalities of the machine and the potential sources of future breakdowns. This concept is widely used in mass production based mainly on machining operations. However, the blast furnace process is a continuous process with very specific operations in the area of maintenance. As far as the blast furnace itself is concerned, there is a limited number of periodic minor maintenance operations. Major interventions will take place during the general overhaul of the blast furnace which can be carried out even after several years of operation. It is different for other supporting production devices which can be found within the scope of a blast furnace plant. The article is trying to analyze the possibility of using the concept of Total Productive Maintenance in metallurgical processes and other follow-up operations.

Keywords: maintenance, iron, production process, costs

1. INTRODUCTION
As a result of the global economic crisis, metallurgical companies are more and more intensively forced to look for eventual cost savings [1]. Iron and steel manufacturing belong to the most complex manufacturing procedures. The complex nature is mainly caused by its technological demandingness but also by high amount of necessary input materials. In this branch as well as in other follow-up branches such as: forming processes, foundry industry and engineering, great stress is laid on economic side of the manufacturing processes.

New modern methods from other industrial branches are used in order to increase the efficiency of production. These methods make it possible to increase the production potential but also to save some very expensive resources [2]. Total Productive Maintenance method is an interesting alternative from the point of view of reduction of maintenance costs.

Total Productive Maintenance develops preventive and predictive maintenance approaches and it establishes new elements such as autonomous maintenance, engaging small team groups, visual management or elements of safe workplace [3]. The main task Total Productive Maintenance must deal with is to eliminate interruptions in operation of machines, thus increasing the efficiency of production equipment. Maintenance in the traditional approach is mainly focused on interruptions as a result of machine or
equipment breakdowns. TPM also covers areas such as losses when a machine is running with broken components or even when wrong technological procedure is used or when the workplace is arranged in an unsuitable way, which can, for example, lead to unnecessarily long set-up time. Total Productive Maintenance philosophy consists of the following programmes: programme of autonomous care of equipment, programme of planned maintenance, programme of education and training, programme of planning for new equipment and components. Total Productive Maintenance concept utilization is possible mainly in processes which are not purely continuous.

The main objective of the article is to assess the potential use of TPM method in metallurgical processes. The analysis will cover not only the basic metallurgical production, but also the forming processes, foundry and, last but not least, the engineering processes.

2. PROBLEM FORMULATION

Loss in metallurgical company means any activity which requires time, resources or space but does not bring value to the product of to the entire manufacturing process. Some activities, such as material transfer during production are necessary, but they do not add value. As far as the metallurgical processes are concerned, maintenance belongs to very costly and technologically demanding processes [4]. The continuous nature of production, but also the complexity of the production equipment and their mutual connection will always require a specific approach in terms of maintenance management. TPM is a long-term concept that requires major changes in thinking and collaboration between the maintenance and production departments. You can also find applications of TPM in companies that have decided to outsource maintenance; however, this is sometimes associated with more significant problems. The principle is based on the cooperation between the equipment operation personnel and the maintenance, in order to gradually reduce unscheduled repairs and to increase the proportion of planned maintenance activities. The implementation of the concept of TPM can be seen through the basic elements used in this activity. The total productive maintenance system often exceeds normal maintenance activities and it is also concerned with order, clean workplace, but, for example, also with optimal location of production equipment. Bearing in mind this fact, the article will also review the utilization the TPM system elements in various characters of production. The following methods are included: program of autonomous care of production facilities, planned maintenance program, program of education and training of workers, program increasing the overall efficiency of equipment, program of planning for new equipment and parts, and, last but not least, a system of good management. It can be assumed that all these elements used within the scope of the TPM concept have completely different applications in the processes of iron and steel production, forming, foundry and in engineering.

3. EXPERIMENTAL WORK

The basic principle of the total productive maintenance concept is to reduce the interventions of maintenance workers and to try to substitute their work as much as possible with the personnel operating the production equipment. For effective realization, the concept of TPM uses a set of tools that enable easier implementation. The original use of this maintenance system was in the automotive industry. A survey was conducted in order to evaluate the possible utilization in the sphere of iron and steel production, and in other related industrial processes.

- Autonomous care of production equipment

This method can be most commonly understood as daily preventive maintenance activities. An employee working on the equipment performs basic diagnostics, cleaning, lubrication, minor repairs and cooperates with maintenance personnel to address larger abnormalities or defects in equipment operation. This concept deprives the maintenance workers of their daily operational activities. The maintenance of blast furnace plant requires necessary regular inspection and continuous removal of problematic situations. The complexity of the production equipment in this case does not allow delegating these tasks to workers who are not part of
maintenance. The greatest possibility of application can be seen in the area of machine production, where the basic repairs and diagnosis can be carried out by a worker operating the device. The employees working with the manufacturing equipment are usually the first ones to identify any potential problem situations.

- Planned Maintenance

These are regular and planned maintenance activities and repairs. It is the basic concept of repairs and reconstructions of blast furnaces [5]. Due to the continuous and long-term operation of this equipment, the repairs and maintenance must be planned long time in advance. The planned maintenance program can also identify: periodic inspections and maintenance, predictive maintenance, and extending equipment life cycle. In general, this concept can be applied both in the area of material forming, foundry, and also in engineering. In case of new production facilities, such activities are often part of the warranty.

- Improving the overall equipment efficiency

The point here is to maximize the productive use of the production equipment. The first step is to monitor and reduce losses of all types regarding the equipment capacity. In case of the blast furnace process, the possibility of application is reduced only to the secondary and supporting units. This method can also have a major impact on the engineering processes and on the forming processes. In the area of machinery, it is important to identify the major losses affecting the available production capacity. A poorly scheduled system of preventive maintenance may often mean long downtime and it is a great source of wasting. Systematic improvement of total efficiency of production equipment contributes to the profitability and continuity of the production process.

- Planning for new equipment and parts

The basic principle rests in cooperation of maintenance when planning investments to new equipment and its commissioning. Monitoring the life cycle cost of equipment is an important element as well. The main objectives can be seen especially in higher equipment reliability, better maintainability, lean concept of the device, but also in a stable operation of the equipment after installation. This TPM feature can be generally used in all the processes. When buying a machining, rolling or sintering unit, it is always necessary to take into account any eventual aspects related to the maintenance system. Any complications in providing the maintenance of production equipment can significantly reduce the life of the machine.

- The system of good management (5S)

The system of good management is often named by the five steps, indicating the individual stages. When 5S are not present it means wasting, low efficiency, lack of self-discipline, low working morale, bad quality, high costs and inability to deliver. Five steps of good management are: Seiri (sort), Seiton (set in order), Seiso (shine), Seiketsu (sustain), Shitsuke (standardize) [6]. 5S System mainly relates to order and discipline at the workstation. Figure 1 shows one of the principal violations of the 5S concept, when waste (machinery production) is placed among the finished products. The most significant utilization in metallurgical industry can be seen in control and keeping order at the workstations, but also in the area of labour protection rules building and safeguarding. Forming, foundry and engineering companies can, with regards to their great number of tools necessary for realization of their work activities, use this system to improve their management and maintenance. Tidy workplace, preventive maintenance of equipment, system of cleanliness and order can ultimately have significant influence on the trouble-free operation of equipment.
Fig. 1 Shortcomings in the workplace within the scope of mechanical production

- Education and training of workers

The program of education and training of workers is mainly focused on increasing the qualification of employees in the field of servicing and maintenance interventions. This area may include [6]: maintenance skills, diagnostics, predictive maintenance techniques, quality tools. If an employee working with the production equipment is to perform certain maintenance tasks, he must be prepared for that. Education and personal development of employees is a key prerequisite for the implementation of the TPM concept. However, the application is again given by the complexity and the technological demandingness of the production processes.

4. RESULTS AND DISCUSSION

Total Productive Maintenance is essentially based on the application of key elements. They are the techniques and methods attempting to achieve maximum possible involvement of wider spectrum of employees in the maintenance process. The usability of all TPM concept elements has been assessed for the monitored production processes. The usability evaluation was classified on a scale from 1 to 5, where 1 means that the given element can be used in this type of production without any use restrictions.

Table 1 Possible utilizations of the elements of total productive maintenance

<table>
<thead>
<tr>
<th></th>
<th>Production of iron and steel</th>
<th>Forming processes</th>
<th>Foundry industry</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous care of production equipment</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Planned maintenance</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Increasing the overall efficiency of equipment</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Planning for new equipment and parts</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<tr>
<td>System of good management (5S)</td>
<td>1</td>
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<td>Education and training of workers</td>
<td>3</td>
<td>2</td>
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Rating 5 means virtually impossible application. Table 1 shows the results of the analysis. The most versatile tool used within the frame of TPM concept is the 5S system. The application of this method is not excluded in any of the monitored production processes. Planned maintenance is another usable principle. This system is used especially in the sphere of metallurgical production, due to the continuous nature of the
manufacturing process. Increasing the overall efficiency of production equipment finds its use mainly in engineering, where it encourages increasing the available production capacity.

Autonomous care of production equipment is virtually out of the question in production of iron and steel, but also in the foundry industry. The application can be found primarily in engineering and, again, in the forming processes. The element related to the planning of new equipment is essentially usable in all areas, but the degree of its influence is, once more, reduced by the complex nature of the individual types of production. As far as the continuous production processes which require a complex system of secondary aggregates are concerned, the purchase of new equipment will especially have to take into account the production and technological criteria. Education and training of workers is a necessary condition for the introduction of TPM. It is particularly important during complex implementation of this method. In case of metallurgical processes, its contribution can be seen mainly in increasing the knowledge and qualification of employees, who will unfortunately not be able to participate in the total productive maintenance process in real life.

5. CONCLUSION

Total Productive Maintenance has been trying as much as possible to eliminate the traditional division between workers who work with manufacturing equipment and the personnel responsible for maintenance. The applicability of this concept often faces the complexity of the manufacturing process.

The application of the TPM principles in metallurgy has a number of limitations. The continuous character of production, along with the complexity of the supporting production units pose great demands on maintenance. The eventual jeopardy of the continuous flow of the blast furnace process can also mean huge financial losses. All these factors support the conclusion that it will be very difficult to delegate operational maintenance tasks to workers who do not belong to the maintenance department. Many metallurgical corporations around the world are also considering using the principles of outsourcing in maintenance. Even in this case, however, we can not draw a clear conclusion. Effective use of external maintenance systems is usually subjected to long-term cooperation and close links between the cooperating companies. The complexity of the blast furnace process makes sudden change of the maintenance system very difficult.

Machinery production, and partly also the forming processes, provide excellent possibility for the application of the TPM system. In the area of mechanical production equipment, a wide range of basic maintenance activities can be transferred to operating personnel. These workers can also easily identify any anomalies and problem situations. The introduction of the elements of total productive maintenance is suitable even during the installation of new production equipment. It is not good to let the equipment deteriorate and to laboriously clean it and build a system of autonomous maintenance afterwards. The implementation of the TPM system usually begins with the building of autonomous equipment care. These activities may be an appropriate part of building of autonomous teams. The success of TPM implementation is highly dependent on the support of top management, which must properly define the goals and organizational framework for the implementation of the individual elements. It is not possible to expect immediate radical reduction in maintenance costs or decrease in the number of maintenance staff once you have implemented the system of total productive maintenance. The TPM process is especially about efficiency of production equipment and quality of maintenance activities. TPM tries to maximize the involvement of all company employees in the process of maximization of the overall production facilities efficiency. However, quality cooperation of production and maintenance, application of supporting methods, utilization of quality tools and system of good management in the workplace are important as well.

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