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# TPM SAFETY IMPACT – CASE STUDY

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**Abstract:** The global production companies of today are exposed to increasingly stronger pressure to implement new technologies, improve quality and decrease production costs. All this is related to ensuring a proper technical condition of machines and devices. This article presents the results of an analysis of the impact of implementation of TPM at the rolling mill on work safety. The number of near misses and accidents was used as a measure of the safety level.
**Keywords:** TPM, safety, rolling mill

## 1. INTRODUCTION

Total Productive Maintenance is understood to mean improving total effective maintenance of equipment and machines. It is one of the lean management methods. Its purpose is to ensure maximum effectiveness of machines and equipment (Wang, 2006). The idea is to make the most of a machine availability time to produce good quality goods and to minimize time wasting (Singh et al., 2013; Chan et al., 2005). Originally a Japanese invention, TPM consists in machines and equipment in a plant being maintained by operators and maintenance staff. It is part of Lean Management, which is based on the attitude of all staff to adopted standards. The TPM system is based on eight pillars (McKone et al., 2001):

- continuous improvement, stemming from the KAIZEN philosophy. Taking actions aimed at decreasing the production costs, improving the organization of work and increasing profits.
- Autonomous maintenance - getting each employee involved in decreasing the failure rate of machines. It is assumed that no one knows a machine better than its operator. Therefore, it is he or she who should come forth with suggestions related to their machine's functioning.
- Planned maintenance - scheduled maintenance and repair tasks based on previous experience and observations.
- Training and education - endowing staff with required information and skills. Increasing employees' awareness positively influences the quality of their work.
- Early equipment managing - already at the stage of designing a production line should it be decided how the operators will diagnose machines, how ongoing maintenance will be handled and how the stock of replacement parts will be managed.

- Quality maintenance - proper understanding of how a machine wears out and how its technical condition affects the quality of products. Parts replacement should be scheduled following consultations with machine operators.
- TPM in administration - also office processes must support production and should be treated equally seriously.
- Safety, Health, Environment - the idea is to minimize the number of accidents at work. In-company processes are scrutinized in terms of which of them pose the greatest threat to employees. Accident risk should be eliminated or minimized by modifying processes and introducing new forms of employee protection.

The idea behind the TPM system is to adapt a set of individual rules to a specific case - a plant (Brah and Chong, 2004). Thanks to this requirement, ever since its creation in Japan, TMP has been discussed in numerous publications in terms of implementing it in practice rather than in terms of its theoretical assumptions (Sun et al., 2003). This is also the purpose of this paper, which discusses the application of the TPM method in a preventive maintenance system of a hot-rolled bars rolling mill.

## 2. IMPLEMENTING TPM

A discussion on an objective optimization of production is possible only following an analysis of the Overall Equipment Effectiveness ratio - OEE. It allows to measure the extent to which we use our machines and how they are affected by availability, effectiveness and quality loses (Nakajima, 1988).

$$(OEE = A \times PE \times QR) \tag{1}$$

where:

A - availability ratio (losses resulting from a machine stops),

PE - performance effectiveness ratio (losses resulting from small stops and slow cycles,

QR - quality ratio (losses resulting from quality issues).

Gradual implementation of each TPM pillar at the Rolling Mill has brought measurable benefits in the form of increased availability of machines and devices, which has translated into a continuous production growth.

Implementation of the TPM method has also resulted in improved working conditions and safety at the Rolling Mill.

Continuous maintenance staff improvement through application of the Deming Cycle while analysing failures and malfunctions, as well as through application of common problem solving methods (Root Causes Analyses, the 5 Why method, the Ishikawa Diagram, etc.) has significantly reduced the effects of unscheduled failures, as a result of which our staff are capable of performing their work as previously scheduled, bearing in mind the risks previously estimated for each activity (Ulewicz et al., 2013).

A Pareto analysis of criticality of individual devices allows taking appropriate preventive actions. The above-mentioned methods have been used to prepare action plans aimed at increasing the reliability of devices identified in the course of the analysis. Fig.1 shows a Pareto analysis for individual devices at the rolling mill.

Based on the data from Fig. 1 it can be concluded that the Brown saw, the N450t shear assembly and the aprons assembly account for nearly 60% of all stops. The effect of implementing preventive actions for critical devices on the number of unscheduled stops of the plant is presented in Fig. 2, 3 and 4, for the Brown saw, the N450t shear and he aprons assembly, respectively.

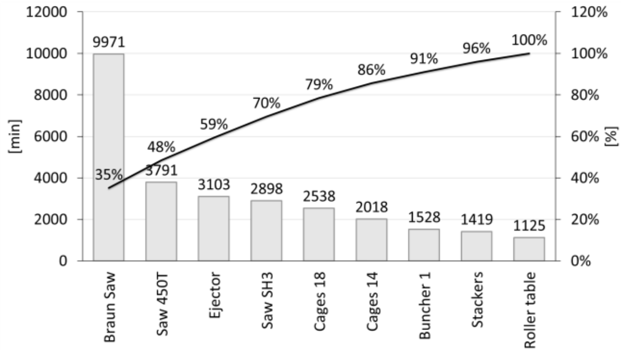


Fig. 1. Pareto analysis for individual devices at the rolling mill

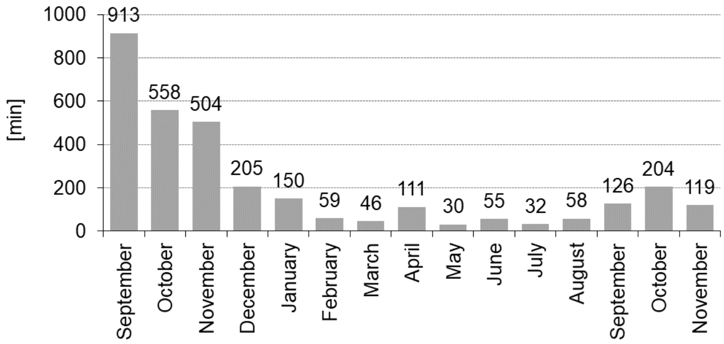


Fig. 2. Effect of implementing preventive actions for the Brown saw

Fig. 2 shows the effects of preventive actions implemented between September and October for the Brown saw. As can be seen, the number of failures decreased by over 50% and accounted for a total of 99 minutes over the last 12 months.

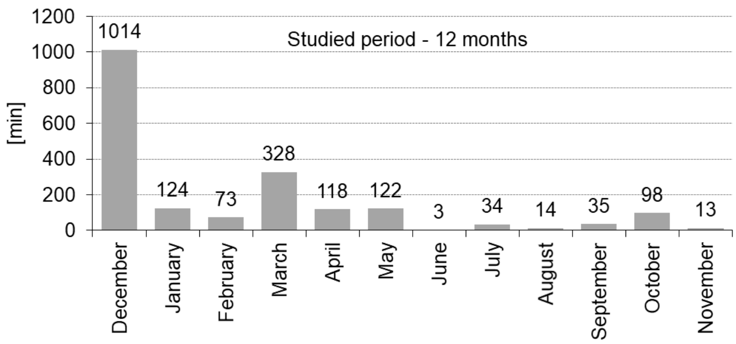


Fig. 3. Effect of implementing preventive actions for the N450 shear

Similar results are shown in Fig. 3 for the N450t shear, where, following implementation of preventive action between December and January, the average total stop time decreased to 87 minutes. As regards the aprons assembly, following implementation of preventive actions between February and March, the total stop time also decreased by over 100% and currently accounts for 55 minutes, as is shown in Fig. 4. Next, Fig. 5 shows the extent to which TPM-based preventive actions have contributed to decreasing total stops at the Rolling Mill over the last 6 years. The biggest progress is visible immediately following implementation of TPM, i.e. in 2014, when stops were reduced from 10.2% to 7.2%, and between 2017 and 2018, when stops at the rolling mill were reduced to 2.1%.

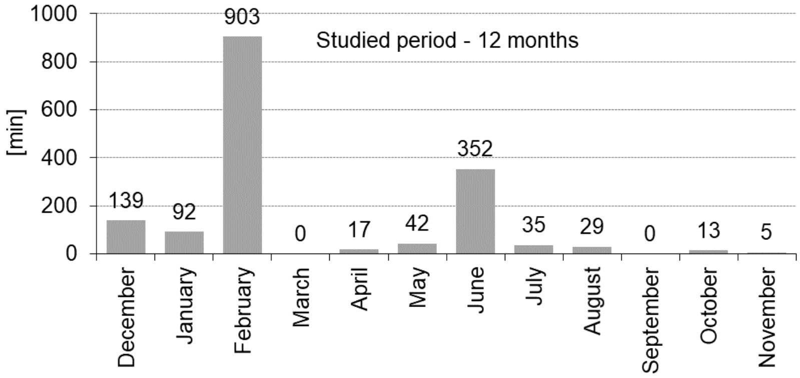


Fig. 4. Effect of implementing preventive actions for the aprons assembly

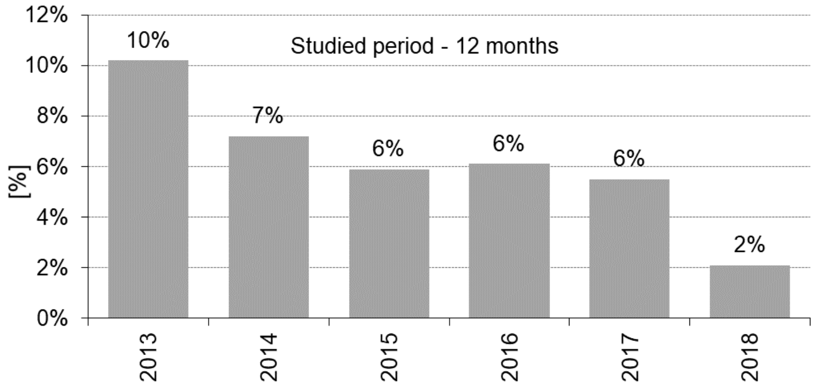


Fig. 5. Effect of preventive actions in the last 6 years on decreasing the total stop time (percentage)

The effect of all implemented actions is shown in Fig. 5. Another pillar implemented by ArcelorMittal Warszawa is continuous increasing of employees' awareness through numerous trainings, preparing work standards for complex activities with a risk analysis prepared for each of them. The trainings provided to the maintenance staff contribute to increasing their competences. They result in a slow but permanent change of the maintenance staff's awareness that it is better to prevent that cure. The Figures 6 and 7 show the average MTBF and MTTR in the past.

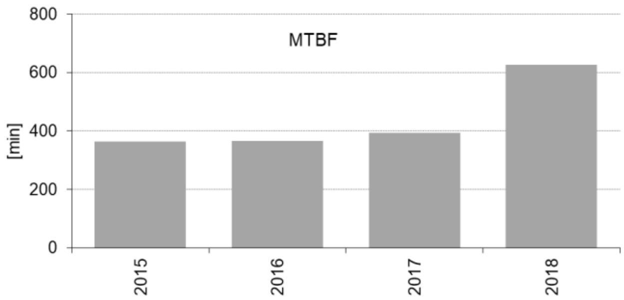


Fig. 6. MTBF at the rolling mill

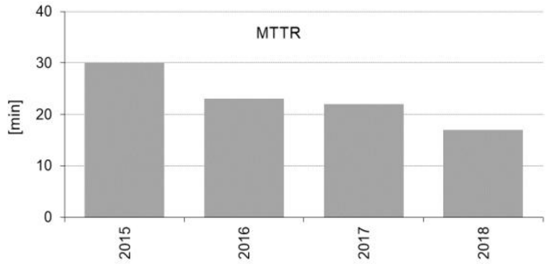

Fig. 7. MTTR at the rolling mill

Planned maintenance plays an important role in the work safety of our staff. The replacement or inspection intervals for individual units prepared over the years are detailed in the prevention schedules.

Sticking to the replacement and inspection schedules has largely helped us avoid unplanned stops. Strictly defined maintenance staff inspection activities allow us to undertake early preventive actions on a daily basis. Thanks to regular reporting and planning of repairs we have been able to keep the machine failure ratio at a very low level. All preventive actions are included in Action Plans and carried out as scheduled.

## 3. EFFECTS OF TPM IMPLEMENTATION ON WORK SAFETY

One of the goals of TPM is to create a safe workplace and an area around it that will not be exposed to damages as a result of processes or procedures. Staff safety is of the highest importance. Comprehensive maintenance of machines and equipment are allies of the the safety department (Nowicka-Skowron and Ulewicz, 2016).(Nowicka-Skowron and Ulewicz, 2015) The purpose of this symbiosis is to completely eliminate near misses, accidents, damages resulting from failures, and fires. In addition to the 5S system, being strictly related to work safety or the many procedures applied in the plant, the company's policy advocates a proactive approach to occupational safety and health (OSH) based primarily on activities of teams and their leaders (Duda and Dwornicka, 2010). This approach is based on setting proactive goals, such as: the number of audits carried out by a leader (a leader must meet with each of their subordinates at least twice a year), the number of incidents i.e. behaviours, situations/near misses reported by employees (at least once a year each employee should report at least 1 incident) or additional OSH trainings carried out by a leader (2 trainings a month). The above figures are recorded in a special computer programme to which new kiosks (locations) are added on a regular basis, along with a smartphone application. The programme allows to generate reports and analyse trends.

These goals are monitored monthly at the OSH Committee meetings in the presence of the top management, trade union and Social Labour Inspection representatives, the company physician, representatives of the OSH Department and the CEO. The best results, both of individual employees (the biggest number of incidents reported) and whole teams, are rewarded e.g. during the OSH Day organized by the ArcelorMittal Group annually.

In addition to standard risk assessment for routine activities (required by law), risk management involves the so-called HIRA (Hazard Identification and Risk Assessment) carried out for non-routine activities prior to their performance. This "simplified" risk assessment is related only to threats and control means without assessing the risk level. It is comprised of five "steps" and is carried out by a superior and designated employees. HIRA is documented on a special (simplified) form, which must be available where the HIRA activities are being performed throughout their duration. This risk assessment is also applied by external companies carrying out temporary works at the plant as part of the company's subcontractor management system related to OSH.

In addition to the above-mentioned hard process tools, the so-called soft tools are being introduced into OSH management. These tools are aimed at increasing the staffs' OSH awareness, i.e. at eliminating human errors being the most frequent cause of accidents at work. These primarily include active trainings in the form of workshops. Each blue-collar employee is expected to attend a one-day training each year. These trainings are called "Safety is US" and cover a total of 20 days. The purpose of the trainings is to build a team spirit and interdependence in order to attain the highest level of safe work culture as shown on the Bradley curve and as captured in the following principle: "Let's watch one another." Building an effective safe work culture requires the managers at all levels to assume an appropriate attitude to OSH. To this effect, in addition to the "Safety is US" training, workshop trainings named "Leadership" have been introduced for top- and middle-level managers.

I have pointed only to examples of the so-called hard and soft OSH management tools, which should be applied simultaneously to result in effective protection of the life and health of employees in the long run.

## 4. SUMMARY AND CONCLUSIONS.

All the above-mentioned activities combined with measuring the machines and equipment allow us to take safe preventive actions in time. This way we can plan maintenance or repair activities which reduce the number of failures, potential threats and extend the intervals between failures.

Fig. 8 shows the number of preventive actions implemented between 2016 and 2018 for electrical/automatical (UREiA) and mechanical (URM) maintenance. As can be seen, in 2018 the number of preventive actions exceeded 5000, an 8% growth compared with 2016.

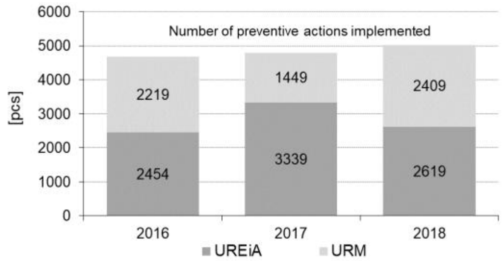


Fig. 8. Number of preventive actions introduced between 2016 and 2018.

Such mode of operation of the Maintenance staff, combined with work culture improvement through gradual implementation of the methods constituting part of each pillar, has a significant effect on improving safety, as each activity is properly scheduled and discussed in advance.

The approach, similar to the one presented in this article, can also be very useful both in other branches of industry as well as in the research area. It seems that may successfully applied in metallurgy (Ulewicz et al., 2014; Salek and Klimecka-Tatar, 2016), materials science (Korzekwa et al., 2014; Ulewicz and Novy, 2016; Dudek et al., 2017; Korzekwa et al., 2018), chemistry (Ulewicz and Radzyminska-Lenarcik, 2014; Ulewicz and Radzyminska-Lenarcik, 2015), machining (Radek et al., 2017a; Radek et al., 2017b; Pietraszek et al., 2017; Radek et al., 2018), even supported by an image analysis methods (Gadek et al., 2006; Gadek-Moszczak, 2017; Gadek-Moszczak and Matusiewicz, 2017), and especially in very environment-sensitive biotechnology (Skrzypczak-Pietraszek, 2016; Skrzypczak-Pietraszek et al., 2018a; Skrzypczak-Pietraszek et al., 2018b). It would be very interesting to include a fuzzy description of the problem (Fabis-Domagala et al., 2018; Filo et al., 2018), which allows you to express uncertainty about the process.

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