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IMPACT OF MICRO-STOPPAGES ON OVERALL EQUIPMENT EFFECTIVENESS MEASURE

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Abstract

The basic activity carried out in the aluminium sections manufacturing market is the extrusion process. The large demand for aluminium products makes it very important for entrepreneurs to achieve the highest possible production effectiveness, expressed in product tons manufactured within a unit of time. The recognition of the factors affecting the machine operation time losses is a valuable source of information that creates the opportunity to introduce changes improving production effectiveness. One of the identified factors affecting production effectiveness, specified through the OEE (Overall Equipment Effectiveness) measure, are micro-stoppages, the impact of which is rarely noticeable due to the difficulty in their recording. However, it is extremely important due to the total machine operation time losses. For the purpose of analysing micro-stoppages in selected machines in this paper, the authors used testing tools for the quantitative statistical analysis as well as Pareto charts.

Keywords

Micro-stoppage, management, enterprise, production effectiveness.

1. Introduction

Machine, device or production line standstills, without triggering a non-function, for longer than 5 minutes are called micro-stoppages.

A standstill related to a micro-stoppage is the lack of ability to perform operations determined by the course of technology, which causes elongation of the production cycle time and evident losses.

The conventional micro-stoppage time of approximately 5 minutes is a specific feature that distinguishes it from a breakdown. The data show that a machine's stoppage for more than 5 minutes usually involved an expert's intervention, which is symptom of a breakdown. Therefore, the ability of starting-up the machine after a short stoppage by the operator, without a third person's intervention, distinguishes a micro-stoppage from a breakdown.

The Overall Equipment Effectiveness (OEE) is a measure commonly used to determine the effectiveness of machinery operation. The measure was described for the first time by Seiichi Nakajima in 1982 in the book "TPM tenkai" as an element of the TPM (Total Productive Maintenance) methodology. The OEE level does not only determine production effectiveness, but also points to areas of potential improvement that enhance its level. Unplanned stoppages and micro-stoppages are an important factor that affects the OEE measure and are a plague for contemporary technologies in which machinery control and start-up strongly depends on the efficiency of electronic systems as well as the quality and efficiency of employees.

Studying and calculating the OEE measure is an important element of enterprise management that allows for evaluating the degree of utilisation of machinery operation and its comparison within a plant or even within bigger management units.

OEE includes three components: availability, effectiveness and quality. It is estimated based on the available time of operation and total time of losses that exist in the given calculation unit (production shift, day, week, etc.). The OEE measure is defined as follows:

$$\text{OEE} = (\text{total time} - \text{loss time})/\text{total time}.$$

The losses cover any type of machinery failures, adjustments, control measurements, including also micro-stoppages lasting for less than 5 minutes, related among others with machinery start-up time, unidentified moments of production capacity losses, etc.

In the OEE analysis, each component factor is assigned to a specific type of loss, which is presented in Table 1.

Table 1
Determination of losses in the OEE components.

Availability	Unplanned standstills	Shortage of materials
Performance	Shorter standstills	Reduction in speed
Quality	Production defects	Reduction in performance

The calculation method and nature of the OEE measure makes it difficult to achieve its high level. For example, despite the fact that three parameters will be equal to 90%, the OEE will only amount to 73%. Therefore, the "global standards" for this measure were established, which have the following values: availability 90%, performance 95 %, quality 99%, OEE 85% [2].

Lean Management, including the TPM (Total Productive Maintenance), uses the OEE measure to analyse production effectiveness [12]. Total Productive Maintenance is an important factor that affects the enterprise's profit and directly illustrates the OEE component factor that decreases its level, which is why it is important in analysing management problems [7, 9].

The Total Productive Maintenance consists of five basic modules [5].

Module 1 – TPM management concerns the construction of a system that ensures the purchase of machinery and devices that are easy in operation and maintenance or the designing and manufacturing of such equipment internally.

Module 2 – Current maintenance engages the operators into the operation maintenance process.

Module 3 – Planned maintenance is the creation of a system of planned inspections, overhauls, maintenance and preventive activities.

Module 4 – Targeted TPM improvement assumes the elimination of main losses related to the TPM functioning thanks to the work of task forces.

Module 5 – Operator improvement trainings concern the improvement of knowledge and skills of machinery and device operators and operation maintenance service employees as part of specialist trainings.

Production line standstills are reported many times during production. The standstills can be planned, e.g. lunch breaks, trainings, cleaning, etc. Unfortunately, a large number of standstills is unplanned. This category includes, e.g. machinery failures, tool replacements, adjustments, settings, unforeseen additional activities, etc. In terms of production effectiveness, standstills constitute evident losses, because the product is not manufactured during stoppages. Another category of losses are losses related to, e.g. machinery start-up time at the beginning of each production shift. Such losses are defined as effectiveness losses.

Effectiveness is defined as the ratio of the productivity time against the available time, whereas the productivity time is the available time decreased by effectiveness losses.

Quality is defined as the ratio of the effective time against the productivity time, whereas the effective time is the productivity time decreased by quality losses.

A good indicator facilitating loss analysis is the Pareto analysis, which facilitates the search for the process' weak spots and points to the areas with the highest potential of process improvement. The Pareto principle states that 20% of activities provides 80% of work effects. It allows selecting areas from a broad set of data that generate the most income and determine the activities that generate the highest losses [1, 4, 13].

The presented paper features an analysis of micro-stoppages occurring during the operation of three machines. The collected data was presented on Pareto charts and analysed using the OEE model in relation to losses in machinery availability caused by micro-stoppages. A specific feature of the machinery subjected to testing are the production shifts and its discontinuity due to changing orders, it is therefore necessary to expect a substantial impact of these phenomena on productivity. Taking into consideration the micro-stoppages factor and its impact on the OEE measure, the authors took steps to estimate the losses caused by micro-stoppages and discussed the parameter's significance for the production process.

2. Micro-stoppage distribution analysis

The issue of machinery availability is strictly related to production effectiveness and the enterprise's profit. The determination of losses caused by short machinery standstills followed by the recovery of full production capacity without a specialist's intervention takes more and more attention. These include the so-called micro-stoppages, the duration of which does not exceed 5 minutes. Nevertheless, the total time of machinery stoppage, after considering the total number of micro-stoppages in a given time period, often turns out to be significant and strongly affects the production indicators.

One of the serious problems is the ability of measuring micro-stoppages with simultaneous identification of their causes. It is possible to record stoppages and micro-stoppages indirectly, e.g. through a system that records the power consumption of machine engines. Unfortunately, this does not determine the cause of the machine's stoppage. The most advantageous measurement in terms of management and the ability to improve the effectiveness indicators is the use of special recording programs that allow automatic capturing of unplanned stoppages as well as the determination of the majority of the causes of micro-stoppages. Such programs include CINDY by Y-COMs used in the conducted studies [15]. In this paper, the Y-COM program allowed the automatic data collection in the period of two years.

During production, the recorded standstills were virtually imperceptible and only their automatic recording allowed for evaluating the scale of the phenomenon.

The analysis of micro-stoppages of the machines tested in this paper demonstrated that the recorded standstills are most often related to such event as: charge reheating, jamming, operator intervention, material breakage and repeated insertion, distribution of products, manual material pulling, cooling adjustment, lubrication system interventions and other unidentified incidents.

The testing covered three machines. In order to conduct an analysis of the production process and the occurring production standstills, the authors developed tables presenting the determined information about the duration of the standstills and their causes. The collected data was segregated, analysed and presented in the form of Pareto charts [3, 11].

A specific feature of all three tested machines was the dominance of three to five causes of micro-stoppages, the total time of which in the given period was the longest. The time resulted from both the number of micro-stoppages and their duration.

Figures 1–3 present the Pareto charts for the tested machines.

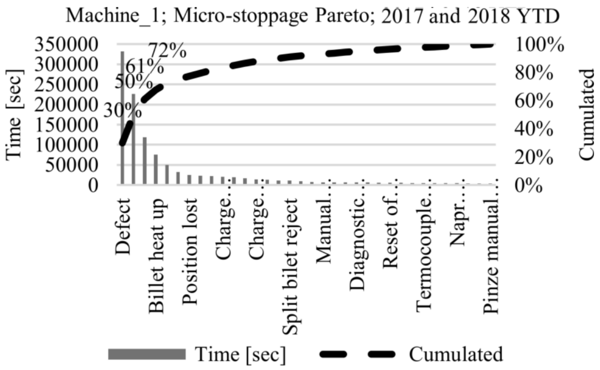

Fig. 1. Micro-stoppage Pareto chart for machine no. 1.

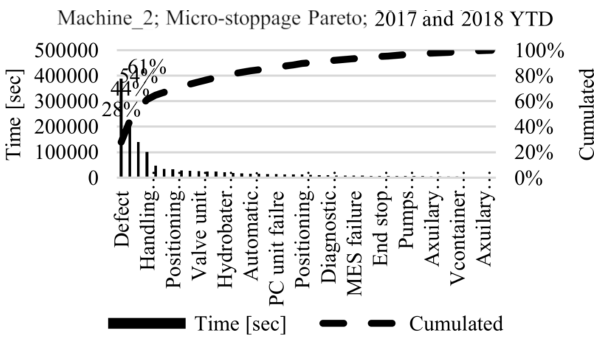

Fig. 2. Micro-stoppage Pareto chart for machine no. 2.

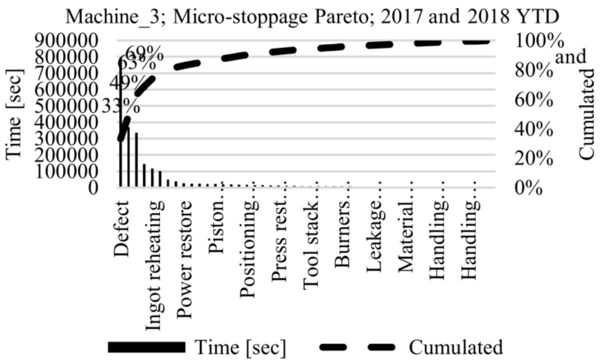

Fig. 3. Micro-stoppage Pareto chart for machine no. 3.

It is possible to observe an accumulation of approximately 50–60% of micro-stoppage losses in the following categories: defects, machine locking, ingot reheating and machine start-up, as well as due to unidentified causes. The occurrence of micro-stoppages with unidentified causes is a huge challenge for the production process management, because with a substantial intensity of this phenomenon their recognition can be of key importance for improving the production effectiveness.

It was established that for the first machine, the first three causes of micro-stoppages with the highest occurrence frequency cover 57% of the total time of all types of micro-stoppages, whereas for the second machine, it is approximately 51% and for the third machine – approximately 63%. This results from the fact that the rest of the causes, which constitute a large number, is equivalent in terms of time to the three dominant causes in terms of occurrence frequency and the total time of micro-stoppages.

An interesting result is the most frequent occurrence of micro-stoppages lasting approximately 140–180 s (approximately 2 minutes).

These are very short standstills that could be omitted if they had not been recorded. This indicates areas that should be noticed and considered for detailed analysis, because they contribute to the loss occurrence in the highest degree. The occurrence frequency figures covering particular micro-stoppages feature an analysis of the distribution of the occurrence frequency in the assumed time intervals. Figure 4 presents the course of frequency of micro-stoppage occurrence for machines no. 1, no. 2 and no. 3.

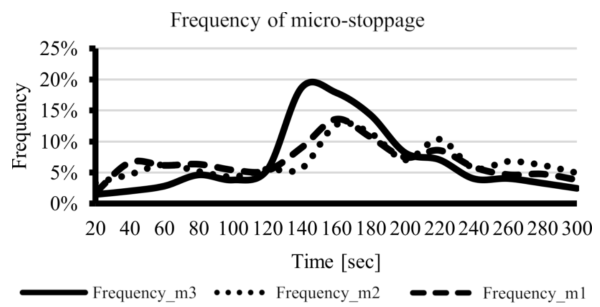

Fig. 4. Distribution of the frequency of micro-stoppage occurrence for machine no. 1, 2 and 3.

The analysis shows that the most common micro-stoppages in all three machines are events that last approximately 2–3 minutes. The identification of incidents demonstrates that these phenomena include: reheating, start-up, locking, defects, unidentified causes. These events were recognised as dominant in the Pareto charts. The performed analysis confirms that the identified causes have a great potential for the improvement of production effectiveness.

3. The OEE measure analysis

The evaluation of the impact of micro-stoppages on the OEE measure is of substantial importance for the assessment of the production process course and their significance for improving production effectiveness. The paper includes calculations aimed at the determination of the measure's value without micro-stoppage occurrence and with the machinery operation time loss resulting from their occurrence. The components of the OEE measure for both variants were calculated based on actual operating parameters of the analysed machines.

The variant that considers micro-stoppages includes time losses of both the availability and performance components, keeping in mind that each micro-stoppage also affects performance, because it lowers the number of manufactured products in a specific period of time and shortens the effective machine operation time.

The chart (Fig. 5) presents the percentage changes in the OEE measure for particular quarters of the analysed period of 2 years. The solid line indicates the mean value of OEE for all analysed machines.

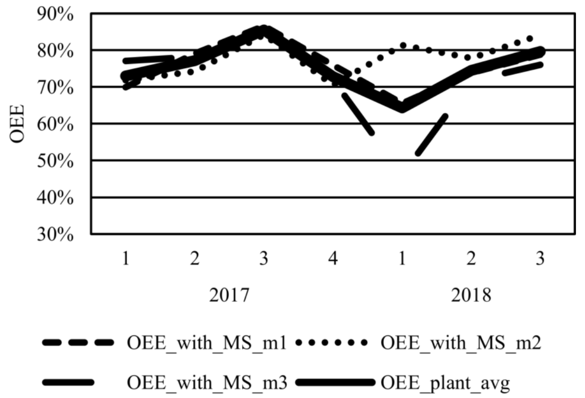

Fig. 5. The OEE chart for machine no. 1, 2 and 3 with micro-stoppages for particular quarters of the analysed period of 2 years.

The OEE waveform is not a straight line, but reminds a sinusoid and points to the value's fluctuations over time.

The designated OEE waveform lines display local increases and reductions that in the case of micro-stoppage consideration demonstrate the same progress, but with a lower OEE value (Fig. 6).

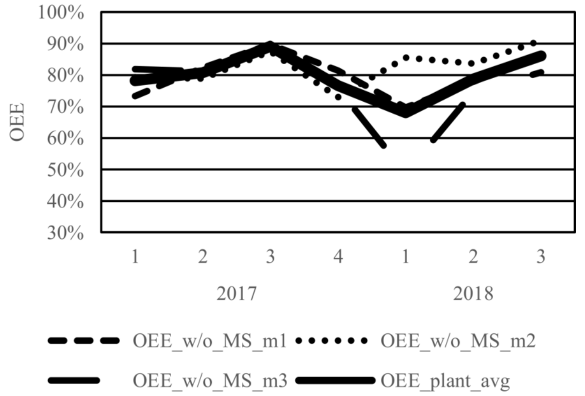

Fig. 6. The OEE chart for machine no. 1, 2 and 3 without micro-stoppages for particular quarters of the analysed period.

The impact of micro-stoppages on the OEE measure was estimated by comparing the values calculated without considering the micro-stoppages with the values that consider them. The mean value of OEE for three investigated machines is presented in Fig. 7.

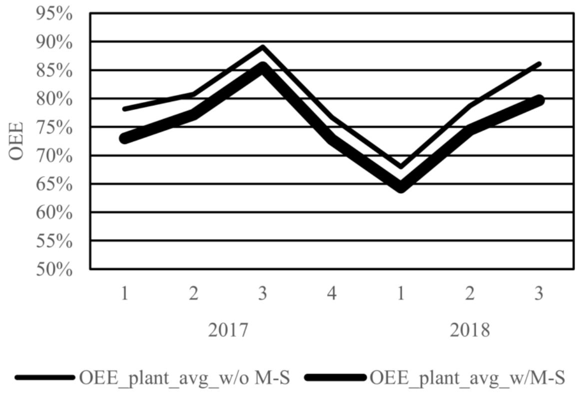

Fig. 7. Comparison of the mean OEE course with and without micro-stoppage.

The data analysis shows the reduction in production performance due to micro-stoppages by nearly a constant value of 3–6% for all tested machines. It is also noticeable that in the initial (1 quarter of the first year) and final testing stage (3 quarter of the second year), the reduction in performance due to micro-stoppages was higher than in the intermediate time interval for machine no. 2 and machine no. 3 (Fig. 6). In the case of machine no. 1, the differences in the OEE progress for the operation without and with the consideration of micro-stoppages are more stable at the beginning of the studied period and diverge in the final stage of the studied machine operation time. The mean value OEE measure lines demonstrates an increase in the indicator in the case of omission of micro-stoppages in comparison to the course of OEE with micro-stoppages and a slight decline occurs in first and last measured period (Fig. 7). The OEE measure's line demonstrates a variable tendency.

Biggest lowering the mean value of the OEE (enumerated as the average for three machines) took place in the first quarter of 2018 (Fig. 7). It results from here that it was a least beneficial period, with reference to the effectiveness of the production.

Analysis of causes of the OEE fall is pointing on compound character of adjuncts for production process. To the OEE value influenced changes of the demand for extrusion shapers received from aluminium. At the turn of the final period of previous year 2017 and the next beginning of a year 2018 an accumulation of small quantitatively of orders took place what bound oneself with more frequent rearming of machines. In such conditions, the temporal losses appeared influenced on availability of machines and also materials losses connected with the procedure of the technology. It is projecting onto the productivity and availability components in OEE measure. After rejection of micro-stoppages it was found the about 3–6% increase of OEE value.

4. Summary

The rejection of micro-stoppage didn't influence on the course of the OEE (Fig. 7). However increase productivity and enterprise profitability, especially in the case of big enterprises.

The production effectiveness increase is one of the most important parameters in an enterprise. There are many factors that affect its level. In general, they can be divided into the following categories:

- technological factors (technology modernity, machinery efficiency, production process automation, innovative materials and machines, etc.);
- organisational factors (machine park utilisation, service level, work station organisation, etc.);
- external factors (demand, market situation, customer requirements);
- human factor (work organisation, motivation, service awareness level).

An enterprise's business is a collection of numerous undertakings that are dependent on one another and often overlapping. Nevertheless, when considering the impact of individual, singled out factors, it is possible to evaluate which of them, in given production conditions, is predominant. Many production aspects, which affect performance, may not be recognised in the conditions of insufficient attention.

The awareness of introducing large changes through small steps is one of the ways to a production success [8]. It is, however, necessary to recognise the causes determining the areas which require change to avoid losses.

Micro-stoppages seem to be an elusive and rarely recordable fact in enterprises. The carried-out research indicate that they indeed are an important parameter that affects machine operation time, because their accumulation can lead to substantial performance losses. Regular recording of time micro-losses allows for evaluating incidents that lead to a reduction in performance. The area of recognition of the possible causes of micro-stoppages can be divided into identifiable and unidentifiable causes, often independent, for various reasons, from the tested device's operator. In terms of identifiable time losses resulting from micro-stoppages, not all of their causes can be removed or corrected. There are factors, the occurrence of which is integral to the production process, which results in an acceptable time loss, because it is a part of the product manufacturing process.

As for the group of recorded time losses designated as unidentified, it is also difficult to introduce any improvements. Therefore, the evaluation of the issue related to time losses during production is difficult and often impossible to be quickly improved or improved altogether.

However, the awareness of the issue and the evaluation of its impact on production effectiveness is a very valuable information in the management process, because it enables mature control of the phenomena that affect the enterprise's situation, which translates into its efficient management and the overall production evaluation.

In the case of the tested machine, the most best OEE measure was demonstrated by machine no. 2 (Figs 5 and 6), which despite including micro-stoppages featured an increase in the OEE measure both without and with the consideration of micro-stoppages.

Due to the difficulties in testing and estimating the time of micro-stoppages, the most advantageous method of recording them is monitoring through programs that capture standstills in the operation time of devices. It is difficult to expect a precise recording of such losses using other methods.

The publications concerning the analysis of the impact of micro-stoppages on the OEE measure confirm the OEE decrease as a result of such losses [6, 10, 12, 14]. The impact of micro-stoppages is visible in the availability and performance components. Stoppages and standstills, including micro-stoppages, cause a drop in availability and performance [6].

In order to get the efficiency rise of the production through meaning valid for the elimination of micro-stoppages has identified crucial of their causes, and then developing procedures which would enable their elimination. It results from conducted examinations that in analysed production conditions the most temporal losses were associated with the following phenomena: heating the ingot up, removing deadlocks, new starting the press but also with unidentified apprehensions of the process. Part of causes of micro-stoppages, possible to identify, is associated with the service of presses and here it is possible to search improvements, through trainings, the control and the supervision of the staff. In case of unidentified causes one should concentrate on attentive controlling processes and as far as possible for preventing unforeseen events.

The presented research works demonstrate that micro-stoppages, being one of the sources of machinery operation time losses, can become a potential area of increasing production effectiveness by their reduction or limitation. It is however necessary to monitor and estimate them as well as to analyse the scope of their occurrence. Due to the difficulties in recording micro-stoppages, this field is scarcely recognised and exploited, which is why it constitutes a large reserve in terms of increasing enterprise's profits.

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