EVALUATING AND IMPROVING THE EFFECTIVENESS OF THE ROLLING MILL IN THE PRODUCTION OF MEDIUM STEEL SECTIONS IN THE SELECTED COMPANY FROM THE METALLURGICAL INDUSTRY

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Abstract

The article presents the use of OEE metric to evaluate the effectiveness of the rolling mill line used for production of medium steel sections. Achieving maximum effectiveness of machinery and equipment by shortening the production cycle, resulting from continuous and uninterrupted flow of material results from Lean management, which is the result of continuous evolution and development of the concept of production management in industrial enterprises. More and more companies come to the conclusion that their success on the market decides the stable operation of machines and equipment used in the production process. One of the measures used to assess the level of utilization of owned machinery is OEE, the use of which allows to improve the productivity and effectiveness of the manufacturing process. The article presents the results of effectiveness evaluation of the rolling mill line used for production of medium steel sections by using OEE metric in a period of one year. Classification and quantification the reasons for standstills the rolling mill line by using the Pareto-Lorenz diagram were conducted. They have been identified and grouped root causes of rolling line stops by using the Ishikawa diagram. The article concludes with proposals to improve the effectiveness of maintenance of analyzed rolling mill lines.

Keywords: Rolling mill line, effectiveness, OEE, Pareto-Lorenz diagram, Ishikawa diagram

1. INTRODUCTION

Machinery and equipment are treated as strategic assets of the company, because they participate directly in the course of the technological process, during it is created the product quality and added value for the customer [1]. Nowadays, in an era of increased competition in both product quality and their price are very important to customers. The price of products can be reduced without affecting product quality through appropriate use of equipment used in the production technology [2, 3]. Optimizing the functionality and duration of uninterrupted work of equipment is an important issue associated with increased business performance of its competitiveness on the market in each industry [4, 5]. In many companies, each machines certainly could operate more efficiently. Research shows that most devices produce only half of what could, the total resource utilization is on the level of 30-50% [6]. To increase the effectiveness of machine and devices, it is important to know on what level of machines are currently being used. To find out about this, it's best to use some indicator. One of the indicators measuring the effectiveness of machines is OEE. Using this measure is very important. Information about the OEE percentage value give the close and true knowledge about the production effectiveness and increase this indicator by even a few percent brings the company huge financial benefits [7]. The aim of each company, its management is taking such action, which will increase the value of the OEE.

The aim of this article was to present the results of the use OEE to measure the effectiveness of the rolling mill producing medium sections in one of the largest companies in the metallurgical sector in Poland. Also presented in order to refine the analysis, usage of two classic quality tools, ie. Pareto-Lorenz and Ishikiawa diagram for quantification and classification of the reasons for standstill the rolling mill line. Based on the information were proposed actions increasing OEE level. An attempt was made to shorten the cycle of rolling and improve the process implemented on the analyzed rolling mill line.

2. OEE INDICATOR AS A MEASURE OF THE MACHINES EFFECTIVENESS

The OEE factor - Overall Equipment Effectiveness - is a key standard concerning effectiveness of machines, individual posts, production teams as well as assembly lines used in the TPM program - Total Productive Maintenance [8]. Its idea consists of comparing machine usage to ideal usage, that means to the situation when production and its preparation are conducted according to a schedule [6]. OEE is interpreted as the multiplication of Availability, Performance and Quality. *Availability* takes into account Down Time Loss, and is calculated as: ***Availability*** = *Operating Time / Planned Production Time. Performance* takes into account Speed Loss, and is calculated as: ***Performance*** = *(Ideal Cycle Time * Total Pieces) / Operating Time*. Quality takes into account Quality Loss, and is calculated as: ***Quality*** = *Good Pieces / Total Pieces*. OEE takes into account all three OEE Factors, and is calculated as: ***OEE*** = *Availability x Performance x Quality* [9, 10].

The improvement of OEE is via looking into the six big losses which are responsible for availability, performance ratio, as well as quality ratio of OEE and are classified under three main losses [11]. This metric allows to monitoring of elements influencing on company's productivity: level of product's quality, speed and capacity, time of machine availability [12, 13, 14]. Having calculated the OEE value for each machine participating in the process, the values need to be compared. For adequate evaluation of the machine efficiency, it is essential to analyze the data in a long-term perspective and then adopting an average, mean result [15].

Knowing the OEE rate for particular machines and equipment helps to assess the efficiency of machine usage, and in consequence the entire process from the perspective of equipment and devices. Based on the acquired data, it is possible to evaluate the conditions and maintenance of technical units and objects, resulting from the contemporary production plan [16].

3. OEE CALCULATION FOR THE ROLLING MILL LINE

3.1. Rules of the rolling mill time losses classification

To analyze the efficiency of the rolling mill with the use of OEE indicator [17] a division of time losses were divided into three categories: availability, performance and quality to increase the overall performance of equipment [18]. For the calculation *availability losses*, data containing information relating to the settlement of monthly working time of the rolling mill line was used. The time was divided into 4 categories: 1. Time calendar, informing about the number of hours available in a given month, 2. Standstill associated with such activities as: repairs, planned shutdowns, etc. divided into: repairs, planned shutdowns, other planned shutdowns, 3. Running time, informing about the number of hours available during which the process could be realized, 4. Total breaks, which include: technological breaks, mechanical, electrical, energy-related, external, other.

To calculate the *performance losses* was used data containing information about the total production volume realized in different settlement periods and output, which could be realized during the operation time and was not realized due to unplanned shutdowns of rolling mill line.

For the calculation of *quality losses* was used data containing information about the total size of the batch, from which we get the final product and volumes of baling production.

The study was conducted within 12 months. Unit of account was one month.

3.2. OEE indicator calculation for a period of one month

Table 1 shows the results of the settlement time of the rolling mill line for a period of one month - January. **Table 2** provides more details about the value of production in the analyzed period of time. **Figure 1** is a column diagram showing the distribution of disruptions (losses) occurring on the analyzed production line. The time in the **table 1** and **2** and in the **Figure 1** saved in the form of 00:00:00, where the first number determines the number of hours, the second - the number of minutes, the third - the number of seconds.

Table 1 Monthly settlement of the work time and breaks for the rolling mill line

Calendar time (hr:min:sec)	Planned shutdowns (hr:min:sec)			Running time (hr:min:sec)	
	Repair	Planned	Other		
744:00:00	0:00:00	11:30:00	0:00:00	732:30:00	
Rolling time (hr:min:sec)	Total breaks (hr:min:sec)	Technological breaks (hr:min:sec)			Total technological breaks (hr:min:sec)
		Rebuild	Pass	Other	
444:50:00	287:40:00	96:50:00	14:00:00	66:55:00	177:45:00
Mechanical (hr:min:sec)	Electrical (hr:min:sec)	Energy-related (hr:min:sec)	External (hr:min:sec)	Total (hr:min:sec)	
11:20:00	4:05:00	0:30:00	37:35:00	56:25:00	

Table 2 Monthly settlement of made production for the rolling mill line

Batch for production (ton)	Raw production [ton]	Scrap (ton)
44020	42600	99
Baling production (ton)	Sent production (ton)	
40742	38370	

OEE indicators calculation:

$$Availability = \frac{Operating\ Time}{Planned\ Production\ Time} = \frac{444{:}50}{621{:}40} = \frac{444.83}{621.67} = 71.55\%.$$

$$Performance = \frac{Ideal\ Cycle\ Time\ \text{x}\ Total\ Pieces}{Operating\ Time} = \frac{00{:}00{:}36\ \text{x}\ 44020}{444{:}50} = \frac{0.01\ \text{x}\ 44020}{444.83} = \frac{440.2}{444.83} = 98.96\%.$$

$$Quality = \frac{Good\ Production}{Total\ Production} = \frac{40742}{42600} = 92.55\%.$$

$$\boldsymbol{OEE = Availability\ \text{x}\ Performance\ \text{x}\ Quality = 71.55\%\ \text{x}\ 98.96\%\ \text{x}\ 92.55\% = 65.53\%.}$$

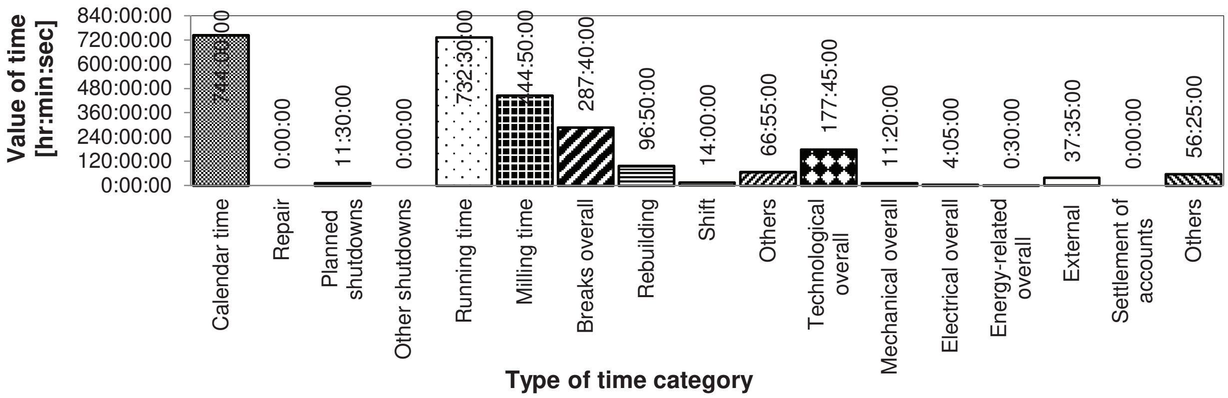

Figure 1 Monthly distribution of production disruptions and other time categories for the rolling mill line

3.3. Summary of OEE indicators for a period of one year

In the **Figure 2** the results of OEE indicator and its sub-indicators calculation were presented in the period of 12 months and they were compared the average value for these indicators with the value adopted as a World Class OEE.

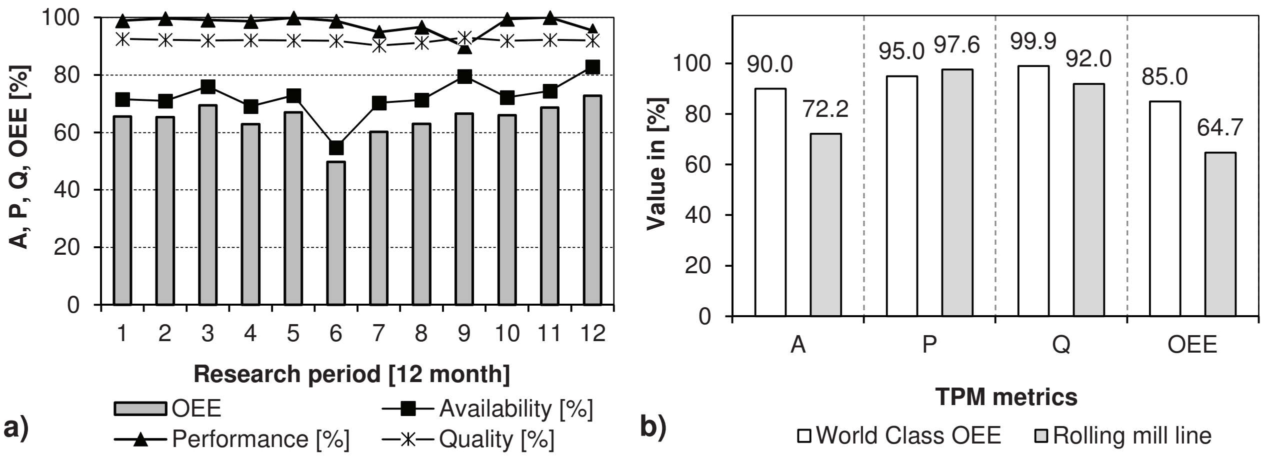

Figure 2 Distribution of OEE indicators values in the period of 12 months (a) and the comparison the actual value of TPM's indicators with the World Class OEE for the rolling mill line (b)

Analysis of OEE during the year indicates that the performance line indicator in the production process of medium still sections ranks as the average level of 64.7 % in the 12-month period and it is lower than OEE World Class value. The biggest impact on the low level of OEE indicator was losses related to the availability, the level of which fluctuated significantly in the considered period, having attained the highest level of 82.84 % in December, while the lowest in June, 54.78 %. This indicator remained at the average level of 72.2 %. Performance indicator lowest level obtained in October - 89.96 % and the highest in November - 99.99 %, the average for the examined period amounted to 97.6 %. The level of this indicator in a period of analyzed year was higher than World Class for this indicator. While the quality indicator remained at an average of 92.0 %, the highest level recorded in September, 93.06 %, while the lowest 91.21 % in August.

By comparing the calculated mean values for indicators TPM for the analyzed line with the values of the level of the world's visible is a large potential for improvement in terms of ratios, the largest, with respect to the availability indicator, the smallest with respect to the quality indicator. The elimination of unplanned shut downs, that for the analyzed period amounted to 1714.75 hours, will increase the availability of the line work time, which directly translate into an increase in the value of OEE. Performance indicator devices can be even more raise during the optimization of charge, which is used in the process of rolling. The optimum charge size (length, width, thickness) to allow faster processing of a single piece of material (the length of the heating, rolling speed), optimization and more efficient cutting the band, already finished the steel section, on the length ordered by the client.

4. CLASSIFICATION AND QUANTIFICATION OF THE ROLLING MILL LINE STANDSTILL REASONS BASED ON ISHIKAWA AND PARETO-LORENZ DIAGRAM

To increase the value of the OEE indicator for the test line, made a comprehensive analysis of loss and their causes related to low availability of the line. Information about the standstills of the analyzed line, collected during its monitoring was based on data from the crop rotation report. Basis on it the eight basic, the most often occurring groups of disturbance of the test lines connected with accessibility, such as: rebuilding, pass, other technological, external, other finishing bank, mechanical, electrical, energy-related. There have been quantifying the causes of detention tested lines using the diagram Pareto-Lorenz (**Figure 3**) to indicate the critical reasons for standstill.

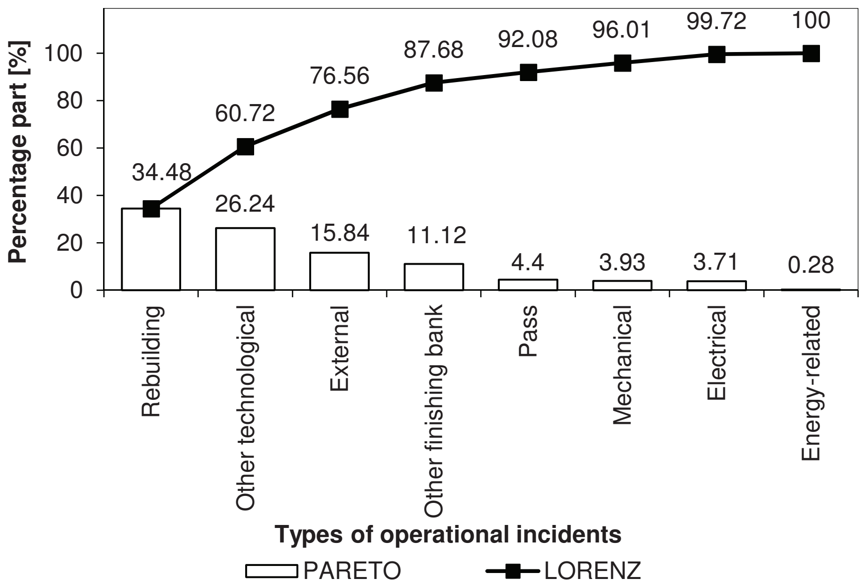

Figure 3 Pareto-Lorenz diagram to analyze the reasons for standstill the rolling mill

The most common reasons for detention tested lines include: rebuilding the line, other technological standstill, external standstills, and other reasons connected with standstill of the finishing steel sections. Extracted during the analysis of Pareto-Lorenz reasons, were further analyzed by Ishikawa diagram (**Figure 4**) [14, 15]. It was made it possible to reach the lower levels of the reasons for the production line standstill.

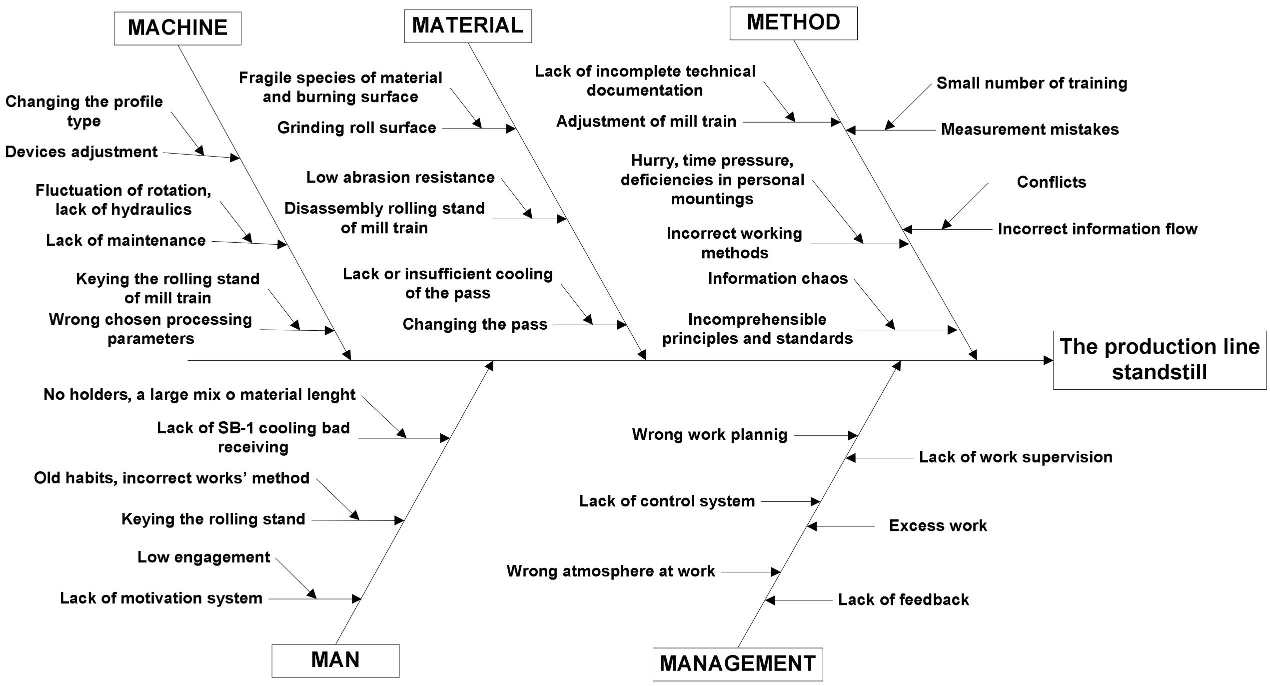

Figure 4 Ishikawa diagram for the root cause of standstill the rolling mill line

In order to shorten the time of rebuilding of the rolling mill line, there is a need for a faster set-up the line and campaign planning in such way that rolled profiles on the same or similar assemblies, the rollers were rolled up after themselves. Other technological standstill and external are due to other causes, so they were divided into further causes, which include: improving the equipment frames of rolling stand, improving cooling frames of rolling stand, lack of SB-1 cooling band receiving, adjustment the section straightener, grinding the roll surface, changing the pass of the rolling stand, adjustment of frames of rolling stand, building the rolling stands.

5. CONCLUSION

The aim of the research was to improve the efficiency of the rolling mill line that produces medium sections on the basis of information obtained from the OEE analysis. Proposed specific improvement actions, the implementation of which will increase the efficiency of the line and shorten the production cycle. Effective use of the available time of the line is the primary factor in the production volume of the tested product. Information about how, in fact, is as available time is important to determine the correct length of the production cycle of the tested product. Knowledge of these values allows for precise work plan to develop the rolling mill plant. The proposed method of evaluating the use of working timeline - OEE - made it possible to assess the effectiveness of the use of the tested line from the point of view of the availability, performance and quality. Usage the research tools such as Pareto-Lorenz and Ishikawa diagram allowed to identification, classification of factors affecting the availability of the line, quantification these reasons, then eliminating or reducing the possibility of their occurrence, which contributed to a better use of the tested lines and resulted in improving the flow of goods.

Proposed improvement actions based on the information obtained through the analysis of OEE indicator. Eliminating standstill time classified as external standstill, so related with the lack of frame rebuild to other section allowed to increase the effective time of rolling of 443.92 hours. The desire to obtain a perfectly smooth movement of material through the finishing part of rolling train with the use of Heijunka tool provide more 311.75 hours to the time of rolling. Standstills included as technical or mechanical, electrical, energy-related, a total of 141.83 hours will be minimized through the implementation of the TPM program. The time spent on the pass and rebuilding in amounts of 774.83 hours will be optimized using the SMED method. Continuous monitoring will allow you to add more minutes to the time of rolling. According to the methodology Kaizen these changes will be implemented in stages, continuously. Implementation of the listed solutions will affect: prolonged rolling time, reduced standstills, optimize staying ingot in the furnace, reducing the time of rebuilding and pass, increasing time and number of campaigns, increase volume of production, increase capacity of rolling mill plant, savings obtained due to more efficient usage of media.

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