Production Engineering Archives 17 (2017) 45-48

Production Engineering Archives

ISSN 2353-5156 (print)
ISSN 2353-7779 (online)

Exist since 4th quarter 2013
Available online at www.qpij.pl/production-engineering-archives

The analysis of machine operation and equipment loss in ironworks and steelworks

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Article History
Received 28.09.2017
Accepted 28.12.2017
Available 31.01.2018

Keywords
utilization
losses
TPM

Abstract

The article presents a case study of the identification and analysis of operating and equipment losses in a steel plant. Losses may be visible in costs resulting from premature wear of machine and equipment components, removal of emergency failures related to quality losses, including loss of reputation of a reliable supplier, as well as losses related to production, especially in the case of continuous production. The analysis of losses was based on the cost criterion, including losses resulting from the loss of a potential client. The real data from the 2016 were used in the case study. In order to ensure proper operation at the finishing department, standard solutions have been developed. The analysis of losses was based on the Pareto principle and the analysis of TPM coefficients.

DOI: 10.30657/pea.2017.17.10

1. Introduction

The TPM system (Total Productive Maintenance) is currently widely implemented in Polish companies (Kardas E. 2017). Measuring the effectiveness of this system implementation is usually done with KPI (Key Performance Indicator). In the KPI analysis, a wide range of indicators related to: breakdowns, technological shutdowns, mass as well as cost, energy consumption is used. In the following analysis two main indicators analyzing the operation and equipment losses in the steel plant will be presented, i.e. MTBF (Mean time between failures) and MTTR (Mean time to repair) (Palchun Yu. A., Yelistratova I. B. 2014). It is difficult to indicate a production company that implements a lean management philosophy without a TPM system. The goal of TPM is to improve the efficiency of the use of the machine park by reducing the so-called Six Big Losses (Ng TC., et al. 2017): failures, too long set-up time, micro-stops at work of machine, reduced work speed, quality defective product, reduced performance during machine start-up.

From the point of view of TPM, the losses in the efficiency of the machines, failures are of utmost significance. Their reduction has an impact on improving the availability of machines. Two indicators serve this purpose, mainly identified with the Maintenance Department (Zhou D., et al. 2014): MTTR, MTBF. Their monitoring and measurement are crucial in reducing losses by minimizing the risks associated with unforeseen failures (minimizing failure times). These activities are aimed at increasing the machine availability ratio. Analysis of MTBF and MTTR indicators works best by monitoring their trends in the following days/weeks/months (Niwas R., et al. 2016). Afterwards, it becomes visible whether the activities undertaken as part of the TPM bring the intended positive effect. Production systems in many cases are characterized by a high degree of complexity of the machine park in terms of quantity and composition. The key challenge is to determine how to accurately analyze the MTBF and MTTR indicators. The effective functioning of one selected device may depend on the effective functioning of components or other separate independent devices. In order to avoid excessive data, a generalization according to the theory of fuzziness is used, and it is limited to the most important elements of the system in terms of operational efficiency and generating potential operational losses (Hooi L. W., Leong T. Y. 2017).

2. Case study

Analysis of operation and equipment losses in the steel plant for the purposes of this article was limited to the Finishing Department. The presented research results are only a part of the ongoing research process aimed at improving the value stream in the steel plant by limiting the Muda. Processes in the Finishing Department can be divided into two main lines, which are the main elements of the added value in the value stream and areas of additional work in which a significant part of the operations can be defined as not adding value.

Analyzing the documentation related to failures and stops on Finishing Department, the following main reasons for their occurrence were identified. On line A, 23 stop areas have been identified, which after grouping are as follows:

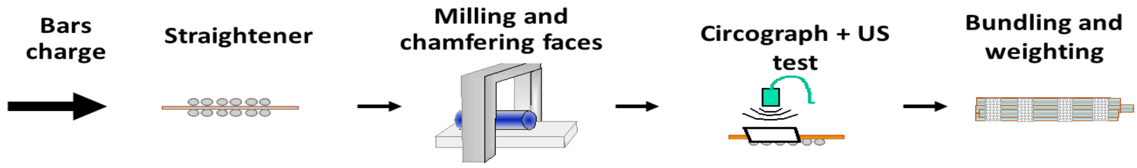

Fig 1. Elements of value stream in the finishing department – line A. Dimension range ϕ 20 ÷ 45mm

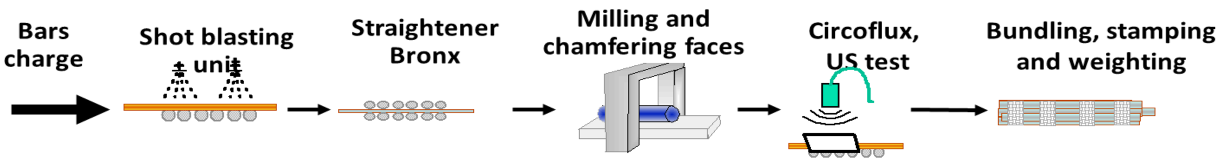

Fig 2. Elements of value stream in the finishing department – line B. Dimension range ϕ 36 ÷ 80mm

The main processes of the Finishing Department are heat treatment and processes carried out on finishing lines. Heat treatment is carried out in two tunnel furnaces which are powered with natural gas and one electric aggregate furnace. On gas furnaces, heat treatments such as annealing (softening, normalizing, isothermal, spheroidizing and stress relief) can be carried out. These processes are performed in the furnace by adjusting the material speed (processing time) and zone temperatures. Depending on the type of heat treatment which is carried out, the temperatures of individual zones can be adjusted or deactivated (turned off). The heat treatment processes are done first and after that the material is transferred to finishing lines.

Finishing lines, except for the difference in the dimension of the prepared bars, are configured in a very similar way (Fig. 1, Fig. 2). The main operations on both lines are: straightening - 100% material, chamfering or milling (both ends) - depending on requirements, testing surface defects (eddy current method), examining internal defects (ultrasonic method), packaging. On both lines for testing surface defects Foerster devices are used, whereas to examine internal defects the devices are the GE/Krautkramer. The material after testing is automatically sorted - defective bars are transferred to the non-conformity/defect insulator and satisfactory material in terms of the requirements for internal and surface defects is transferred to the packing machine. Bundles of material are tied with a special tape. A tag containing the information about the material is attached to each bundle. In addition, on the line B before straightening machine a shot-blasting machine is used for cleaning the material after heat treatment from scale.

Working dimension range for line A:

- Dimension from 20 – 45 mm, length bars 3.5 – 12.0m

Working dimension range for line B:

- Dimension from 35 – 80 mm, length bars 3.5 -12.0 m.

In addition, the material can be color-coded or self-adhesive stickers depending on the customer's requirements.

- stops related to the straightener - three types of stops,
- stops related to the packing machine - three types of stops,
- stops related to the chamfering table - two types,
- stops for the trolley and the roller table - two types,
- the table and the roller table bringing to the chamfering table - two types,
- switchboard,
- roller table of Foerster - two types,
- chain transporter of packing machine,
- roller table bringing to the straightener - two types,
- chamfering table,
- loading grid,
- Foerster,
- chamfering machine,
- switching grid.

The important element from the point of analysis and Muda view is to focus on the most significant failures. Failures are grouped because not all failures are homogeneous in terms of time and cost. On the line B, 33 stop areas were identified in the following way:

- stops related to the Bronx straightener – eight types,
- switching end setting grid – three types,
- stops related to the packing machine – two types,
- stops related to the chamfering machine – six types,
- roller table after shot-blasting machine,
- switchboard,
- rotary handle to the roller table,
- sideway roller table,
- shot blasting machine – two types,
- chain grid before the Bronx,
- roller table bringing to the chamfering table,
- roller table after the Foerster – two types,
- head of Foerster,
- rotary handle of defect bars and baskets for defect bars,

- table of packing machine,
- roller table of packing machine.

Figures 3 and 4 present the Pareto loss analysis of time associated with failures for individual lines – line A and line B.

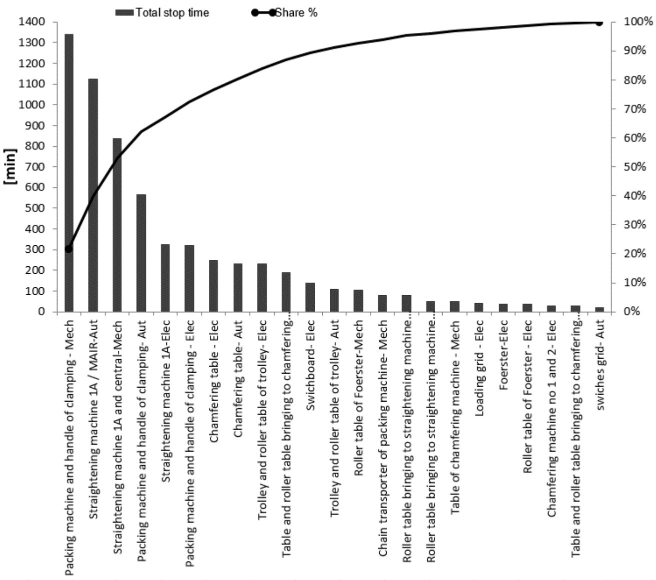

Fig. 3. Pareto analysis on finishing department – line A

3. Losses analysis on lines A and B using MTTR and MTBF

In order to limit the amount of data in the process of making decisions, the focus was on monitoring and analyzing losses by means of MTTR and MTBF. The article presents analyzed research data for the 12-month 2016 year. The data was collected from two lines A and B, as shown in Table 1. Line A during year 2016 achieve 1.4% stops, compared to the available time, which is 0,25% worse than expected for 2016. The MTTR target (meant time of failure removal), which was exceeded by 11.3min/failure, was not met. Line B achieved 1.4% of available time per year, which is a 0.4% better result than assumed in 2016. Other indicators such as MTBF (average time between failures) and MTTR were not kept for line B.

Table 1. Percentage share of breakdown to the available time

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	2016
Line A	0.75%	2.9%	0.7%	0.4%	0.2%	0.8%	1.8%	1.4%	0.3%	0.0%	4.2%	2.6%	1.4%
Line B	1.4%	1.3%	2.7%	0.5%	1.2%	0.5%	1.2%	1.0%	1.3%	2.7%	1.9%	0.5%	1.4%

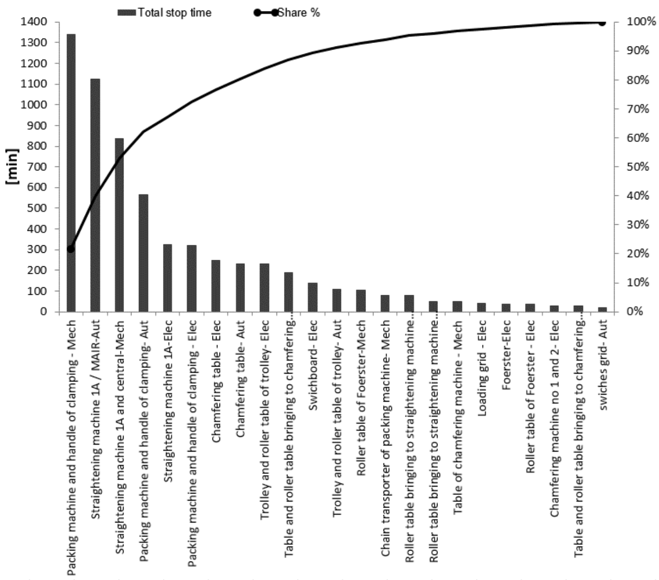

Fig. 4. Pareto analysis on finishing department – line B

Table 2 presents summarized results and goals.

Table 2. Values of indicators MTBF and MTTR

	Line B		Line A	
Failure goal / Failure execution [%]	1.8	1.4	1.15	1.4
MTBF goal / MTBF execution [min]	2700	4021.2	3700	5683
MTTR goal / MTTR execution [min]	45	46.4	35	46.3

4. Discussion and conclusions

The important element from the point of view of the analysis of operational losses and devices is the analysis of the ratio of unplanned times - failures in relation to the planned technological and other that can be defined. In the case of the line A, the average monthly time is 730 hours - it is calendar time. By subtracting from it the average planned maintenance shutdowns in the level of 77 hours, we get the time available on average to 653 hours. The difference between the time available and the working time consists of three groups, some of which can be planned while analyzing.

These groups were divided into:

- technological stops – these are stops related with the change of profile, calibration, replacement of equipment and trials,
- maintenance breakdowns – these stops are related with mechanical, electrical and automation failures
- other stops – these stops are related with defective material, change of orders, lack of personnel, equipment limitation (short material, chamfered, milled), breakthrough shift changes, cobbles, jams.

The individual losses in the groups for the line A are as follows:

- technological stops – on average 8.8%, which is on average 57.3 hours per month,
- maintenance breakdowns – on average 1.4%, which is on average 8.9 hours per month,
- other stops – on average 3.2 which is on average 21.2 hours per month.

For line B, the average monthly calendar time is 730 hours. By reducing from it the average planned maintenance shutdowns on the level 56 hours, an available time on average on the level 674 hours is achieved. For line B stops and losses divided into groups are as follows:

- technological stops – on average 7.9% which is on average 53.6 3 hours per month,
- maintenance breakdowns – on average 1.4% which is on average 9.2 hours per month,
- other stops – on average 3.6% which is on average 24.3 hours per month.

The distribution of results shows that both for line A and line B have not been fully complied with the 70/30 rules. In the case of the line A, the result is 53/47 and for line B it is 38/62. However, taking into account the analysis not the type of failure, but the key device (machine type), both for the A and B lines, the principle remains maintained and the result respectively are 73/27 and 59/41. With such broken losses, it is easy to determine after what time the preventive replacement or review of a given device should take place. In case of a mechanical failure of the Bronx straightener on line B, the inspection time should take place no more frequently than every 1200 minutes. It can be clearly seen that the straightener on the B line generates approximately 30% of the all line loss. Regarding the line A, the critical device is a packing machine and a straightener, which translates into 73% of the total line loss. Here, both the packing machine and the straightener should be inspected on average every 1100min.

Of course, the principle of division into key elements in each production plant can be adapted to the needs of each device or line separately. It is important, however, that such a preventive exchange takes place on key parts of the machine.

In this situation, preventive replacement can take place more often. That is why it is so important to prioritize MTBF and MTTR indicators to prioritize machines, and to identify key parts on them.

Measurement of MTBF and MTTR indicators is not only to see general trends in the operation of the maintenance department in the plant. Due to these indicators, one can plan preventive inspections and replacement of parts on priority machines. They also give the opportunity to analyze the effectiveness of implementing activities related to shortening the time of failure removal. They are also an excellent measure of the implementation of Autonomous Conservation activities, which are the basis for the implementation of the TPM system. These indicators are closely related to the failure analysis, which is why they are a great support for the maintenance departments in production plants. It is worth using these indicators, but not only to measure them, but in order to draw conclusions and implement actions aimed at reducing the failure rate of machines and shorten the time of failure removal. All of this will translate into increased machine availability and improved OEE.

Identification and weighting of indicators gives the possibility to monitoring devices, greater safety in taking risks, gives a safe lifetime and provides information when and what needs to be changed or done. In this way, we are able to minimize the risk of failure and better use of available time and provide greater security at the workplace.

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钢厂运行和设备损失分析

關鍵詞

采用
损失
TPM

摘要

文章介绍了一个钢铁厂运行和设备损失识别和分析的案例研究。与机器和设备部件过早磨损有关的成本可能会出现损失，消除与质量损失有关的紧急故障，包括可靠供应商声誉的损失，以及与生产相关的损失，特别是在连续生产的情况下-tion。损失分析基于成本标准 包括潜在客户流失造成的损失。案例研究中使用了2016年的实际数据。为了确保精加工部门的正常运行，标准解决方案已经开发完成。 损失分析基于帕累托原理和TPM系数分析。