THE ASSESSMENT OF EFFECTIVENESS OF BLAST FURNACE USING PAMCO METHOD

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Abstract

One of the basic factors influencing the good results of any production system is the optimal organization of the production process so that the use of machines is as effective as possible. One of the methods of assessing the use of machine working time is the PAMCO (Project Analysis and Monitoring Company) method. The main goal of the paper is the presentation of results of PAMCO method of blast furnace working in one of Polish steelworks. The analysis includes data related to different types of time for calculating appropriate indexes. The analysis covers the period of one calendar year.

Keywords: Blast furnace, pig iron, effectiveness, PAMCO method

1. INTRODUCTION

Blast furnace process is the basic manufacturing process of pig iron and the first step in steel production chain. It is a device which works continuously. Blast furnace process is very complex and involves enormous streams of materials and energy. There are many factors influencing the production costs, among them are: the use of well-prepared and high-quality materials and fuels, maintenance of parameters of blast furnace process at the optimum level and the most efficient use of working time of the installation [1]. The paper focused on the working time of selected blast furnace device. Analysis of efficiency of working time should be divided into two parts: Overall Equipment Effectiveness – OEE and PAMCO. The results of OEE analysis was presented in other work [2]. The main goal of this paper is the presentation of results of PAMCO method of blast furnace conducted in one of Polish steelworks. The analysis includes data related to different types of time for calculating appropriate indexes. The analysis covers the period of one calendar year.

The methodology presented here can be applied in many ways when it comes to the use of expensive machines, the working time of which should be monitored and optimized. These are both industrial (e.g. automotive [3,4], lean management [5,6], logistic [7], quality [8,9], food production [10]) and service (e.g. databases [11], intelligent buildings [12], e-commerce [13] and education [14]), but also research-laboratory (e.g. protective coatings [15,16], surface machining [17,18], fatigue analysis [19] and biotechnology [20,21]) areas. The analysis carried out and the results obtained may also be inspiring for researchers using similar analytical methodologies (e.g. risk management [22] or knowledge management [23]).

2. PAMCO – METHODOLOGY OF THE RESEARCH

One of the basic goals of any enterprise is the optimal use of its resources. To assess their use, one can use many technical and economic indicators, which include, among others, productivity or efficiency. One of the methods used to assess the efficiency of machines and equipment is PAMCO. The PAMCO method is used to measure the performance of machines and is based on indicators that are defined based on the time structure [24]. The PAMCO method shows the measurement values and reports the operation of machines and technical devices. This method also determines the working time of the tested devices, reduces the

number of parameters used, giving a picture of the measurement of these devices [25]. Time, according to the PAMCO method, was divided into types presented in **Table 1**.

Table 1 Activities and events included in the individual types of times and ways of calculating [25,26]

Calcucated time	Components. Time calculation formulas	Components included in the analysis of the operation of blast furnaces
TT – total time	Total time, number of hours covering the study period	Total number of hours for blast furnace under study
UAT – unavailable time	Free time related to holidays, and free weekends	As the devices work in a continuous system, this time is 0
AT - available time	AT = TT – UAT	
AUT - available but unused time	Number of hours associated with downtime due to lack of orders, autonomous maintenance	Number of hours for blast furnaces doe to the lack of receipt of pig iron or no materials (sinter and coke)
UT – utilization time	UT = AT – AUT	
PNOT – planned nonoperational time	Number of hours related to changes in plans, technological trials, repairs	Standstill times of blast furnaces related to repairs
OT – operational time	OT = UT – PNOT	
Routine stops, rps	Number of hours related to routine stops for: cleaning, assortment changes, production stoppages and losses, routine machine changes	Number of hours of operation of blast furnaces related to technological and mechanical breaks
PT – production time	PT = OT – rps	
Unplanned stops, us	Hours of unplanned downtime: minor stops, breakdowns, adjustments, errors, decreased machine performance, technological problems, logistic disruptions	Unplanned breaks in the operation of blast furnaces related to electrical and energy breaks, power limitation and others
ET – effective time, ET	ET = PT – us	

Individual types of times were used to calculate indicators that give a complete and clear picture of the use of the machine's work [24-26]:

1) Production Efficiency (PE)

$$PE = \frac{ET}{PT} \cdot 100\% \quad (1)$$

2) Operational Efficiency (OE)

$$OE = \frac{ET}{OT} \cdot 100\% \quad (2)$$

3) Available Utilization (AU)

$$AU = \frac{OT}{AT} \cdot 100\% \quad (3)$$

4) Asset Availability (AA)

$$AA = \frac{AT}{TT} \cdot 100\% \quad (4)$$

5) Asset Utilization (AUt),

$$AUT = \frac{UT}{TT} \cdot 100\% \quad (5)$$

6) Operational Utilization (OU)

$$OU = \frac{OT}{TT} \cdot 100\% \quad (6)$$

7) Production Utilization (PU)

$$PU = \frac{PT}{TT} \cdot 100\% \quad (7)$$

8) Effective Utilization (EU),

$$EU = \frac{ET}{TT} \cdot 100\% \quad (8)$$

Optimum values of indicators in the PAMCO methods should reach the following optimum [24-26]:

– PE - as high as possible and exceed value of approximately 95%,

– OE - about 92.5%,

– AU - about 90%,

– AA - about 97%,

– AUt - it is required that it takes value of 65%,

– OU - about 62%,

– PU - exceed 60%,

– EU - at level 50%.

Research was conducted in one of Polish steelworks. One blast furnace was selected. The analysis covers the monthly data of the period of one calendar year. During the analysis, on the beginning the information about the work of the device was collected, then main indicators were calculated according to the **Table 1** formulas (1) - (8). Values were compared to the average and optimum values.

3. THE ANALYSIS OF RESULTS

Analysis of PAMCO indicators for blast furnace device was conducted. Values of basic indicators were calculated according to gathered data and were compared to the average values in the study period. Results of this analysis are presented in **Figures 1-7**.

The PAMCO analysis conducted for the selected blast furnace device (**Figures 1-7**) allowed for the conclusion that:

- Production Efficiency (PE) indicates what part of the production time is the effective time (less unplanned stops). The average value of the index was approx. 99.6%. In four months it was lower than the average, the lowest value was recorded in July. It was caused mainly by energetic breaks. However, this indicator was still at a high level and exceeded the optimal value (95%).
- Operational Efficiency (OE) indicates what part of the operational time is effectively used during the manufacturing process, and what part of this time are interruptions related to routine and unplanned stops. The average value of this indicator was over 98.4% and remained at a similar, high level for almost the entire period, the lowest value was recorded months 7, 8 12, what was caused mainly by technological breaks. The values for the entire period exceeded the optimal value of 92.5%.
- Available Utilization (AU) defines the percentage of operational time in the available time (planned nonoperational time is taken into account) and its value should be at least 90%. During the study period, the average value of over 88% was obtained, slightly below the optimal value. The lowest values were recorded in months 3 and 9-11, which was related to the planned current repairs of the device.
- Asset Availability (AA) is the percentage of available time in total time, and it should be at level of minimum 97%. Because the blast furnace device work continuously, value of this indicator is 100%.

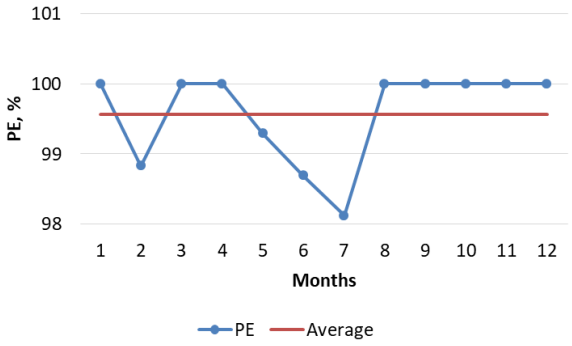

Figure 1 Value of Production Efficiency (PE) in comparison to the average value in the study period (Own study based on [27])

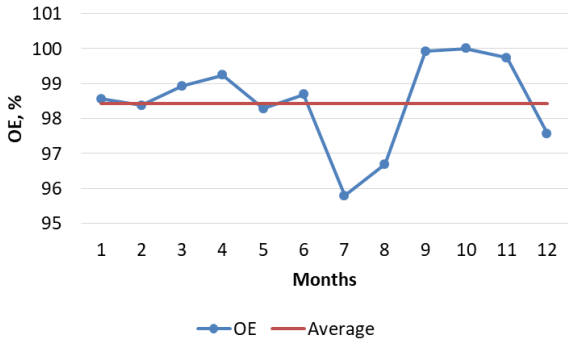

Figure 2 Value of Operational Efficiency (OE) in comparison to the average value in the study period (Own study based on [27])

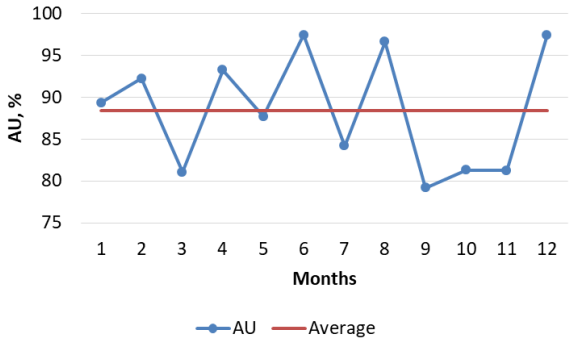

Figure 3 Value of Available Utilization (AU) in comparison to the average value in the study period (Own study based on [27])

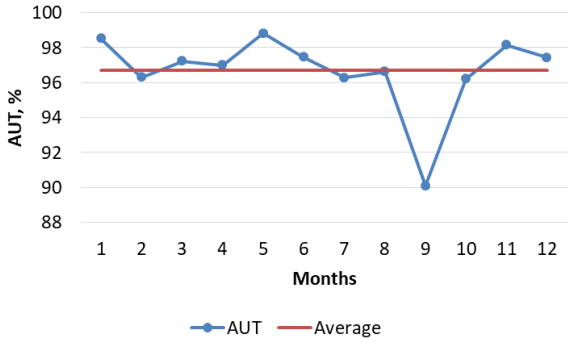

Figure 4 Value of Asset Utilization (AUt) in comparison to the average value in the study period (Own study based on [27])

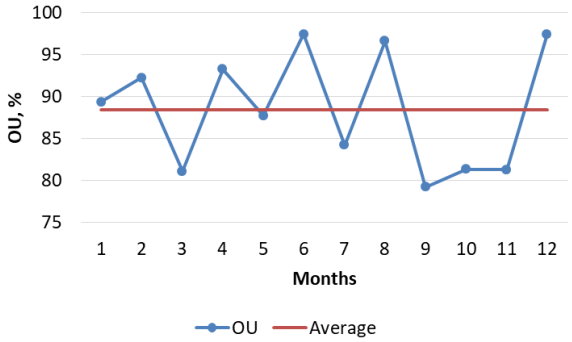

Figure 5 Value of Operational Utilization (OU) in comparison to the average value in the study period (Own study based on [27])

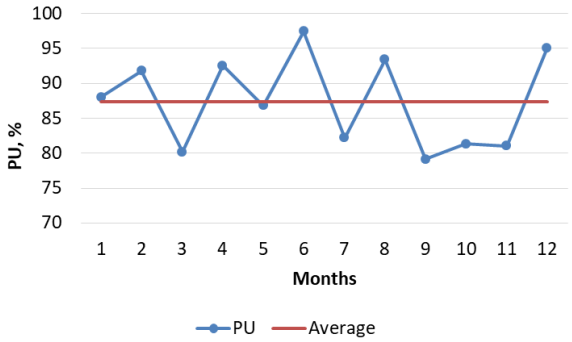

Figure 6 Value of Production Utilization (PU) in comparison to the average value in the study period (Own study based on [27])

- Asset Utilization (AUT) shows how much of the total time is used, and how much of that time is downtime due to lack of orders or material. The average value of this indicator was above 96%. In this case, value below the average was recorded in month 9. Throughout the entire period, the optimal value (65%) was exceeded.
- Production utilization (PU) indicates what part of the total time is the production time and what part of the time is spent on interruptions related to the available unused time, repairs and routine stops. The

average value of this indicator throughout the period was over 87%, and it significantly exceeded the optimal value of 60%. In months 2, 9-11 it was well below the average due to significant downtime in the operation of the machine.

- Production utilization (OU) was on the same level as AU, since the bases of reference in both indicators (time available for AU and total time for OU) are the same. The optimal value was significantly exceeded.

The indicator of effective utilization EU (average level of approx. 87%) usually significantly exceeded the requirements (50%), which proves the good organization of production and optimal use of blast furnace working time. Moreover, the values of this indicator were very close to the PU indicator.

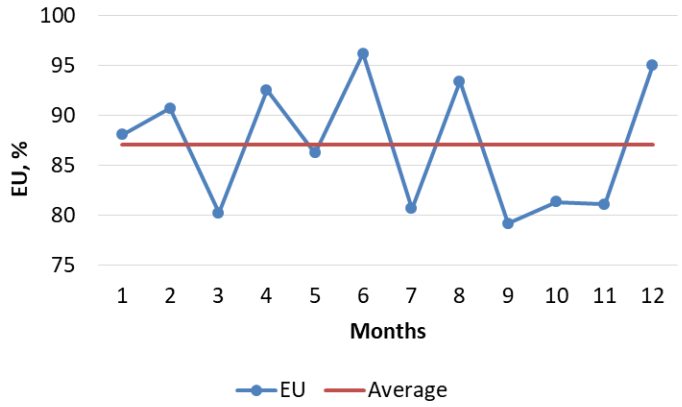

Figure 7 Value of Effective Utilization (EU) in comparison to the average value in the study period (Own study based on [27])

4. CONCLUSION

Conducting continuous evaluation of efficiency of working time of machines is very helpful for all organization, because it allows assessing current situation, identify factors, which should be improved, and optimize their work. Many various methods can be used in such situation, one of them is PAMCO. In this work the analysis was conducted for selected blast furnace device working in one of Polish steelworks. The results show that main indicator of this analysis is on very high level and exceeds the minimum values what proves the high efficiency of working. In case of blast furnace many factors can influence on the values of indicators: situation on the steel market in Poland and the world, demand for raw materials, work organization of blast furnace, number of repairs, length of breaks and stops, way of working of device. Such analysis should be done continuously, and the results should be compared with similar devices that work in other steel plants.

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