

Evaluation of efficiency of working time of equipment in blast furnace department

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ABSTRACT

Purpose: The main aim of the paper is the evaluation of efficiency of working time of equipment in blast furnace department with the use of Overall Equipment Effectiveness (OEE) and PAMCO method.

Design/methodology/approach: The investigation was made for blast furnace department in Polish steel plant. Two methods: OEE and PAMCO was used. The analysis covers the period of 7 years. The analysis was made based on different data: different types of time connected with work of blast furnaces, interruption in blast furnace work, level of pig iron production, unit production time and quantity of non-conformance production.

Findings: Performed research made it possible to determine the level of efficiency of blast furnace department. It can be concluded that working time in this department is used efficiently. Factors that reduce efficiency are usually not-dependent on the company; mainly are connected with the situation on the steel market.

Research limitations/implications: It is necessary to continue the research in order to assess individual blast furnaces. That analysis may enable to show if these units have the same level of efficiency and if they are affected by the same factors in the same way.

Practical implications: Optimal utilization of capacity and working time of machines and equipment are important for the reduction of production costs. Use of OEE and PAMCO methods helps to assess the level of efficiency of working time and allow to find factors that have great importance for level of efficiency.

Originality/value: Results of this analysis can be taken into consideration by blast furnace department under study. Analysis can help to assess the level of efficiency and find factors that influence on it.

Keywords: Production and operation management; Statistic methods; Blast furnace operation; Pig iron

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1. Introduction

In almost all companies a lot of machines and devices could work more efficiently. Many of them do not use their production capacity and the use does not exceed 50% very often. Evaluation of the effectiveness of their use will assess properly the situation in company and enable to identify the factors that require to improve.

Blast furnace process is the basic manufacturing process of pig iron. Production factors, which are relevant for the production cost, are [1, 2]:

- the use of well-prepared and high-quality materials and fuels,
- maintenance of parameters of blast furnace process at the optimum level,
- the most efficient use of working time of the installation.

Blast furnace is the device which works continuously [3]. In steel plant under study, there are three blast furnaces, which work interchangeably in order to maintain continuity, appropriate level of production and the optimum use of working time [4]. The unit out of operation undergo general overhaul, so it is ready to be put on in case of stopping of working device. It enables the efficient and effective operation of the entire department.

The assessment of the effectiveness of blast furnace working time enables the evaluation of the effect of various factors on their work. These factor can be divided into following groups connected with:

- changes in working speed,
- unplanned downtime,
- variable quality of products.

This paper presents the analysis of efficiency of working time of blast furnaces in the chose steel plant with the use of OEE and PAMCO indicator. Researches were made in collaboration with one of blast furnace departments in Polish steel plant. The analysis covers the period of 7 years.

2. Methodology of OEE and PAMCO analysis

Overall Equipment Effectiveness indicator (OEE) is one of key criterions in Total Productive Maintenance. The Overall Effectiveness is a measure of efficiency of machine calculated on the basis of its performance [5]:

- accessibility in terms of active operation of the machine,
- use in terms of planned percentage of the duty,
- quality of products made by the machine.

Knowledge of this indicator allows to evaluate the effectiveness of use of equipment and consequently the whole process from viewpoint of machinery and equipment [6]. This indicator can be used to measure the efficiency of machines, individual stations, work centres and assembly lines. It helps to identify main problems of companies and calculates the benefits connected with elimination various problems [7]. To determine the value of OEE data connected with: available time, machines working time, interruption in their work, level of production, unit production time and quantity of non-conformance production should be taken into account. The method of calculation of OEE indicator can be presented schematically as in Table 1.

The analysis of use of resources (called Plan and Machines Control - PAMCO) is a method of evaluation of companies and machines. It allows to use uniform criteria to compare companies with similar profiles and production machinery. It is also possible to compare different companies in simple and fast way. This method is divided into time types, which are used to calculate indicator of use of working time [8]. The following indicators should be calculated in this analysis [6]:

- **Production Efficiency (PE),**

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

where:

ET - effective time,

PT - production time.

Table 1.

Scheme of calculation of OEE indicator [6]

CALCULATION SHEET OF OEE for the machine		
ACCESSIBILITY		
A. Theoretical production time		unit
B. Planned machine downtime (planned maintenance, interruptions, etc.)		min
C. Available production time	A-B	min
D. Planned machine downtime	a+b+c	min
a. failures min	
b. changesmin	
c. other reasonsmin	
E. Valuable operating time	C-D	min
F. Accessibility indicator	E/C×100	%
USE		
G. Number of products (the sum of good and defective products)		unit
H. Theoretical unit production time		min/unit
I. Actual unit production time		min/unit
J. Production Speed indicator	H/I×100	%
K. Utilization indicator	[H×G/E]100	%
QUALITY		
L. Number of non-conformance products		unit.
M. Quality indicator	[(G-L)/G] ×100	%
OEE		
N. Overall Equipment Effectiveness indicator	F×K×M×100	%

- **Operational Efficiency (OE),**

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

where:

ET - effective time,

OT - operational time.

- **Available Utilization (AU),**

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

where:

OT - operational time,
AT - available time.

- **Asset Availability (AA),**

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

where:

AT - available time,
TT - total time .

- **Asset Utilization (AUt),**

$$AUt = \frac{UT}{TT} \times 100\% \quad (5)$$

where:

UT - utilization time,
TT - total time.

- **Operational Utilization (OU),**

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

where:

OT - operational time,
TT - total time.

- **Production Utilisation (PU),**

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

where:

PT - production time,
TT - total time.

- **Effective Utilisation (EU),**

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

where:

ET - effective time,
TT - total time.

Types of time can be defined as [7]:

TT - total time - including study period,

AT - available time - total time minus free time,

UT - utilization time - available time minus number of hours related with stops due to lack of orders, autonomous maintenance, OT - operational time - utilization time minus number of hours related with changes of plans, technological tests, repairs,

PT - production time - operational time minus available time minus number of hours related with stops due to routine cleaning, changing of production line, retention and loss of production,

ET - effective time - production time minus number of hours related with unplanned interruptions: minor stops, failures, regulations, errors, reduced productivity of machines, technological problems, logistic problems.

3. Results of research

Analysis of OEE indicator for blast furnace department was made. Basic indicators were calculated. Results of this analysis are presented in Figures 1-4.

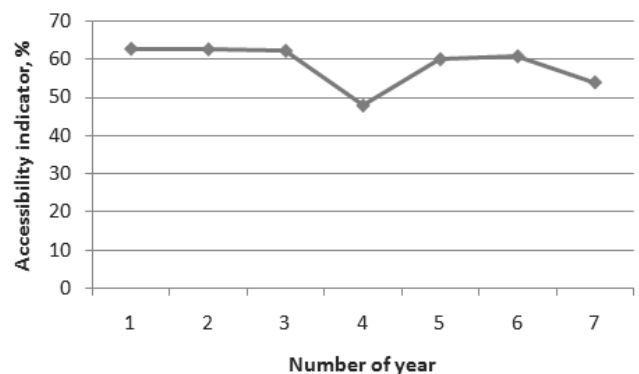


Fig. 1. Value of accessibility indicator of blast furnace department during study period

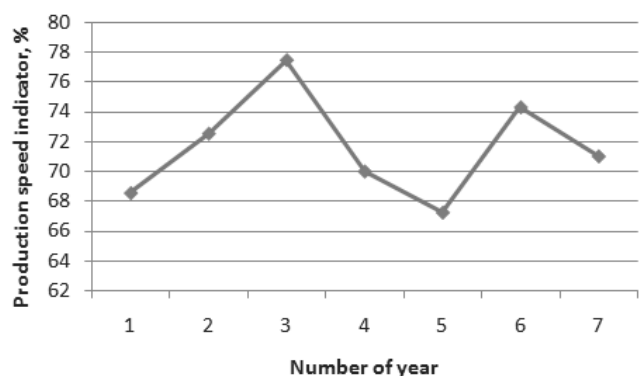


Fig. 2. Value of production speed indicator of blast furnace department during study period

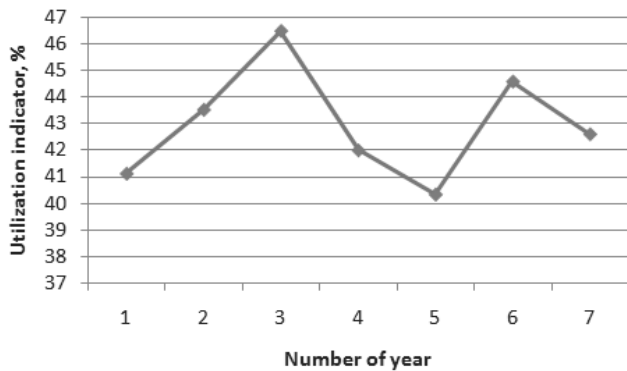


Fig. 3. Value of utilization indicator of blast furnace department during study period

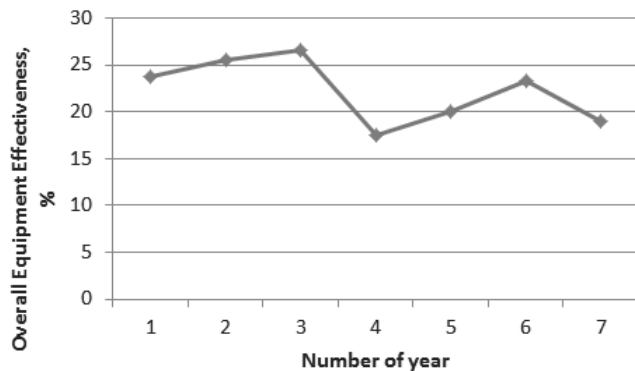


Fig. 4. Value of Overall Equipment Effectiveness indicator of blast furnace department during study period

According to the analysis of OEE, presented in Figures 1-4, it can be concluded that:

- The accessibility indicator was approximately on the level of 58%. During most month it was on the level above 60%, in year 4 was very low and below 50%, in year 7 - below 55%. Average value of this indicator at the level of 58% was caused by the specificity of metallurgical industry. Blast furnace department under study has 3 blast furnaces, however, usually two of them work simultaneously, one is stopped and renovated. The low values of this indicator in years 4 and 7 were caused primarily by renovation processes of two blast furnaces (year 4) and bad situation in the steel market (year 7).
- Production speed indicator and utilization indicator underwent similar changes. Average value of production speed indicator was approximately 72%, while utilization indicator - 43%. Utilization indicator was growing during first three years to the level of 47%, in two subsequent years was decreasing to 40%, then there is slight increase and decrease. Changes of this indicator were also caused primarily by the situation in the steel market. During this period there were problems with delivery of materials and problems with delivery of pig iron to the steel department. Blast furnace outages were results of this situation, what effected on his efficiency.

- OEE indicator was on the average level of 22%. In first three month it increased to the level of 26.5%, then in year 4 - decreased significantly to 17%, during next two year it slightly increased to 23% and in the last year it was fallen down to 19%. The level of value of this indicator was influenced by many factors connected with three major elements:
 - The level of use of available production time - simultaneous production of two blast furnaces and renovating of the third, periodic operation of one blast furnace,
 - Utilization of working time - unit time of pig iron production was longer than theoretical unit production time usually,
 - Level of quality - the amount of pig iron production with parameters that meet requirements of steel department.

It can be concluded that diversity of values of this indicator is influenced primarily by the situation on the steel market, because it caused problems with demand for pig iron and difficulties with the supply of raw materials with appropriate quality.

Analysis of PAMCO indicators for blast furnace department was made. Basic indicators were calculated. Results of this analysis are presented in Figures 5.

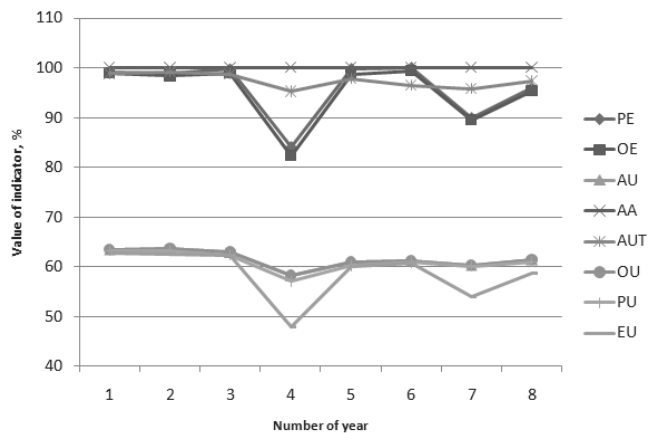


Fig. 5. Values of PAMCO indicators of blast furnace department during study period

Averages values and requirements of indicators are presented in Table 2.

Table 2.

Average values and requirement for PAMCO indicators

Indicator	Average	Requirement [6]
PE	96.08	95
OE	95.30	92
AU	61.49	65
AA	100.00	97
AUT	97.42	90
OU	61.49	62
PU	60.99	60
EU	58.60	50

According to the analysis of PAMCO, presented in Figure 5 and Table 2, it can be concluded that:

- Only two indicators: available Utilization (AU) and Operational Utilization (OU) took the average values below requirements. Moreover, the values of these indicators are the same, because denominators for both indicators (available time for AU and total time for OU) have the same values (it is due to continuous operation of blast furnaces). Low value of this indicators are caused by operation system of this department: two of blast furnaces work simultaneously, one is stopped and renovated.
- Similar changes for all indicators were observed. In years 4 and 7 a significant decrease of value was recorded. The low values of this indicator in years 4 and 7 were caused primarily by renovation processes of two blast furnaces (year 4) and bad situation in the steel market (year 7).
- EU indicator usually exceeded the requirements (except for years 4 and 7), what shows good organization of production and optimum utilization of working time of blast furnaces.

4. Conclusions

Continuous evaluation of the efficiency of working time of machines and equipment in companies has many measurable benefits, because it allows to assess current situation, identify factors, which should be improved, and optimize their work.

OEE and PAMCO analysis, presented in this paper, enabled to assess and identify factors which had great effect on efficiency of blast furnace department under study. It can be concluded that:

- During study period taken into consideration the two main indicators was at level of: OEE - 22%, EU - 58.6%.
- The value of OEE indicator may seem to be small, but it should be underline that three components influence on its value: the level of use of available production time, the level utilization of working time and level of quality.
- The value of EU indicator exceeded requirements significantly, what proves the high efficiency of working time for tested blast furnace department.
- The level of efficiency is influenced by many different factors that often are not depend on the blast furnace department. Among them there are:
 - Situation on the steel market in Poland and the world: changes in demand for steel products cause changes in the volume of production of pig iron, what effects on the efficiency of blast furnaces department.

- Demand for raw materials: changes in demand for raw materials on the market often cause situation when steel plants are forced to order raw materials which are low quality, what effects the quantity and quality of produced pig iron and quantity of slag.
- Work organization of blast furnace - to maintain continuity of production and equipment in proper condition, company accepted the rule that while two blast furnaces work, the third undergoes renovation. In case of very low demand for pig iron, it is possible to work with only one blast furnace.
- It should be concluded that the blast furnace department under study uses its machinery and equipment efficient and factors that reduces efficiency are usually non-dependent on company.

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