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THE QUALITY OF COKE AND ITS CONSUMPTION BLAST FURNACE PROCESS

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The assessment of quality of coke and its consumption in blast furnace process is presented in the paper. The statistical analysis of three basic parameters of coke was made. As a main quality parameters: moisture content, ash content in the dry state, volatile matter content in dry state and calorific value were selected. Then influence of two selected parameters of coke on fuel consumption was calculated. The study was carried out in cooperation with a Blast-Furnace Department of a Polish steelworks and was based on the results coming from this Department. The analysis covers the period of three calendar years.

Keywords: blast furnace, coke, quality, fuels consumption, linear regression method

INTRODUCTION

In every production process during the production phase, the following factors, that significantly affect the quality of products and efficiency of process, are distinguished: quality of materials (input raw materials, fuels and semi-finished products), quality of work (determined on the basis of working conditions as well as the quality of contractors) and production quality (storage, placement of machines and equipment, transport and other. So, it can be said that quality of fuels used in production processes is one of factors that affects the quality of product [1].

The use high-quality fuels, such as blast furnace (stabilized) coke, in blast furnace processes allows for optimal running the process, maintaining the parameters of its operation at optimal level. The use of cheaper sort of fuels at appropriate quantities can worsen the operation of the device and extend the time of melting and affect the chemical composition of the finished product [2].

The purpose of the paper is the assessment of the four selected quality parameters of stabilized coke used in the blast furnace process and the affect of selected parameters on coke consumption in the process.

Quantitative analysis of four selected parameters of stabilized coke was made. The content of moisture, the content of volatile matter and ash in dry state, calorific value was taken into account in the first part of the analysis. The statistical analysis of these parameters was made (descriptive statistics and variation cards). In the second part of the paper the affect of two selected parameters on fuel consumption using regression function was calculated. The analysis covers the time of three calendar years. The results were gathered in Blast Furnace Department which is a part of one of the biggest Steel Plant in Poland.

CHARACTERISTICS OF BLAST FURNACE COKE

The main fuel for blast furnace process is stabilized coke. It plays triple function: technically as a fuel, chemical as a reducer and for carburizing of pig iron and mechanical as grate resistant to high temperatures [3, 4]. It is also the main factor responsible for costs of the process. Therefore, efforts should be made to minimize its use. However, it entails high requirements for the coke used in the process. According to many authors, the quality of coke is determined in a multiparametric way, by determining the percentage of analytical component (moisture, ash), volatile matters and elements, and recently alkaline compounds. Next, physical properties such as density, porosity, grain composition are evaluated and the characteristics of coke is completed by the broad possibilities of testing its mechanical properties, such as strength and abrasiveness [3-5].

Polish standard [6] shows requirements for basic characteristics of stabilized coke that should be used in blast furnace process:

– Grain dimensions: 25-80 mm,
– Ash content in dry: max. 10,5 %,
– S content in dry state: max. 0,8 %,
– Moisture content: max. 5 %,
– Volatile matter content in dry state: max. 1,1 %,
– Calorific value: min. 29 500 kJ/kg.

In addition to stabilized coke, also other fuels in the form of finer sorts of coke are used, e.g. breeze coke that significantly reduces the cost of coke, coal dust and

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small amount coke-oven gas and natural gas. During production process also blast furnace gas is used to heat the blast. These fuels are used to reduce total production costs of pig iron [7].

ANALYSIS OF SELECTED PARAMETERS OF COKE

Stabilized coke as a main fuel of blast furnace process was selected to the analysis. In the first step, the analysis of four basic statistical characteristics was made. Results of this analysis are presented in Table 1. Then, the changes in these parameters during study period in comparison to the average value and requirements were analyzed. These results are presented in Figures 1-4.

Based on the results presented in Table 1 and Figures 1-4 it can be said that:

– Average moisture content in coke was on the level of 5,39 % at it was higher than maximum required value. The parameter was characterized by high variability (over 18 % of average value). On the beginning of the study period value of this parameter exceeded the average value, then it decreased. It must be noted that all materials and fuels are collected in special landfills outside, so weather conditions have a significant impact on this parameter. Higher values of this parameter were notices in winter months, while the lowest – in the summer.

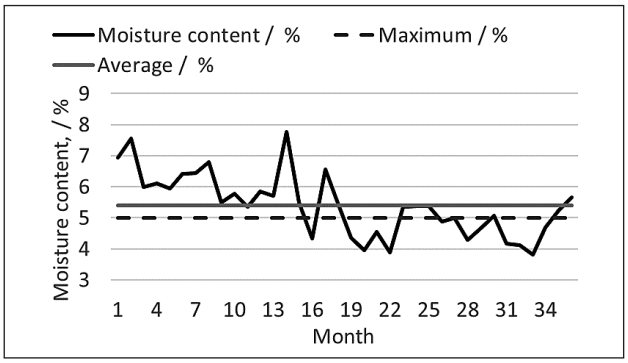

Figure 1 Analysis of moisture content of blast furnace coke in the study period

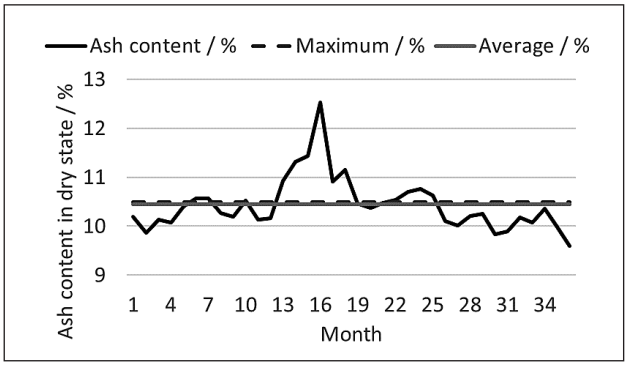

Figure 2 Analysis of ash content of blast furnace coke in the study period

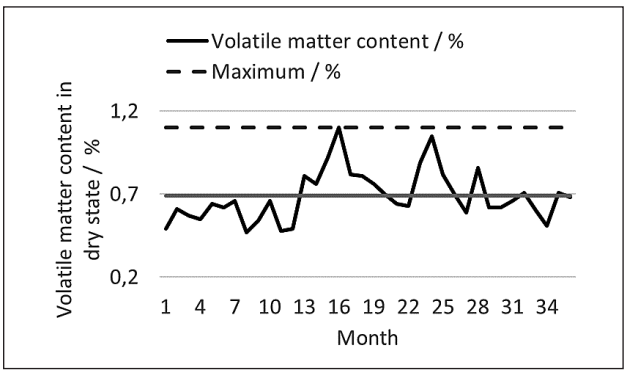

Figure 3 Analysis of volatile matter content of blast furnace coke in the study period

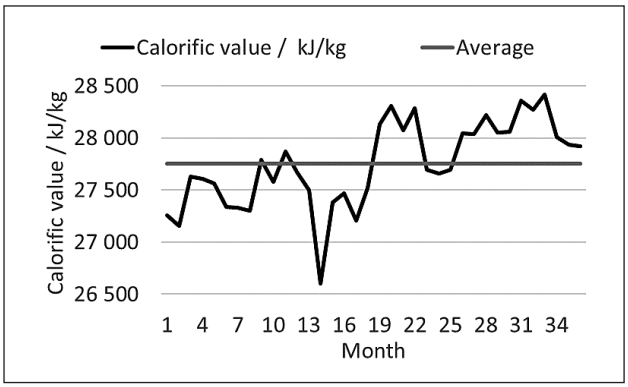

Figure 4 Analysis of calorific value of blast furnace coke in the study period

– Maximum and average values of ash content in dry state in coke were nearly the same (10,5 and 10,45 %), parameter was characterized by slight variability (5 % of average). The individual values were evenly distributed around the mean. Months 14-18 were the exceptions, when the values significantly exceeded the average, which was related to the poor quality of coke supplied to the steelworks.
– Values of volatile matter content in dry state in coke met requirement given by the standard, only in one month it reached the maximum. Average value of this parameter was 0,69 %, while this parameter was

Table 1 **Basic statistical characteristics of selected parameters of coke**

Characteristics	Moisture content / %	Ash content in dry state / %	Volatile matter in dry state / %	Calorific value / kJ/kg
Average	5,39	10,45	0,69	27 752,22
Standard deviation	0,99	0,54	0,15	404,48
Variation	18,4%	5,2%	21,7%	1,5%
Maximum value	7,78	12,53	1,10	28 419,25
Minimum value	3,81	9,59	0,47	26 605,30

characterized by the highest variability (nearly 22 % of average). The highest values were noticed in months 14-18 (similar to ash content) and 22-25.
– Average calorific value of coke was on the level of 27 752 kJ/kg (lower than required value), while variation of this parameter – only 1,5 % of average. The lowest values were noticed in months 14-18, while the highest – at the end of the study period.
– It can be said that during months 14-18 quality of tested coke was the worst (high ash and volatile matter content and low calorific value). Problems with moisture content was caused mainly by the way of seasoning the fuels in landfills.

THE COKE CONSUMPTION IN BLAST FURNACE PROCESS

During the study period the average fuels consumption was on the level of 515 kg/1 Mg of pig iron. The influence of two selected quality parameters on fuel consumption was analysed. First, the correlation analysis was made. It showed that ash and volatile matter content in dry state in coke had the greatest impact on this parameter. So, models showing linear dependence of fuel consumption on ash content and volatile matter content were calculated. These dependencies are presented in Figures 5-6, while auxiliary calculations are presented in Table 2.

Table 2 **Auxiliary calculations for the regression functions of fuel consumption**

Parameter	Ash content / %	Volatile matter content / %
S	13,51	14,29
V	2,62	2,78
F	19,74	14,01
Ist - F	8,93 10-5	0,000 67

where: S – standard error, V - coefficient of residual variation, F - the value of the Wald test for the significance of the independent variable, Ist-F - probability value of F.

Based on results presented in Figures 5-6 and Table 2 it can be concluded that:
– The regression functions shows that the fuels consumption increases with increasing content of ash and volatile matter in dry state in coke.
– The increase of ash content by 1 % resulted in increasing fuel consumption by app. 18 kg/1 Mg of pig iron.
– The increase of volatile matter content by 1% resulted in increasing fuel consumption by app. 59,6 kg/1 Mg of pig iron.
– Auxiliary calculations show a good fit of the regression functions to the empirical data.

CONCLUSION

The results of the analysis presented in the paper showed the changes of four selected quality parameters of

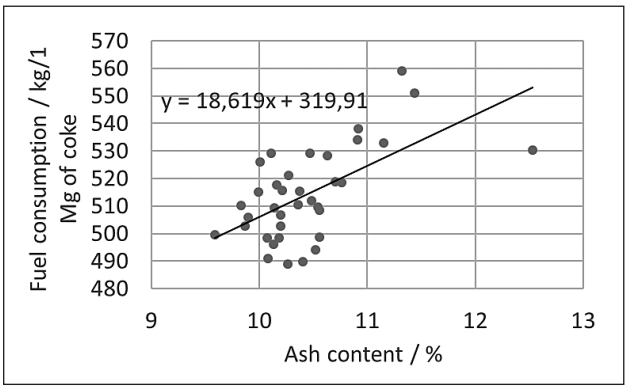

Figure 5 Linear dependence of fuel consumption on ash content in coke

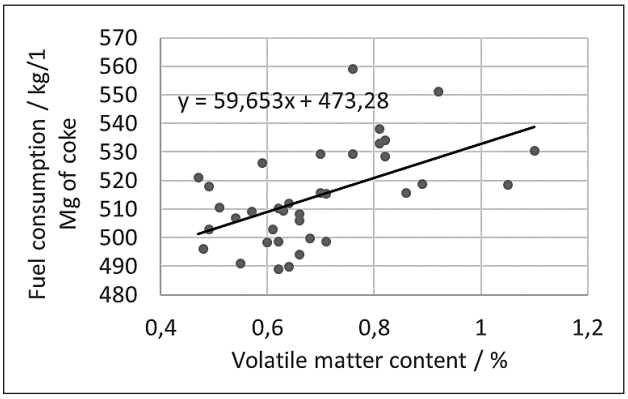

Figure 6 Linear dependence of fuel consumption on volatile matter content in coke

stabilized coke in the analysed period of time and indicated the periodic exceeding of limit values in a few cases:
– Moisture content in coke was exceeded, usually on the beginning of each year. It is caused by conditions of storing of materials and fuels in steelworks (external landfills specially prepared for this purpose). It should be said that atmospheric conditions had a major influence on the values of this parameter (low temperatures and rainfalls).
– Ash content in dry state in coke usually underwent slight variability, only on the beginning of second year (14 - 18 this parameter was very high and significantly exceeded the maximum required value).
– In case of content of volatile matter and ash in dry state in coke, there was no exceedance of limit values (only once it reached the maximum required value), and it should be also noticed that parameters were under significant variability in the entire study period.
– For calorific value, the average value of this parameter was much lower than minimum required value. The use of coke with exceeded minimum calorific value was mainly due to economic reasons and the signed contract with the supplier of this fuel.
– Both ash and volatile matter content in coke influenced the increase of fuel consumption during blast furnace process.

Therefore, it can be concluded that the tested stabilized coke was of satisfactory quality. Periodical use of

coke with exceeded recommended values of some parameters was dictated mainly by the economic aspect. In case of slight decrease of quality of coke, the deterioration of condition of blast furnace process were also noted. However, these changes were small and did not increase the production costs.

REFERENCES

[1] S. T. Dziuba, M. Ingaldi, M. Kadlubek, Quality analysis of the steel bars in chosen metallurgical enterprise, Metal 2018, 27th International Conference On Metallurgy And Materials, Ostrava. Czech Republic 2018, TANGER Ltd, 1893-1898

[2] E. Kardas, P. Pustějovská, S. Brožova, Statistical Analysis of Quality Parameters of Pig Iron, CzOTO 1(2019) 1, 616-623, DOI: https://doi.org/10.2478/czoto-2019-0078

[3] M. Niesler, The role of coke grain in the blast furnace process. Institute of Ferrous Metallurgy, Gliwice, 2012.

[4] A. Mianowski, T. Radko, A. Karkoszek, Assessment of the high-quality blast furnace coke by using the reactivity and strength integrated Nippon Steel Corporation test, Chemical industry 88(2009) 6, 692-698.

[5] H. Zieliński(red.), Cokemaking. Publishing House Slask, Katowice, 1986.

[6] PN-86/C-02050.06, Hard coal coke - Industrial and heating coke, 1986.

[7] M. Bernasowski, A. Ledzki, R. Stachura, A. Klimczyk, Basic structure of the fuel rate optimization model and its practical use at the blast furnace technology, Conference Proceedings, Metal 2014 - 23rd International Conference on Metallurgy and Materials, Ostrava. Czech Republic, 2014, Tanger Ltd, 39-44.

Note: E. Kardas and R. Prusak are responsible for English language, Czestochowa, Poland