A. KONSTANCIAK

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THE EFFECT OF BLAST FURNACE COKE QUALITY ON THE POSSIBILITY OF ITS USE

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In the paper behavior of the blast-furnace coke in the high temperature was presented. Comparative analysis of the chemical composition of the blast-furnace coke and the heat treatment of it were done. Coefficients M10 and M40 with the thermo -abrasiveness for chosen c okes were compared. The influence of ash c ontent of the c oke on the blast-furnace bed permeability was defined. Usefulness of the coke to blast-furnace process was also defined.

Keywords: blast furnace, coke, thermoabrasion coefficient

INTRODUCTION

As the blast-furnace process fuel, coke gains importance at the time of the ore charge softening and then melting. From this point on, the only remained solid charge column element, called the "skeleton", will be the lumps of coke. These coke lumps should be reasonably stable so as not to undergo degradation at elevated temperatures and under the influence of chemical reactions occurring in lower blast furnace zones. The stability of the particles of coke depends largely on the amount, structure and chemical composition of ash contained in it. The properties of coke ash can, therefore, influence the coefficients determining the correct blast furnace operation, the quality of produced pig iron, the composition and quantity of slag forming in the blast furnace, and the integrity of coke lumps in the range of ash occurring in a liquid state.

It is, therefore, important from both the theoretical and practical points of view to determine the changes in the structure and chemical composition of ash during its heating and the volume increases resulting therefore, causing bursting of coke lumps or formation of voids [1-4].

METHODS OF EVALUATION OF THE MECHANICAL STRENGTH OF COKES

The evaluation of the strength properties of coke intended for the blast-furnace process in the conditions of Polish coking plants is normally performed by either cold (e.g. MICUM or IRSID) or hot (e.g. CSR by Nippon Steel) methods. However, these methods do not reflect the blast furnace operation conditions. It would be more appropriate to use the pre-tuyère chamber model method (known also as the thermo-abrasion method) for the evaluation of the suitability of coke for the blast-furnace process [4].

TESTING OF COKE PRODUCED FROM COKE PLANTS

Cokes produced from "standard" coal mixes were used in the tests. Coke was subjected to chemical analysis and testing in a MICUM drum. Then, a 10 – 13 mm fraction was separated from the above 40 mm fraction after the MICUM test (by crushing and classification on square-mesh screens) for the determination of the thermoabrasion coefficient in the blast-furnace pre-tuyère chamber model [1].

RESULTS

The main goal of work was to determine the thermoabrasion coefficient for cokes from two different Coke Plants in Polnad (1) and (2). This cokes were used in blast furnace in selected metallurgical plant in Poland.

The analysis of the properties of cokes used for the thermoabrasion testing were presented in Tables 1 and 2.

Table 1 **Chemical composition and the values of indicators M40, M10 for coke from Coke Plant 1**

Nr of test	M40	M10	W^r_t/%	A^d/%	V^{daf}/%
1	62,0	5,9	5,7	10	1,1
2	69,7	6,1	4,6	9,3	0,7
3	71,1	5,7	4,8	9,2	0,8
4	63,8	6,0	5,3	9,7	0,8
5	61,0	6,2	5,9	9,1	0,9
6	74,5	6,0	4,0	9,3	0,9
7	59,9	6,7	5,8	8,3	0,7

A. Konstanciak - Czestochowa University of Technology, Faculty of Materials Processing Technology And Applied Physics, Czestochowa, Poland

Subsequently, for selected samples the thermoabrasion coefficient (ξ) in the blast-furnace pre-tuyère chamber model was analyzed [4].

Regression functions presented the dependence of the thermoabrasion coefficients from test of MICUM 40 (Figure 1) and MISUM 10 (Figure 2) for investigated Cokes Plants were determined.

Table 2 **Chemical composition and the values of indicators M40, M10 for coke from Coke Plant 2**

Nr of test	M40	M10	W^r_t/%	A^d/%	V^{daf}/%
1	63,0	6,2	6,0	9,9	0,8
2	63,5	5,8	5,8	10,0	0,9
3	65,5	6,2	5,9	10,2	0,8
4	65,9	6,5	4,8	10,9	0,7
5	65,9	6,1	5,8	10,0	0,7
6	72,1	5,7	5,1	8,5	0,6
7	65,5	6,2	5,5	10,0	0,8
8	61,7	6,3	5,8	10,0	0,6
9a	65,2	6,4	6,0	10,7	0,6
9b	70,0	6,0	5,1	10,6	0,6
10	66,3	6,2	5,2	10,4	0,6
11	71,5	5,8	4,2	10,7	0,6

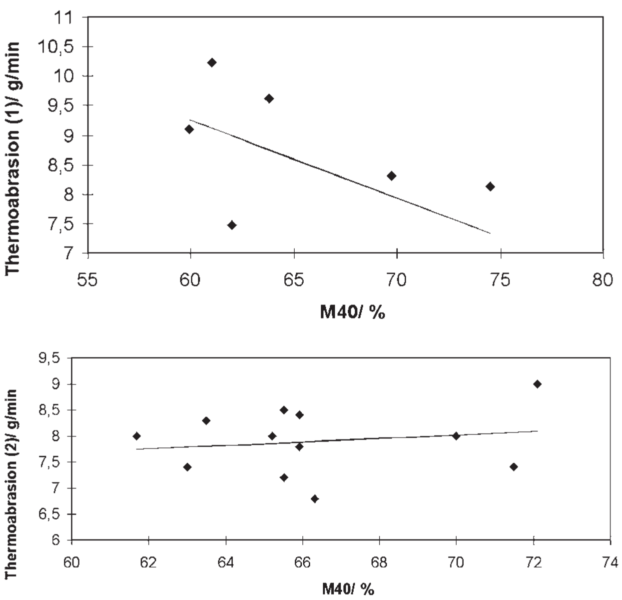


Figure 1 Dependence of thermoabrasion from MICUM 40 for Coke Plants (1) and (2)

According to the comparison of graphs presented in Figures 1 and 2 functional dependences for this coefficients cannot be determined.

The dependence of changes of MICUM 10 from contents of ash in cokes for investigated Coke Plants were analysed (Figure 3). The comparison of these graphs shows that the increase in ash content in coke decreases the quality of coke – MICUM 10 rate increases.

Similarly, for ξ = f(M40) and ξ = f(M10) it is impossible to determine functional dependences for this ash in coke.

The effect of the ash content of coke on the thermoabrasion coefficient from investigated Coke Plants were compared. These relations are shown in Figure 4.

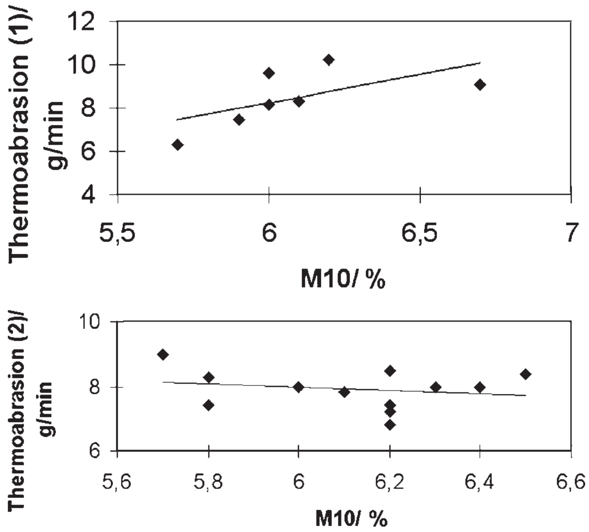


Figure 2 Dependence of thermoabrasion from MICUM 10 for Coke Plants (1) and (2)

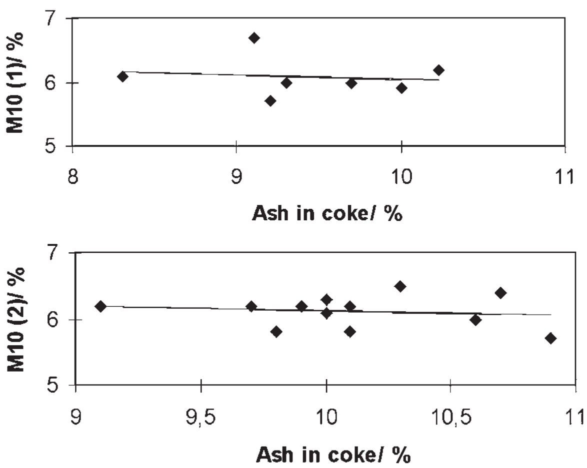


Figure 3 Dependence of MICUM 10 for Coke Plants (1) and (2) from ash in coke

As it was expected, the higher ash content in coke, the worse mechanical properties. It was confirmed for cokes from investigated Coke Plants (Figure 4).

The porosity of surface tests were investigated for samples with extreme results the thermoabrasion coefficient for coke from investigated Coke Plants. The tests were performed on Quantimet-720.

The analysis of porosity of surface for the samples presented in Table 3 cannot determine unequivocally, which of cokes would be more desirable for the blast furnace. This porosity of coke depends primarilly on the grade of coal used for coke production (ie. the content of volatile matter and the resilience of puffing) and method of preparing coal for the coking process (mainly from coal fineness and density of the solid carbon).

The analysis the uniformity of distribution of macropores and the weakened area inside the grain coke after heating were a more meaningful assessment of the suitability of coke for blast furnace process. The tests of assessment of the grain structure of coke were also performed. These tests were made with confocal microscope OLYMPUS 3300.

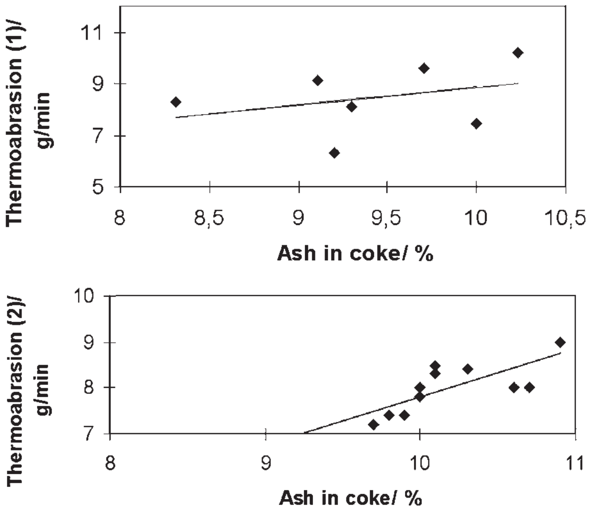
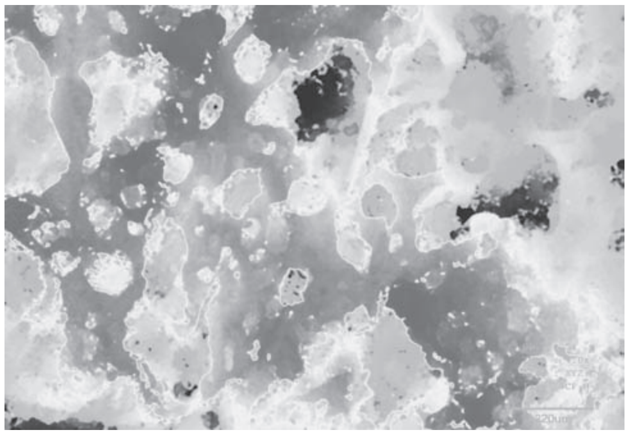


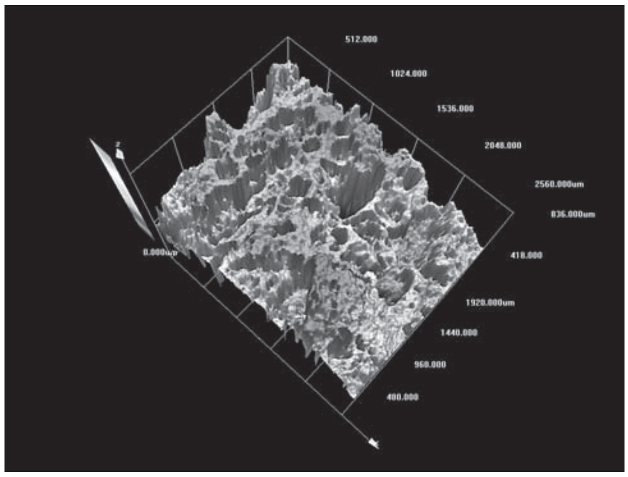
Figure 4 Dependence of the thermoabrasion coefficient from ash in coke for Coke Plants (1) and (2)

Table 3 **Porosity of surface for the samples from Coke Plant (1) and (2)**

Nr of test	Characteristic of specimen	Thermoabrasion coefficient/ g/min	Porosity of surface/%
1(1)	before heating	6,31	67,2
1(1)	after heating	6,31	75
6(1)	before heating	10,52	73,2
6(1)	after heating	10,52	68,9
10(2)	before heating	6,83	65,6
10(2)	after heating	6,83	74,9
6(2)	before heating	9,08	70,2
6(2)	after heating	9,08	75,8



a)



b)

Figure 5 The structure for coke from bearings: a) the structure, b) the determinant of size for pores

The sample of the grain structure is shown in Figure 5. These observations were confirmed in a study for cokes in the pre-tuyère chamber model method (known also as the thermo-abrasion method).

The three generic groups of coke were analyzed: batch coke (from coke plant), coke from level of blast furnaces tuyères, coke after the thermoabrasion test. It follows that the crystallinity ratio and crystallinity size increases as a result of heat treatment of coke. [4]. This increase is clearly even at short heat treatment in determining of thermoabrasion. An even greater development of the crystallinity of coke is in the blast furnace. Increase in temperature for coke from 25 ^{0}C to 1 700 ^{0}C takes 5 – 7 hours. Each coke in each of the states are different. Practice confirms the structure of fluctuations of cokes, mainly due to fluctuations in coal petrographic composition of batch, not only in different decks of the same mine, but even in the same board in mine. It can be assumed, that the crystallinity size in coke from tuyères from blast furnace depends on the crystallinity size of coke is charged into the blast furnace and for sure significantly increases in the blast furnace. Probably, this increase depends on the (variable) thermal conditions of operation of blast furnace and on the petrographic characteristic of coal used in coking plant. Comparison of the effects of heat on the coke in the blast furnace and the thermoabrasion clearly demonstrates the significant influence of the time of coke staying at high temperatures (about 1 700 ^{0}C) temperatures. Samples from the blast furnace (ie, heat-treated samples at very high temperatures) have the greatest crystallization. The lowest degree of graphitization of coke was for samples taken straight from the coke ovens, which did not put to any heat (apart from the manufacturing process). Cokes, which were examined of thermoabrasion tests at elevated temperatures, were samples of the intermediate group, with an intermediate degree of crystallinity.

By making thermodynamic calculations, the chemical composition of the products of reaction between coke ash mineral substances with elemental carbon and air, as well as the behaviour of coke at high temperatures under inert gas (argon) conditions are presented, was determined.

It was presumed that several dozen different gaseous and condensed chemical compounds might occur among the reaction products. The thermodynamic data for particular substances were taken from the Computer Thermochemical Database of the TERMO system [4].

From the calculations for cases, where the behaviour of coke under inert conditions - argon and in air with oxygen was examined, it was found the forming gaseous components had different concentrations.

The variations in the carbon monoxide content of argon lay in the range from 0,3 to 2,4 g/kg of the working substance, while in air, in the range from 128 to 130 g/kg of the working substance. Similarly, the CO_2 contents for the inert gas ranged from $2,1 \cdot 10^{-5}$ to 0,0004 g/kg of the working substance, while for air, from 0,02 to 0,6 g/kg of the working substance.

The situation for the occurrence of condensed phases in the coke material subjected to thermal action with the participation of argon and air with oxygen presented itself differently. A higher variability of the compounds was found for the contact of coke with air than for its contact with argon. The following compounds were found to have occurred: Al_2SiO_5, $MgSiO_3$, Na_2CO_3 and K_2CO_3. This was due to the oxygen content of the air with oxygen.

SUMMARY

The analysis of the data presented in Tables 1-2, graphs presented the depending of thermoabrasion coefficient from MICUM 40 and 10 and ash in coke (Figures 1, 2, 3, 4) and photos showing the structure of coke (Figure 5) allows to asses of the impact of ash contained in the coke. For the analyzed ash content at the limit 9 – 11 %, it can be concluded that thermoabrasion method is the method which can be used to assess the quality of the feed material for the blast furnace. The increase in ash content in the sample causes increases the thermoabrasion coefficient.

The study of the structural evaluation of the three cokes type (from coke plant, after the thermoabrasion method and from the blast furnace) indicates that the time of coke staying at high temperatures a has significant impact on the size of crystallites.

The study confirmed the relation between the operation of blast furnaces, and the thermoabrasion method that obtained in previous studies.

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Note: Nowak P. is responsible for English language, Katowice, Poland