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# THE ANALYSIS OF QUALITY OF FERROUS BURDEN MATERIALS AND ITS EFFECT ON THE PARAMETERS OF BLAST FURNACE PROCESS

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The analysis of the effect of the quality of ferrous burden materials on the parameters of blast furnace process is presented in this paper. First, the quantitative and qualitative analysis of ferrous burden materials used in blast furnace process was made. The chemical composition, mainly iron content, is the basic quality parameter taken into consideration. Then, the dependence of parameters of process on the quality parameters of burden materials will be calculated.

*Keywords:* blast furnace, burden materials , quality, quality analysis

## INTRODUCTION

The paper presents results of researches related to the problem of the impact of production factors on the quality of pig iron and process parameters. Researches were made in collaboration with Blast Furnace Department of ArcelorMittal Poland S.A. in Dabrowa Gornicza and were based on the results coming from this Department. The analysis covers the period of eight months.

Ferrous materials are the basic raw materials used in blast furnace process [1]. They are the primary source of iron, which is the main component of pig iron. The use of rich – iron, well – prepared in consideration of chemical and physical properties, ferrous burden materials allows to achieve optimal values of technical and economic parameters of process, enables to operate of blast furnace evenly [2] and to receive a product with appropriate quality. In blast furnace process, apart from iron ores and iron concentrates, a variety of waste materials are used, which influence significantly the economic effect of this process [1]. It follows from the fact that waste materials contains more ion than ores very often [3].

Determining the quality of ferrous burden materials, following properties should be evaluated [4]:

– chemical composition of materials,
– physical properties,
– metallurgical properties.

The correct preparing charge materials for blast furnace process is essential for the quality of produced pig iron and for production costs. It should be noted that proper composition of this materials can affect many parameters of process, among others [5, 6]:

– pig iron quality, expressed by its chemical composition and temperature,
– the amount and chemical composition of slag,
– productivity of blast furnace,
– the cost of pig iron production.

The paper presents the analysis of the first group of properties of ferrous burden materials, their chemical composition. The dependence of qualitative parameters of blast furnace process (yield of production, unit production of slag, unit consumption of fuels, intensity of coke combustion) from the content of the main element, iron, was determined.

## QUANTITATIVE ANALYSIS OF CONSUMPTION OF FERROUS BURDEN MATERIALS USED IN BLAST FURNACE PROCESS

Quantitative analysis of consumption of ferrous burden materials used in analyzed blast furnace process was made. In this process, the following groups of ferrous burden materials are used :

– sinter: own production and SEW-GOK,
– pellets: Poltawskie, SEW-GOK, Michajlowskie, Lebiedenskie, Kostomuksha,
– convertor slag: Fe – Mn, Si – Mn,
– lump ores, ferrous concentrates.

Table 1 presents the quantitative analysis of the unit consumption of ferrous materials used in process in period under study. The table includes only those materials which were used during study period. It should be noted, that many of these materials were used in process occasionally, what is motivated primarily by economic considerations.

According to analysis presented in Tab, 1, it can be concluded that:

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Table 1 **Quantitative analysis of unit consumption of ferrous burden materials (per 1Mg og pig iron) in blast furnace process during study period**

| No. | Component / kg/Mg pig iron | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| I | 1 495,3 | 153,7 | - | - | - | 17,7 | 1,2 |
| II | 1 533,5 | 99,9 | - | - | 12,6 | 19,2 | 5,8 |
| III | 1 588,3 | 56,6 | - | - | - | 19,5 | 5,9 |
| IV | 1 623,9 | 16,7 | - | - | - | 20,2 | 5,9 |
| V | 1 550,9 | 38,13 | - | - | - | 17,9 | 5,6 |
| VI | 1 567,0 | 296,9 | - | - | - | 17,3 | 5,2 |
| VII | 1 550,3 | 19,2 | - | 48,8 | - | 17,2 | 6,3 |
| VIII | 1 492,6 | - | 103,6 | 12,8 | - | 16,7 | 10,1 |
| Aver. | 1 550,2 | 87,3 | 12,8 | 7,6 | 1,49 | 18,2 | 5,7 |
| % | 92,1 | 5,2 | 0,8 | 0,5 | 0,1 | 1,1 | 0,3 |

1 – Sinter, 2 – Poltawskie Pellets, 3 – Michajlowskie Pellets, 4 – Liebiedenskie Pellets, 5 - J-GOK agglomerates, 6 – Convertor slag, 7 – Ferrous Concentrate

- Sinter is basic ferrous burden material use in blast furnace process in analyzed Steelworks. It is used in amount of about 1 550 kg per 1 Mg of pig iron (above 92 % of total materials). Unit consumption of this material underwent to some fluctuations (ca. 1 492 – 1 624 kg/1 Mg of pig iron). It was caused by several factors, such as the use of other materials or their quality.
- Pellets Poltawskie, convertor slag and ferrous concentrates are materials which are also used in blast furnace process in study period. Their unit consumption was, however, very low (ca. 6,6 %). Unit consumption of pellets Poltawskie was at the level of ca. 87 kg/1 Mg pig iron, consumption of convertor slag and ferrous concentrates was ranged between a few and several kg.
- Some materials (eg. Pellets Michajlowskie, Lebiedenskie, J-GOK agglomerates) were used in process only in certain months, some materials were not used in process during period under study. The use of this materials was dictated by economic considerations and their ability on the material market.

## QUALITY ANALYSIS OF FERROUS BURDEN MATERIALS

The analysis of chemical composition of ferrous burden materials was made. The analysis includes the evaluation of content of individual compounds in ferrous materials in total during period under consideration was prepared. Table 2 shows the average content of individual component in the ferrous burden materials in total in study period.

Based on the results of the analysis (Table 2) it can be concluded that for the blast furnace process the content of basic element, iron, in ferrous burden materials has great importance for the quality of pig iron (it is called charge richness). Amount and quality of main product of process (pig iron) and amount of wastes depend on the Fe content in used materials. Content of such elements as: silicon, manganese, sulphur and phosphorus in these materials is also important, because these elements pass into the products and content of these elements in pig iron depends on their content in charge.

Table 2 **Average chemical composition of ferrous burden materials in total during study period**

| No. | Component | Content/% | No. | Component | Content/% |
|---|---|---|---|---|---|
| 1. | $H_2O$ | 2,02 | 8. | Mn | 0,20 |
| 2. | Fe | 57,86 | 9. | $P_2O_5$ | 0,116 |
| 3. | FeO | 5,56 | 10. | $Na_2O$ | 0,068 |
| 4. | $SiO_2$ | 6,42 | 11. | $K_2O$ | 0,042 |
| 5. | CaO | 8,26 | 12. | Zn | 0,040 |
| 6. | MgO | 1,55 | 13. | S | 0,018 |
| 7. | $Al_2O_3$ | 0,79 | 14. | C | 0,153 |

Table 3 shows average content of iron in various ferrous burden materials used in blast furnace process in study period.

Table 3 **The average content of iron in various ferrous burden materials used in blast furnace process in study period**

| No. | Material | Fe Content / % |
|---|---|---|
| 1 | Sinter | 57,92 |
| 2 | Poltawskie Pellets | 62,22 |
| 3 | Michajlowskie Pellets | 63,00 |
| 4 | Liebiedenskie Pellets | 65,50 |
| 5 | J-GOK agglomerates | 59,25 |
| 6 | Converter slags | 24,19 |
| 7 | Ferrous Concentrate | 66,27 |

According to the analysis presented in Table 3 it can be said that in all materials, except convertor slag, iron is the main component in terms of blast furnace process. During study period the highest content of this element was observed in ferrous concentrates (above 66 %), for various types of pellets content of this element was over 60 %, for sinters – under 60 %. In case of convertor slag the content of iron was low, but this material was used in process to increase the content of alloying elements in pig iron.

## THE EFFECT OF CHOSEN QUALITY PARAMETER OF FERROUS BURDEN MATERIALS ON THE TECHNICAL AND ECONOMIC PARAMETERS OF BLAST FURNACE PROCESS

The analysis of the dependence of basic technical and economic parameters of blast furnace process on charge richness was made. The results in form of correlation coefficients are presented in Table 4.

The analysis presented in Table 4 shows that richness of ferrous burden materials used as charge in blast

Table 4 **The dependence of basic technical and economic parameters of blast furnace process on charge richness**

| Parameter | Correlation coefficient |
|---|---|
| Yield of pig iron | 0,93 |
| Unit production of blast furnace slag | -0,99 |
| Unit fuel consumption in blast furnace process | -0,62 |
| Intensity of coke combustion | -0,79 |

furnace process significantly affects the parameters of the process. The better quality of materials (the higher charge richness), the higher yield of pig iron, while the lower unit production of blast furnace slag, unit fuel consumption and intensity of fuel combustion.

Regression functions describing the effect of charge richness on the examined technical and economic parameters of process were determined. Results of analysis regression are presented in Figures 1 – 4 and Tables 5 – 8.

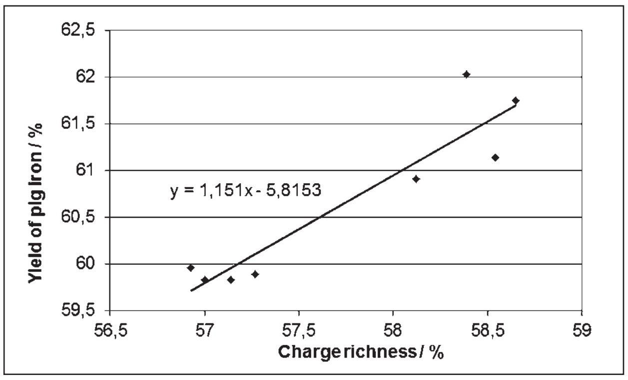


**Figure 1** Regression function describing the effect of charge richness on the yield of pig iron

Table 5 **Calculations for regression function describing the eÃect of charge richness on the yield of pig iron**

| | | | |
|---|---|---|---|
| $R^2$ | 0,87 | F | 41,02 |
| Se | 0,35 | Fist | 0,00063 |
| Ve | 0,57% | | |

Results of the analysis of the effect of charge richness on the yield of pig iron (Figure 1, Table 5) shows that it can be describe by following formula:

$$\hat{y} = 1{,}151+5{,}8153$$

where:

x – charge richness / %,

y – field of pig iron / %.

Calculations presented in Table 5 (standard error not exceeding 1 % of examined parameter, the coefficient of determination close to 1, significance of the variable of charge richness) indicate good fitting of regression function with the experimental values. Based on created regression model it can be said that the 1 % increase charge richness resulted the 1,15 % increase of yield of pig iron.

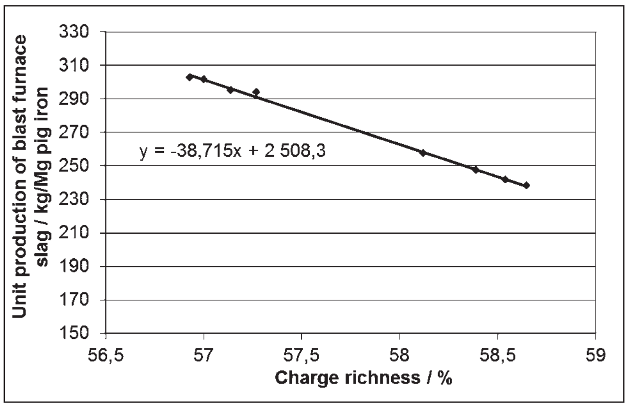


**Figure 2** Regression function describing the effect of charge richness on the unit production of blast furnace slag

Table 6 **Calculations for regression function describing the eÃect of charge richness on the unit production of blast furnace slag**

| | | | |
|---|---|---|---|
| $R^2$ | 0,99 | F | 2701,97 |
| Se | 1,45 | Fist | 3,4×10-9 |
| Ve | 0,53% | | |

Results of the analysis of the effect of charge richness on the unit production of blast furnace slag (Figure 2, Table 6) shows that it can be describe by following formula:

$$\hat{y} = -38{,}715x+2508{,}3$$

where:

x – charge richness / %,

y – unit production of blast furnace slag / kg/1 Mg pig iron.

Calculations presented in Table 6 (standard error not exceeding 1 % of examined parameter, the coefficient of determination close to 1, significance of the variable of charge richness) indicate good fitting of regression

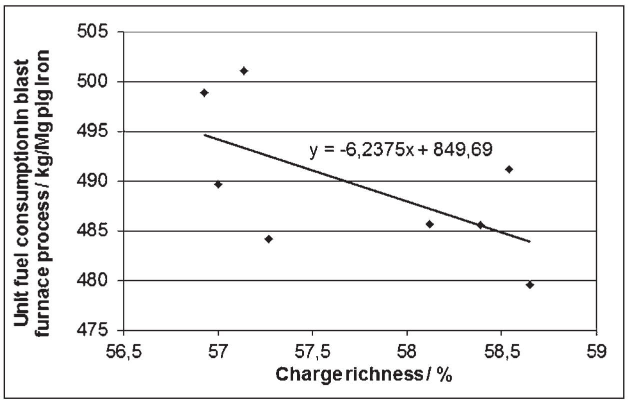


**Figure 3** Regression function describing the effect of charge richness on the unit fuel consumption in blast furnace process

Table 7 **Calculations for regression function describing the eÃect of charge richness on the unit fuel consumption in blast furnace process**

| | | | |
|---|---|---|---|
| $R^2$ | 0,38 | F | 3,81 |
| Se | 6,24 | Fist | 0,098 |
| Ve | 1,27% | | |

function with the experimental values. Based on created regression model it can be said that the 1 % increase charge richness resulted the decrease of unit production of blast furnace slag at the level of 38,7 kg/Mg pig iron.

Results of the analysis of the effect of charge richness on the unit fuel consumption in blast furnace process(Figure 3, Table 7) shows that it can be describe by following formula:

$$\hat{y} = -6{,}2375x + 849{,}69$$

where:

x – charge richness / %,

y – the unit fuel consumption in blast furnace process / kg/1 Mg pig iron.

Calculations presented in Table 7 (standard error exceeding slightly 1 % of examined parameter, the coefficient of determination at the level 38 %, significance of the variable of charge richness) indicate good fitting of regression function with the experimental values. Based on created regression model it can be said that the 1 % increase charge richness resulted the decrease of the unit fuel consumption in blast furnace process at the level of 6,3 kg/Mg pig iron.

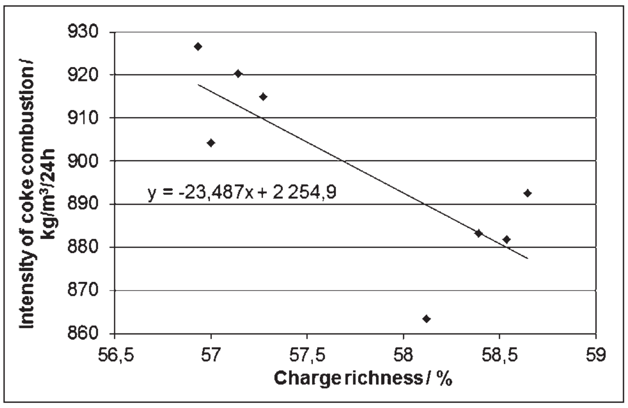


**Figure 4** Regression function describing the effect of charge richness on the intensity of coke combustion

Table 8 **Calculations for regression function describing the effect of charge richness on the intensity of coke combustion**

| $R^2$ | 0,62 | F | 10,18 |
|---|---|---|---|
| Se | 14,38 | Fist | 0,018 |
| Ve | 1,6% | | |

Results of the analysis of the effect of charge richness on the intensity of coke combustion (Figure 4, Table 8) shows that it can be describe by following formula:

$$\hat{y} = -23{,}487x + 2254{,}9$$

where:

x – charge richness / %,

y – the intensity of coke combustion / kg/m3/24h.

Calculations presented in Table 8 (standard error not exceeding 2 % of examined parameter, the coefficient of determination at the level 62 %, significance of the variable of charge richness) indicate good fitting of regression function with the experimental values. Based on created regression model it can be said that the 1 % increase charge richness resulted the decrease of the intensity of coke combustion at the level of 23,5 kg/$m^3$/24h.

## SUMMARY

Pig iron quality, technical and economic parameters of the process are affected by many factors, among which there is quality of ferrous burden materials. Analysis, presented in the paper, allowed to show that the use of ferrous burden materials of higher quality (mainly the basic component, iron) improves parameters of blast furnace process (increases the yield of pig iron, decreases unit slag production and fuel consumption). Economic aspects of this problem should be taken into consideration: whether the savings from lower fuel consumption and lower unit slag production are sufficient to cover higher cost of ferrous burden materials of higher quality.

## Acknowledgement

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