E. KARDAS, R. PRUSAK

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THE ASSESSMENT OF QUALITY OF SINTER AND ITS EFFECT ON THE EFFICIENCY OF BLAST FURNACE PROCESS

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The assessment of selected quality parameters of sinter and the effect of the its quality on the efficiency of blast furnace process is presented. The analysis of chemical composition of sinter was conducted. As a main quality parameter sinter richness (Fe content) was selected. Then influence of sinter richness on two parameters of efficiency 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 one calendar year.

Key words: blast furnace, sinter, chemical composition, pig iron, efficiency

INTRODUCTION

The blast furnace is the first and very often the most critical step in the production of iron and steel [1]. The blast furnace process has been in use for centuries and is still the most important iron making process worldwide. This process is very complex and involves enormous streams of materials and energy [2]. Various types of ferrous materials are used in the blast furnace process: lump ores, sinter or pellets. The main advantage of the blast furnace process is its high efficiency and high thermal effectiveness, while the disadvantage is the need to use very expensive coke [3]. The effectiveness of ironmaking process in blast furnace can be characterized in different ways based on smelting rate, output productivity or fuel consumption [4]. In process of production of pig iron even small changes in the operation of blast furnace can affect the efficiency of the process [5]. As one factor influencing the efficiency of blast furnace process is quality of materials used in this process. The paper presents the analysis of selected quality parameter of sinter and the effect of the its quality on the efficiency of blast furnace process. The analysis was carried out at the department of blast furnaces of one of the steel mills in Poland, and its period of time covered one calendar year. In investigated blast furnace department sinter is ferrous charge material. According to the requirement minimum percentage of sinter is 80 % of ferrous charge materials [6].

METHODOLOGY

The quality parameters of the iron-bearing sinter (chemical composition) and the influence of the main element (Fe) on the selected efficiency parameters were analysed. The analysis used the results on a monthly basis, they covered one calendar year. Basic descriptive statistics were used in the quality analysis: average, standard deviation, coefficient of variation as well as maximum and minimum values [7]. The influence of sinter richness on the efficiency of the blast furnace process was analysed using linear regression analysis.

QUALITATIVE ANALYSIS OF FERROUS CHARGE MATERIALS

The statistical analysis of content of basic elements in sinter was made. Main descriptive statistics were calculated. Results of this analysis is presented in Table 1. The analysis of results presented in Table 1 shows that the most important aspect of quality of sinter is the constant chemical composition and content of main element - Fe. The average content of Fe in sinter was on the level of 56,8 % with standard deviation 0,49 %, it means that content of this element was under small fluctuation. Values of this parameter value ranged from 55,97 to 57,75 %. Most parameters were characterized by slight variability, except Na_2O, K_2O and Zn, where coefficient of deviation was on the level of 14,4, 15,9 and 22,5 %, respectively.

The analysis of changes of content of individual elements of sinter in particular months was made. Values were compared to the average content of element. The results of the analysis is presented in Figure 1. The analysis presented in Figure 1 shows that:

- FeO content went under slight fluctuation. Maximum content (10,3 %) was noticed in month 6, while minimum (7,76 %) in month 2. From month 5 to 11 values far above average value were noticed.
- The average value of FeO content was exceeded between month 4 and 6. Then the decrease of con-

E. Kardas (edyta.kardas@pcz.pl), R. Prusak (rafal.prusak@pcz.pl) - Czestochowa University of Technology, Faculty of Production Engineering and Materials Technology, Czestochowa, Poland

Table 1 **Chemical composition of sinters used in blast furnace process**

Parameter	FeO / %	Fe / %	SiO_2 / %	CaO / %	MgO / %	Al_2O_3 / %	Mn / %	P_2O_5 / %	Na_2O / %	K_2O / %	Zn / %
Average	9,04	56,79	7,59	9,37	1,36	0,89	0,13	0,10	0,063	0,034	0,012
Standard deviation	0,625	0,49	0,344	0,629	0,097	0,027	0,013	0,004	0,009	0,005	0,003
Coeff. of deviation	6,9 %	0,9 %	4,5 %	6,7 %	7,2 %	3,1 %	10,6 %	4,6 %	14,4 %	15,9 %	22,5 %
Maximum value	10,03	57,75	7,97	10,47	1,46	0,95	0,16	0,11	0,077	0,042	0,019
Minimum value	7,76	55,97	6,90	8,28	1,17	0,85	0,11	0,095	0,043	0,024	0,010

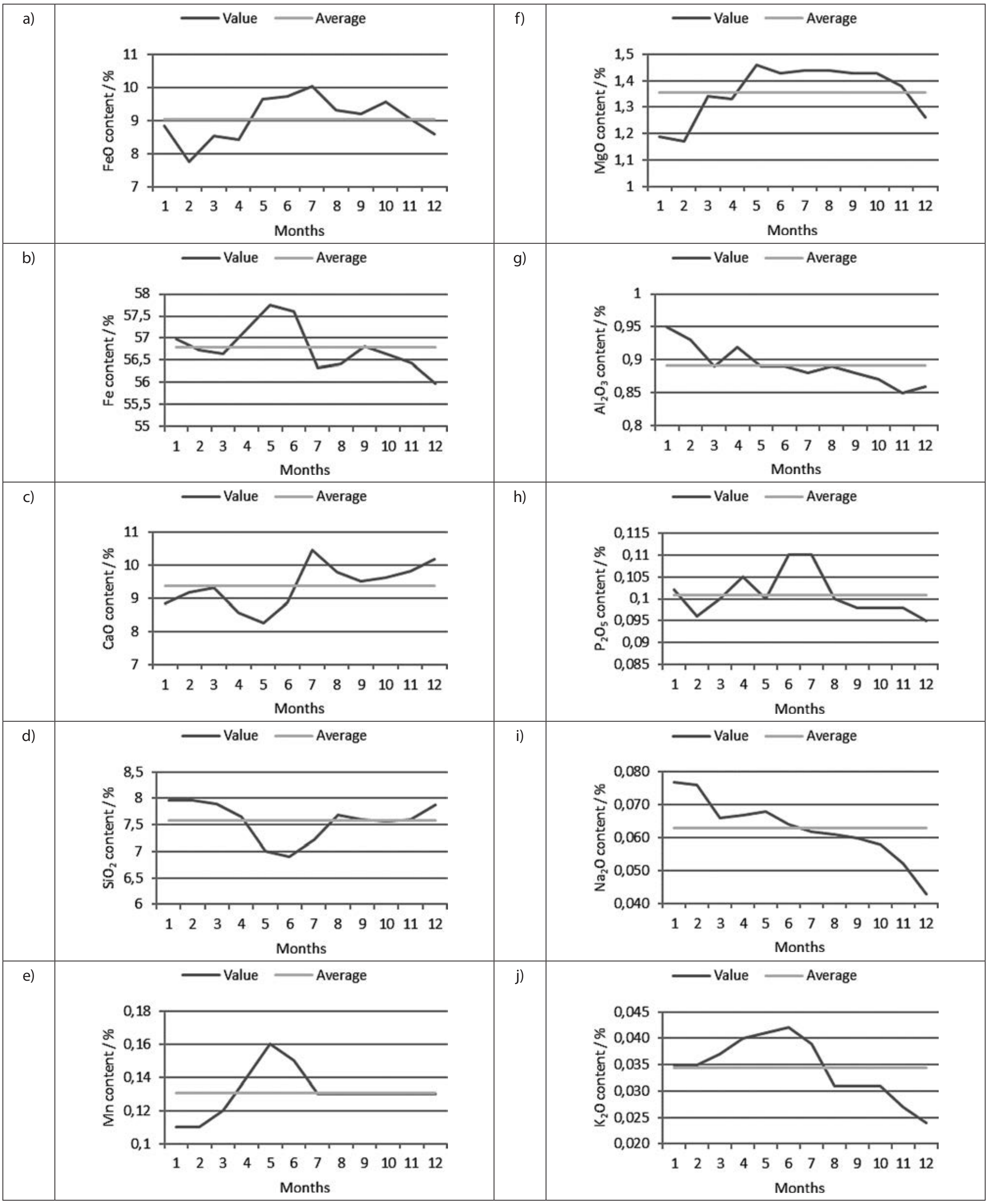

Figure 1 Analysis of content of chemical elements in sinter in the study period: a) FeO, b) Fe, c) CaO, d) SiO_2, e) Mn, f) MgO, g) Al_2O_3, h) P_2O_5, i) Na_2O, j) K_2O

tent was noticed. The maximum value (57,75 % in month 5) and minimum (55,97 % in month 12) were recorded.

- In case of CaO values of this parameter were in the range from 6,9 (in month 5) to 7,97 % (in month 7). From month 7 values above average were recorded.
- The average value of SiO_2 content was on the level of 7,59 %. Between month 5 and 6 values well below average were noticed. The highest value (7,97 %) was recorded in month 2, while the lowest (6,9 %) – in month 6.
- Mn content went under moderate fluctuation. Values ranges between 0,11 % (in month 5) to 0,16 % (in first two months). On the beginning of analysed period was much below average, then form month 4 to 6 – above, than in the second half of the year – values were on the level of the average.
- The average value of Mg content (1,36 %) was exceeded between month 5 and 11. The highest value (1,46 %) was recorded in month 5, while the lowest (1,17 %) in month 2,
- In case of Al_2O_3 values of this parameter were in the range from 0,85 % (in month 11) to 0,95 % (in months: 1 & 2 – 0,93%). In the first part of the year, average value was exceeded, then, it decreased below the average.
- For P_2O_5 values were in range from 0,095 % (in months 2 & 12 0,096 %) to 0,11 % (in months 6 & 7; 0,10 in months 5 & 8). Then, from month 9, the decrease of P_2O_5 content was recorded.

In case of Na_2O, K_2O and Zn significant fluctuation of values was recorded. Na_2O content was decreasing in the study period (values below average were noticed from month 7), K_2O content was higher than average form month 3 to 6, then it started to decrease. In case of Zn, stable values were recorded during 10 month, in the two last – values were much higher than average value.

THE INFLUENCE OF SINTER RICHNESS ON EFFICIENCY OF BLAST FURNACE PROCESS

The main quality parameter of sinter is sinter richness (Fe content in sinter). The analysis of the influence of this parameter on the efficiency of blast furnace process was conducted. As parameters presented the efficiency two indicators were selected:

- Yield of pig iron (that determines the percentage of pig iron production that can be received from 1 Mg of sinter).
- Yield of slags (the amount of slag production that is produced during the manufacturing of 1 Mg of pig iron).

The influence of the sinter richness on the these parameters was calculated and was presented in Figure 2 and Table 2.

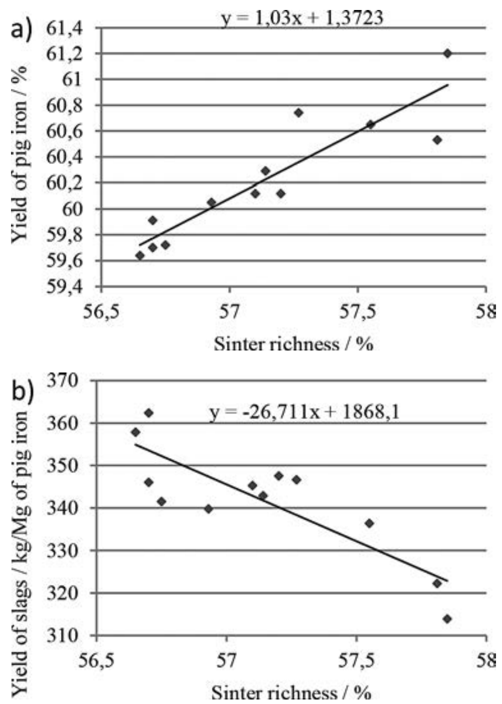

Figure 2 Linear dependence of sinter richness on: a) yield of pig iron, b) yield of slags

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

- Auxiliary calculations for linear regression functions show a good fit of the regression functions to the empirical data in all cases (significance on the level of 0,1).
- For the first case positive dependences are observed. Increasing sinter richness by 1 % resulted in increasing yield of pig iron by app. 1,03 %.
- For the second case negative dependence was observed. Increasing sinter richness by 1 % resulting in decreasing yield od slags by app. 26,715 kg/1 Mg of pig iron.
- Dependences show that higher sinter richness causes higher value of production of pig iron and lower production of slags.

Table 2. **Auxiliary calculations for the regression function**

Parameter	Yield of pig iron	Yield of slags
R	0,89	0,71
S	0,207	7,48
V	0,4 %	13 %
F	48,27	25,06
F_α	$3,96810^{-5}$	$5,32*10^{-4}$

R - correlation coefficient, S - residual standard error, V - coefficient of residual variation, F -value of test and Fα- probability for significance test of Fisher – Snedecor.

CONCLUSION

The analysis presented in the paper allowed for the following statements and conclusions:

1 The investigated quality parameters of the sinter (chemical composition) allowed to state that the composition was at a relatively constant level.

Mn (10 %), Na_2O (14,4 %), K_2O (15,9 %) and Zn (22,5 %) were characterized by considerable variability in terms of the content in the sinter.

2 The main quality indicator of the sinter was the Fe content (sinter richness). The determined dependencies show the influence of the richness of the sinter on the yield of pig iron (positive) and the yield of slag (negative).

3 Optimal preparation of the sinter has a significant influence on the course of the blast furnace process. Its chemical composition (mainly Fe content) and strength properties have an impact on the pig iron yield, i.e. indirectly on the production volume. Thus, the use of low-quality materials increases the amount of by-products (slag), reduces the yield of pig iron from a given amount of material and requires the consumption of more expensive fuel (stabilized coke), the value of which is the basic component of the cost of production.

4 The paper shows only the influence of the sinter quality on the selected efficiency parameters of the blast furnace process. However, it is worth trying to analyse the impact of sinter quality on the quality of the finished product, i.e. pig iron.

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Note: The responsible translator for English language is Edyta Kardas, Częstochowa, Poland.