E. KARDAS, R. PRUSAK

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THE INFLUENCE OF QUALITY OF FERROUS CHARGE MATERIALS ON THE EFFICIENCY OF BLAST FURNACE PROCESS

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The assessment of influence of quality of ferrous charge materials on the efficiency parameters of blast furnace process is presented. The analysis of structure of ferrous charge materials was made. As a main quality parameter charge richness was selected. Then influence of charge richness on four 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.

Keywords: blast furnace, charge, materials, pig iron, efficiency

INTRODUCTION

Metallurgy is one of the most important sectors of the economy of each country. This kind of industry is extremely material and energy consuming, half of charge supplied to the production process is removed in the form of gasses and solid materials. The main goal of the effective operation of blast furnace is the production of liquid pig iron with constant chemical composition and high quality indicators at the lowest possible cost [1 - 3].

The supply of the properly prepared ferrous charge materials is one of the most important element blast furnace operation that has the great influence on efficiency of the process [3]. Over several decades, the quality of ferrous charge materials used in the process has improved significantly. The use of iron-rich ores causes decrease in the amount of slags and the use of fuels in process [4, 5]. The use of ferrous waste, which very often contains more iron than ore is also very common [6]. All these elements cause some economic effects in the blast furnace process, including the increase of efficiency of process.

The main purpose of the analysis is the assessment of the influence of selected quality parameter of ferrous burden materials on parameters of blast furnace process efficiency.

METHODOLOGY

The analysis presented in the paper is divided into the following components:

– Analysis of structure of ferrous charge materials used in the blast furnace process.
– The assessment of variability of percentage of sinter in ferrous charge materials and charge richness.
– The influence of selected quality parameter of ferrous burden materials (charge richness) on four parameters of efficiency of process: yield of pig iron, plan execution index, yield of slags and coke rate. The following elements of the analysis of significance were determined: correlation coefficient (R), residual standard error (S), coefficient of residual variation (V), value of test (F) and probability (Fα) for significance test of Fisher – Snedecor.

The analysis covers the time of one calendar year. The results were gathered in Blast Furnace Department which is a part of one of the biggest Steel Plant in Poland.

CHARACTERISTICS OF MATERIALS

Iron–bearing materials are main production factor in blast furnace process. The use of iron-rich, well prepared chemically and physically ferrous charge materials determines the achievement of optimal technical and economic indicators and enables even blast furnace operation [7]. In the tested blast furnace, the following groups of ferrous charge materials and additives are used: sinter and its screening, pellets, rich iron ores, converter slag, ferrous concentrates and fluxes (limestone and quartzite). Currently, there are blast furnaces in the world that operates on 100 % of sinter or 100 % of pellets, but usually they used mix of sinter, pellets and ores with a satisfactory result [7, 8].

The basic component of ferrous charge materials for the blast furnace in the investigated steelworks is sinter, that is produced in the same steelworks from fine iron-bearing materials [8]. It is a “self-melting” sinter with the basicity slightly above 1, what limits the use of fluxes [6]. According to the requirements of investigated

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

blast furnace minimum percentage of sinter is 80 % of ferrous charge materials [9].

Table 1 presents the basic physical properties of the sinter used in the blast furnace process according to the requirements of the operators. The second group of materials used in investigated blast furnace is pellets, which are made in the process of burning or chemical reaction of fine iron ore concentrates. They are exported from abroad. In addition, the ferrous concentrates and ores are used directly in blast furnace device. Also some waste materials are added as a charge materials, mainly: converter slags and scale. Table 2 presents chemical composition of samples of ferrous charge materials used in the process.

Table 1 **Basic physical properties of sinter [9]**

Property	Value
Grain size / mm	4 – 40
Fine fraction under 4 mm / %	max. 14
Average grain / mm	20
Strength / %	min. 74,0
Abrasibility / %	max. 6,0

QUALITATIVE ANALYSIS OF FERROUS CHARGE MATERIALS

The analysis of ferrous burden materials was made. On the beginning, the analysis of structure of these materials was conducted. The analysis presented in Figure 1 shows that the main ferrous charge materials is sinter produced in the analysed steelworks. The percentage is on the average level of over 87 % and exceeded the minimal required value 80 %. In the process nearly 9 % of charge materials are pellets, while only small amount of lump ores (2,7 %) and rich slag and scale (0,7 %)

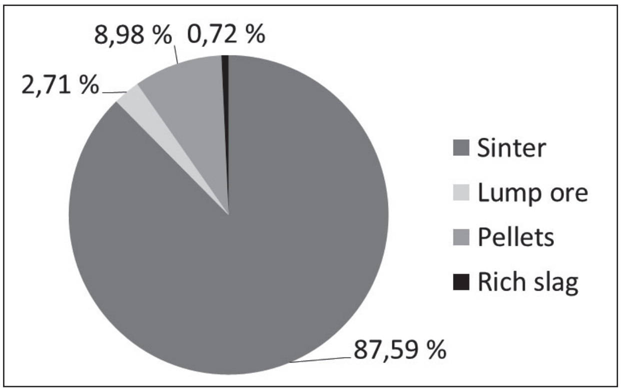

Figure 1 The structure of ferrous charge materials used in the blast furnace process [10]

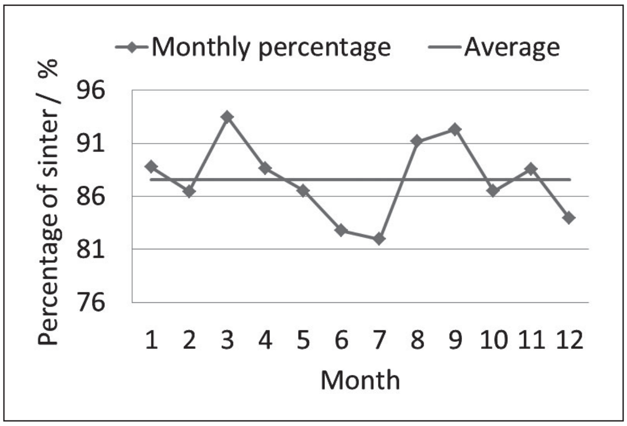

Figure 2 The percentage of sinter in ferrous charge materials [10]

were noticed. In the next part of the paper, the analysis was conducted only for sinter.

The analysis of changes in percentage of sinter in ferrous charge materials were made. They were compared to the annual average value. According to the results presented in Figure 2 it can be said, that during the whole investigated period of time average percentage of sinter in ferrous charge materials is on the level of 87,6 % and it went under slightly fluctuations, from 81,95 (in month 7) to 93,44 (in month 3). Changes in percentage of sinter was mainly caused by economic reason, very often using other kind of ferrous charge materials was cheaper than sinter.

As main quality parameter charge richness was selected. The analysis of changes in charge richness during the whole investigated period of time was made. Results of the analysis presented in Figure 3 shows that value of charge richness fluctuated slightly around the average (57 %). Value was ranged between 56,26 % (in month 1) to 57,84 % (in month 6). It must be underlined, that the lowest values were noticed on the beginning of study period, while the highest - in the middle, on the end value slightly decreased. Charge richness is dictated by richness of ores and concentrates used in production process of sinter.

THE INFLUENCE OF SELECTED PARAMETER ON EFFICIENCY OF BLAST FURNACE

The analysis of influence of selected parameter of sinter on efficiency of blast furnace was calculated. As main quality parameter charge richness was selected. As efficiency indicators of blast furnace process, four parameters were chosen: yield of pig iron, plan execu-

Table 2 **Chemical composition of ferrous charge materials / wt. % [10]**

Material	Fe	FeO	SiO_2	CaO	MgO	Al_2O_3	Mn	P_2O_5	Na_2O	K_2O	Zn	S	C_{tot}
Sinter	56,44	9,06	7,60	9,84	1,38	0,85	0,13	0,096	0,05	0,02	0,015	0,014	0,16
Lump ore	62,46	0,45	3,12	0,29	0,03	0,73	0,02	0,230	<0,01	<0,01	<0,01	0,019	0,31
Pellets	62,72	2,06	6,24	1,56	0,26	0,19	0,03	0,247	0,10	0,06	<0,01	0,010	0,17
Scale	74,41	69,08	0,09	0,31	0,39	0,36	0,64	0,043	0,01	<0,01	<0,01	0,004	0,08

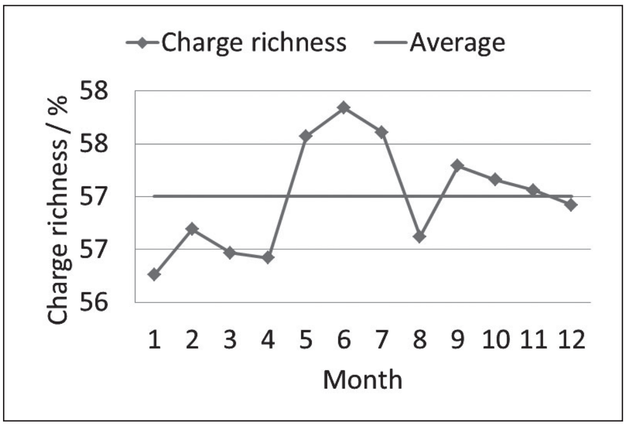

Figure 3 Charge richness [10]

tion index, yield of slags and coke rate. In case of next two indicators dependence should be positive, in case of next two – negative. Results of the analysis are presented in Figure 4 and Table 3.

According to the results of the analysis presented in Figure 4 and Table 3 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 first two cases positive dependences are observed. Increasing charge richness by 1 % resulted in increasing yield of pig iron by app. 1,05 % and plan execution index by app. 0,06 %.

Table 3 **Auxiliary calculations for the regression function [10]**

Parameter	Model A	Model B	Model C	Model D
R	0,924	0,542	0,872	0,530
S	0,235	0,047	7,129	17,31
V	0,4 %	5,1 %	2,06 %	3,5 %
F	58,69	4,16	31,93	3,91
F_α	$1{,}71 \cdot 10^{-5}$	0,06	$0{,}02 \cdot 10^{-2}$	0,07

- For two next cases negative dependence was observed. Increasing charge richness by 1% resulting in decreasing yield od slags by app. 23,5 kg/1Mg of pig iron and coke rate by app. 20 kg/1 Mg of pig iron.
- Dependences show that higher charge richness causes higher value of production of pig iron and lower use of fuels (especially coke) and lower production of slags.

CONCLUSION

High efficiency of blast furnace is important for the economics of production process. The proper quality of ferrous charge materials used in the process significantly improves parameters determining the effectiveness of the process. In the analysis presented in the paper, the

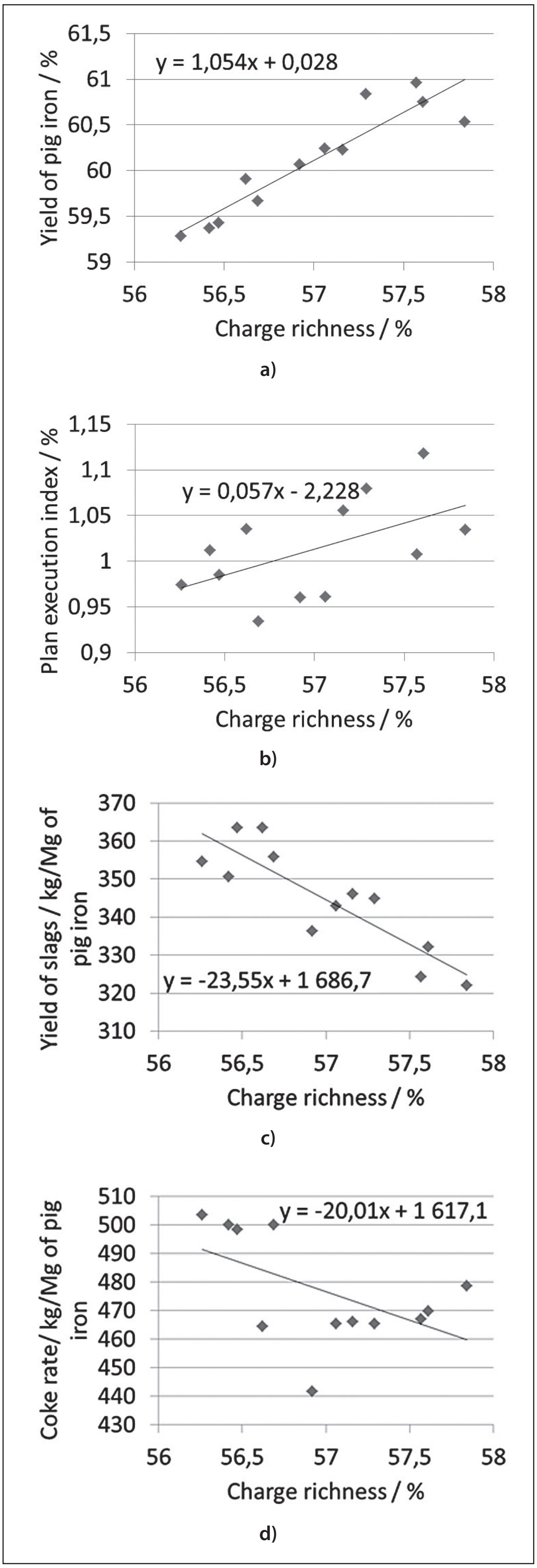

Figure 4 Linear dependence between the efficiency indicators of blast furnace process and charge richness: a) yield of pig iron, b) plan execution index, c) yield of slags, d) coke rate [10]

structure of ferrous charge materials was examined, then changes in content of the most important material (sinter) was assessed. Changes of selected quality parameter, charge richness, was examined. In the next part, the analysis of the influence of charge richness on four parameters of effectiveness was made. It should be underline that it is only a part of the analysis, also other dependences should be calculated. The rest of this analysis will be presented in other works.

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