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EVALUATION OF EFFECTIVENESS OF RAW MATERIALS AND MATERIALS USE IN A BLAST FURNACE DEPARTMENT OF A STEELWORKS

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The paper analyses the quality of raw materials used in the production of blast furnace pig iron. The ferruginous sinter and pellets are the basic raw materials used in the process. The paper presents the impact of those raw materials quality on the effectiveness of the blast furnace process. The process effectiveness will be specified by means of selected process parameters.

Key words: blast furnace, pig iron, charge materials, effectiveness

INTRODUCTION

The quality of finished products and the effectiveness of each production process is affected by many factors, including the quality of raw materials and materials used in the process [1, 2]. On the one hand the use of better quality materials may result in higher cost of their purchase, however, looking at that from a broader perspective this may bring other savings: the production process effectiveness goes up and the quantity of poorer quality products decreases. In the case of the blast furnace process the use of high-quality ferruginous charge may increase the quantity of produced pig iron and its yield, reduce the amount of waste or the fuels consumption. Such changes may result in so great savings that would successfully cover the increased cost of better materials and would even provide some profit [3, 4].

The paper presents the results of a study on the impact of diverse productive factors on the blast furnace pig iron quality and on the process parameters. The study was carried out in cooperation with a Blast-Furnace Department of a Polish steelworks.

METHODOLOGY

The performed analysis was divided into the following components:

1 Characteristic of the ferruginous charge:
   – determination of ferruginous materials used in the process,
   – description of selected quality parameters of the ferruginous charge.
2 Determination of basic parameters of the blast furnace operation effectiveness.
3 The influence of ferruginous charge materials on selected process effectiveness parameters - determination of selected qualitative factor of ferruginous materials on the process effectiveness parameter using the linear regression method.

FERRUGINOUS CHARGE AND ADDITIVES

Basic factors of blast-furnace production include the ferruginous materials [5]. The blending of iron-rich, well prepared from chemical and physical point of view ferruginous charge, conditions obtaining optimum values of technical-economic indices and enables an even operation of the blast furnace [6]. Apart from ores and their concentrates, numerous waste raw materials are used in the blast-furnace process, which substantially affects the economic result of this process [5]. This results from the fact that metallurgical waste raw materials most frequently contain more iron than the ores used [7].

When specifying the ferruginous charge quality it is necessary to evaluate the following properties [8]: chemical composition of the raw material, physical properties and in particular the mechanical strength of material as well as metallurgical properties, primarily the thermal decomposition, seductiveness and temperature as well as the range of softening.

In the studied steelworks the following groups of materials are used as the ferruginous materials and additives: sinter and sinter screenings, pellets, iron-rich ores, converter slags, ferruginous concentrates, fluxes: limestone and quartzite.

QUALITY OF FERRUGINOUS MATERIALS

A ferruginous sinter, a product of sintering fine-grained iron-containing materials, is the basic component of the blast-furnace ferruginous charge in the stud-

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ied steelworks [9]. It is produced from a blend of haematite iron ores, magnetite concentrates as well as metallurgical processes waste: slurries, dust, mill scale and converter slag [10]. This is a 'self-fusible' sinter with the CaO:SiO2 alkalinity slightly exceeding 1, which reduces the application of fluxes [11]. In the studied steelworks conditions it is used at the minimum amount of approx. 80 – 90 % of total ferruginous charge. Table 1 presents basic physical properties of the sinter used in the blast-furnace process.

Table 1 **Basic physical properties of the sinter [12]**

Property	Value
Particle size / mm	4 - 40
Fine fraction, below 4 mm / %	max. 14
Average grain / mm	20
Strength / %	min. 74,0
Abrasibility / %	max. 6,0

Table 2 presents the chemical characteristic of basic ferruginous materials used in the steelworks during the studied period.

Table 2 **Characteristics of ferruginous materials/ wt.% [12]**

Material	H_2O	Fe	FeO	SiO_2	CaO	MgO	Al_2O_3
Sinter	-	58,59	5,96	5,57	7,95	1,58	0,83
Material	Mn	P_2O_5	Na_2O	K_2O	Zn	S	
Sinter	0,19	0,099	0,08	0,04	0,033	0,017	

Two qualitative properties of ferruginous materials were selected for the analysis: the sinter fraction in the charge and the charge richness. Table 3 presented statistics describing the sinter fraction in the charge and the charge richness during the studied period.

Table 3 **Sinter fraction in the charge and the charge richness during the studied period**

Characteristics	Sinter fraction in the charge / %	Charge richness / %
Average sinter fraction in the charge	90,98	57,09
Standard deviation of sinter fraction in the charge	3,70	0,85
Variation	4	1,5
Maximum value	96,85	58,6
Minimum value	83,13	55,29

The data presented in Table 3 show that:

- During the studied period the sinter of average fraction of 91 % was used in the ferruginous burden, the remaining ferruginous burden consisted of additives among other in the form of pellets. The average charge richness was around 57 %.
- The sinter fraction in the charge featured relative stable values, because the diversification amounted only to 4 % of the average value. The charge richness featured also a relative stability, because the variability was only 1,5 % as against the average.

BASIC PARAMETERS OF THE BLAST FURNACE OPERATION EFFECTIVENESS

The pig iron production at as low as possible cost is the basic economic objective of the blast-furnace process [9]. It is necessary to remember that huge material streams are related to the process, so even small changes in the blast furnace operation will affect the costs [10]. To capture changes in the blast furnace operation simple technical-economic indicators should be assessed on a current basis, apart from complicated process parameters [11].

Three basic effectiveness ratios for the blast-furnace process have been used in the paper:

- Daily production P is the basic factor evaluating the economic effect of blast furnace operation. It is defined as the total blast furnace output during a day [12].
- The unit fuel consumption, which may be defined as the total amount of fuels used to produce 1 Mg of pig iron, is an important indicator specifying the blast-furnace process economics [12].
- The pig iron yield U is the third indicator used in the paper. It is defined as the ratio of produced pig iron to the amount of ferruginous materials used to produce it [11, 12].

THE IMPACT OF SELECTED PRODUCTION FACTORS ON THE DAILY PIG IRON PRODUCTION

Figure 1 presents a regression function, showing the impact of charge richness changes on the daily pig iron production, while Table 4 presents auxiliary calculations for this function.

Based on calculations (Figure 1, Table 4) it is possible to conclude that the increase in the charge richness by 1 % resulted in increasing the daily production of pig iron by approx. 302 Mg. Auxiliary calculations (standard error less than 9 % of the studied phenomenon, significance of the model explanatory variable) show a good fit of the regression function to the empirical data.

Figure 2 presents a regression function, describing the unit fuels consumption dependence on the charge

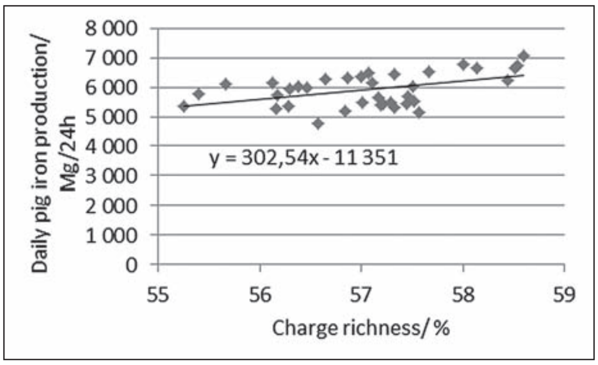

Figure 1 Daily pig iron production vs. charge richness during the studied period

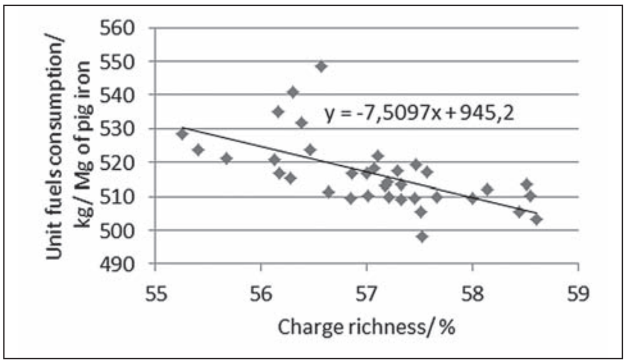

Figure 2 Unit fuels consumption vs. charge richness during the studied period

Table 4 **Auxiliary calculations for the regression function, describing the daily pig iron production dependence on the charge richness during the studied period**

Se	498,42	
Ve	8,5 %	
d(a) = 99,37	t(a) = 3,04	t_α = 2,03
d(b) = 5 671,242	t(b) = - 2,001	

richness, while Table 5 presents auxiliary calculations for this function.

Based on calculations (Figure 2, Table 5) it is possible to conclude that the increase in the charge richness by 1 % resulted in reducing the unit fuels consumption by approx. 7 kg/Mg of pig iron. Auxiliary calculations (standard error less than 1,5 % of the studied phenomenon, significance of the model explanatory variable) show a good fit of the regression function to the empirical data.

Table 5 **Auxiliary calculations for the regression function, describing the unit fuels consumption dependence on the charge richness during the studied period**

Se	8,29	
Ve	1,3 %	
d(a) = 1,65	t(a) = - 4,54	t_α = 2,03
d(b) = 94,319	t(b) = 10,02	

Figure 3 presents a regression function, describing the pig iron yield dependence on the charge richness, while Table 6 presents auxiliary calculations for this function.

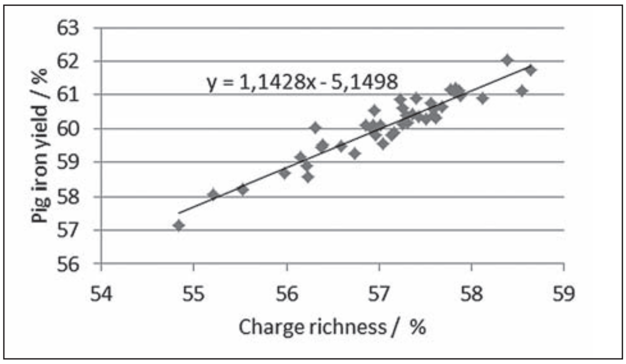

Figure 3 Pig iron yield vs. charge richness during the studied period

Table 6 **Auxiliary calculations for the regression function, describing the pig iron yield dependence on the charge richness during the studied period**

Se	0,32	
Ve	0,54 %	
d(a) = 0,061	t(a) = - 18,721	t_α = 2,03
d(b) = 3,485	t(b) = - 1,47	

Based on calculations (Figure 3, Table 6) it is possible to conclude that the increase in the charge richness by 1 % resulted in increasing the pig iron yield by approx. 1,14 %. Auxiliary calculations (standard error less than 0,6 % of the studied phenomenon, significance of the model explanatory variable) show a good fit of the regression function to the empirical data.

Figure 4 presents a regression function, describing the unit fuels consumption dependence on the sinter fraction in the ferruginous charge, while Table 7 presents auxiliary calculations for this function.

Based on calculations (Figure 4, Table 7) it is possible to conclude that the increase in the sinter fraction in the ferruginous charge by 1 % resulted in reducing the unit fuels consumption by approx. 1,38 kg/Mg of pig iron. Auxiliary calculations (standard error less than 1,5 % of the studied phenomenon, significance of the model explanatory variable) show a good fit of the regression function to the empirical data.

Figure 5 presents a regression function, describing the pig iron yield dependence on the sinter fraction in the ferruginous charge, while Table 8 presents auxiliary calculations for this function.

Based on calculations (Figure 5, Table 8) it is possible to conclude that the increase in the sinter fraction in the ferruginous charge by 1 % resulted in increasing

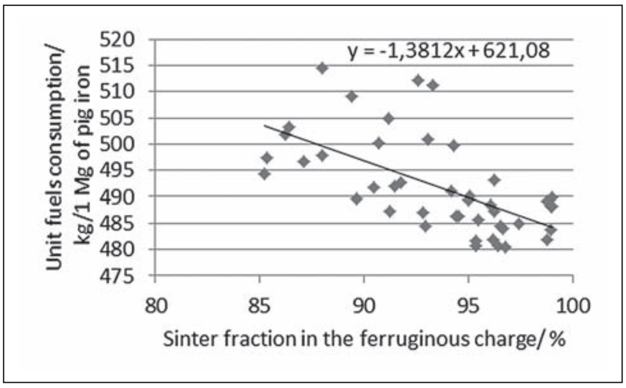

Figure 4 Unit fuels consumption vs. sinter fraction in the ferruginous charge during the studied period

Table 7 **Auxiliary calculations for the regression function, describing the unit fuels consumption dependence on the sinter fraction in the ferruginous charge during the studied period**

Se	7,21	
Ve	1,45 %	
d(a) = 0,2759	t(a) = -5,006	t_α = 2,03
d(b) = 25,8122	t(b) = 24,061	

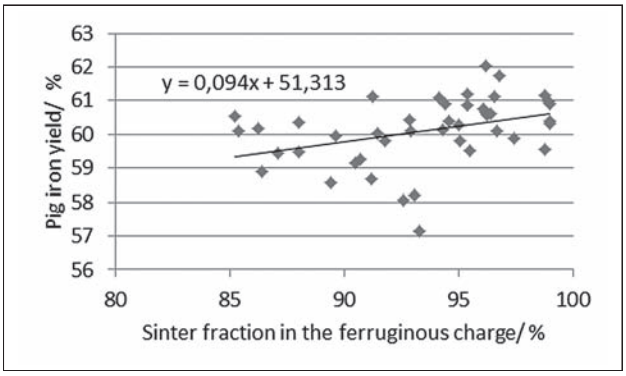

Figure 5 Pig iron yield vs. sinter fraction in the ferruginous charge during the studied period

Table 8 **Auxiliary calculations for the regression function, describing the pig iron yield dependence on the sinter fraction in the ferruginous charge during the studied period**

Se	0,924	
Ve	1,53 %	
d(a) = 0,0353	t(a) = 2,66	t_α = 2,03
d(b) = 3,3066	t(b) = 15,51	

the pig iron yield by 0,09 %. Auxiliary calculations (standard error less than 1,6 % of the studied phenomenon, significance of the model explanatory variable) show a good fit of the regression function to the empirical data.

SUMMARY

Numerous factors affect the blast-furnace process effectiveness, including the quality of ferruginous materials used. The carried out analysis allowed to show how the ferruginous materials quality affects the process effectiveness: it increases the daily output and the pig iron yield as well as reduces the unit fuels consumpshould be evaluated, i.e. it is necessary tion. However, the economic effect of such activities to assess, whether the use of higher quality but more expensive ferruginous materials will result in properly high savings due to a lower fuels consumption and a smaller amount of waste, offsetting a higher price of better quality materials.

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Note: The professional translator for English language is Jerzy Wróblewski, Poland