RECIRCULATION OF THE SECONDARY POWDER MATERIAL IN THE PRIMARY TECHNOLOGICAL FLUXES IN THE STEELMAKING EAF

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During the past years, as society continues to move toward more sustainable disposal methods of waste materials, major progress has been made in the recycling and re-use of some secondary powder materials, resulted from steel industry in primary technological fluxes. The aim of this paper is to present a new technology for recovery of secondary materials powder by realizing cold auto reducing briquettes chargeable in the electric arc furnaces (EAF). These briquettes were subjected to several tests, and finally, it has been established that they can replace partially scrap in steelmaking in EAF, with economic and environmental advantages.

Keywords: recirculation, electric arc furnaces (EAF), performances EAF, secondary powder materials

1. Introduction

During the past years, the society transformation is designed based on the principles defining the sustainable development concept (SD).

Metallurgical industry consumes two times more raw materials to the process of production than the final product produced [1]. Thus, one of the most important industry, by its products and for all social sectors is steel industry, although a huge consumption of energy and material resources and is having a high pollution degree despite of the country. Thus, all the countries conceived and practice priority programs in the field of sustainable development [4]. The specialists may identify and develop new metallic, ceramic and carbonic materials destined to top industry: aeronautical, microelectronics, robotics also. They may provide new materials production technologies thus to valorize to the highest degree

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the raw materials but also the existent resources and, in the same time, to develop recycling and nonpolluting technologies to use as raw material the industrial scrap, thus these technologies to contribute to re–equilibration of the ecosystems and no to their destruction.

The strict environmental regulations as well as the valuable metallic content cause the ability to recycle scales become an important issue [5].

In this way appears the necessity of using different alternative iron sources in the charge of the electric arc furnace [9].

Thus, the steel industry specialist propose the increase of the electric arc furnaces performances based on valorizing secondary raw material resulted in steel industry, by recycling these ones in primary technological fluxes [1].

The main recyclable wastes in an integrated steel making process are the dust from sintering, electrostatic precipitator dust, powders and slurries from blast furnaces, thin and thick steel mill sludge, mill scale from hot rolled, cold rolled mud and mud from chemical residue treatment [2].

The necessity of recycling in primary technological fluxes of these powder secondary materials is explained by two major causes:

- crisis in the field of good quality raw iron supply;
- decrease of the quantity and stocks of scrap iron due to pollution, basically with nonferrous elements (Cu, Sn, Cr, Ni, Mo etc.) affecting the steel quality, as well as the requirements from the beneficiary are higher and higher, and also the extension of the continuous casting procedure resulting in internal scrap iron quantity decreasing [11].

Post input – output analyzes and based on a general mass balance it was established that the main secondary resources that can be introduced in the electric arc furnaces are: dust EAF, scale and slurry [8]. The EAF dust is generated during melting of scrap in electric arc furnace and collected by bag filters or electrostatic precipitators [2].

Function of usage degree of EAF dust and function of the analysis result regarding the repartition degree, chemical composition and grinding it was established that the EAF dust can return in the process only if is worked in briquettes – pelleting and added to the classical charge [8]. Dust from electric arc furnaces includes approximately 30-40% of zinc and 20% of iron [7]. EAF dust can vary greatly in composition of the metallic charge, the furnace additives used and the type of steel produced [12].

The resulted scale from the continuous casting process and from semi-finished products heating for rolling is a coarse product and non-oily [10] and can be introduced in the EAF taking into account that is having a very useful use component (Fe>70%) that should be valorized.

Slurry, as complex mixture, ferrous fine dust – water – oil needs special technology in order to allow reintroducing of this one in EAF circuit.

2. Experimental Research

In order to establish the necessary technology to work the three main ferrous byproducts (furnace dust, scale and slurry) we used ranking technology of their determined characteristics (Zn content, oil content, granulation) and a targeted technological objective (Zn enrichment, Zn recovering, grinding, drying, un-oiling).

We realized the EAF dust characterization by taking into account the two parameter influence: dust proportion in furnace charge and Zn content in EAF dust. We analyzed the following aspects:

- EAF dust proportion in the charge influence on phosphorus content in obtained steel (Fig. 1);
- EAF dust proportion in the charge influence and the EAF dust Zn content on the Zn content in obtained steel;
- EAF dust proportion in the charge influence and the EAF dust Zn content on the Zn content of the new generated dust.

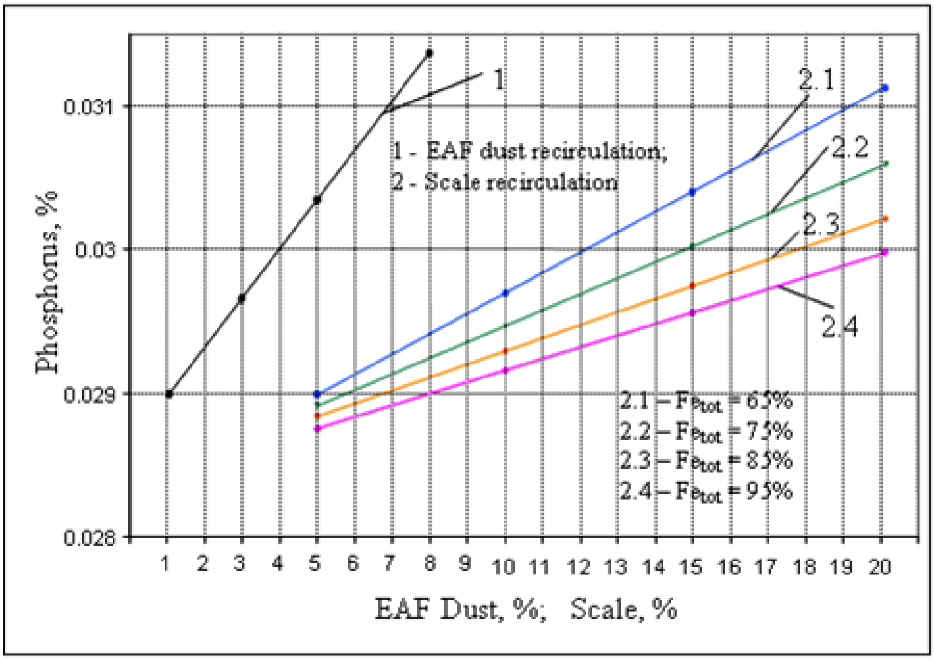

Fig.1. Variation of the pre – calculated values of P at melting, function of EAF dust and scale

We characterize the scale taking into account the two parameters influence: scale proportion in the charge and $(Fe)_{tot}$ content in scale. We analyzed the following issues:

- influence of the scale proportion in the charge and the total iron content (Fe)tot in scale on the phosphorus content in obtained steel;
- influence of the scale proportion in the charge and the total iron content in scale on the quantity of steel;
- influence of the scale proportion in the charge and the total iron content in scale on the deviation in obtained steel quantity.

In the case of slurry we made its characterization following the influence of two parameters (slurry proportion in the charge and total iron content in the slurry), analyzing the following issues:

- the slurry proportion influence in the furnace charge and total iron content in the slurry on the obtained steel quantity;
- the slurry proportion influence in the furnace charge and total iron content in the slurry on the deviation in obtained steel quantity.

Based on the theoretical analyses and experimental research regarding the efficient valorization of these ferrous byproducts (EAF dust, scale and slurry) we concluded that the optimal solution is the manufacturing of cold auto-reducing briquettes that can be charged in the electric arc furnaces by placing them in the initial charge. Manufacturing the briquettes it was realized based on a recipe taking into account the raw materials, added materials necessary to ensure the reducing character and also to ensure the transport and charging resistance.

The necessary reducing agent quantity was determined based on the stoichiometric mass balance, having carbon excess coefficient of 1.3 for 85% reducing C, calculated as:

$$Q_c = \left[\left(Q_{O-FeO} + Q_{O-Fe_2O_3}\right) * \frac{M_C}{M_O} - \sum Q_{C_{byproducts}}\right] * \frac{1,3}{0,85} \qquad [1]$$

The fluxes added (chalk and lime to realize a basicity target index IB=1.2) was calculated with the relationship:

$$IB = \frac{\sum(CaO)_{byproducts} + \sum(CaO)_{chalk} + \sum(CaO)_{lime} + \sum(CaO)_{bentonite} + \sum(CaO)_{cocks}}{\sum(SiO_2)_{byproducts} + \sum(SiO_2)_{chalk} + \sum(SiO_2)_{lime} + \sum(SiO_2)_{bentonite} + \sum(SiO_2)_{cocks}} \qquad [2]$$

In order to realize briquettes that are mechanically resistant, primarily the cocks was added, having also a reducing character and then the bentonite was added.

With the aid of oxide reducing balances O-C and materials balances of the basicity character elements as CAO and SiO_2 (existent as sterile or added) we designed more types of recipes for briquettes.

Due to the fact that others component influence was followed, the realized products based on the recipes presented in tables 1 – 3 were researched, the presented procedures resulted function the added material quantity in the global mass of the prepared briquettes.

Table 1

Recipe of briquettes manufacturing wit EAF dust, [%]

Component	Recipe							
	BD 1	**BD 2**	**BD 3**	**BD 4**	**BD 5**	**BD 6**	**BD 7**	**BD 8***
EAF dust	71.5	72.0	72.5	73.0	73.5	74.5	75.5	76
Bentonite	7	7	7	7	6.5	6.5	6.5	6.5
Lime	3.8	3.8	3.8	3.8	4	4	4	4
Chalk	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0
Cocks	17.2	16.7	16.2	15.7	15.0	14.0	13.0	12.5
Total	100	100	100	100	100	100	100	100

*where BD1…BD8 – EAF dust briquettes

Table 2

Recipe of briquettes manufacturing with scale, [%]

Component	Recipe					
	BS 1	**BS 2**	**BS 3**	**BS 4**	**BS 5**	**BS 6***
Scale	59.5	60.5	61	62	63	63.5
Bentonite	7	7	7	6.5	6.5	6.5
Lime	5	5	5	4.7	4.7	4.7
Chalk	0.5	0.5	0.5	1.0	1.0	1.0
Cocks	28	27	26.5	25.8	24.8	24.3
Total	100	100	100	100	100	100

*where BS1…BS6 – scale briquettes

Table 3

Recipe of slurry briquettes manufacturing, [%]

Component	Recipe					
	BSy 1	**BSy 2**	**BSy 3**	**BSy 4**	**BSy 5**	**BSy 6***
Slurry	62.0	62.5	63	64	65	66.0
Bentonite	7	7	7	6.5	6.5	6.5
Lime	5	5	5	4.7	4.7	4.7
Chalk	0.3	0.3	0.3	0.6	0.6	0.6
Cocks	25.7	25.2	24.7	24.2	23.2	22.2
Total	100	100	100	100	100	100

*where BSy1…BSy6 – slurry briquettes

For the reducing adding the cocks has been added, cocks usually being easy to find in steel industry and as flux the dust lime was added (easy to get) and chalk for some recipe that we wanted to be a little bit foaming by CO_2 found in chalk.

Briquettes manufactured based on these recipes were subjected to tests to characterize secondary powder materials. Thus, after the compression tests we obtained the following results (table 4):

Table 4

Compression tests results

Sample	**R_f,** [kN/cm^2]	**R_s,** [kN/cm^2]	ΔR_{fs}, [kN/cm^2]	**Sample**	**R_f,** [kN/cm^2]	**R_s,** [kN/cm^2]	ΔR_{fs}, [kN/cm^2]
BD 1	0.76	0.91	0.15	BD 5	0.42	0.72	0.30
BD 2	0.68	0.87	0.19	BD 6	0.46	0.71	0.25
BD 3	0.59	0.79	0.20	BD 7	0.48	0.78	0.30
BD 4	0.57	0.80	0.23	BD 8	0.45	0.76	0.31
BS 1	0.39	0.49	0.10	BS 4	0.30	0.40	0.10
BS 2	0.34	0.45	0.11	BS 5	0.31	0.41	0.13
BS 3	0.33	0.43	0.10	BS 6	0.29	0.43	0.14
Bsy 1	0.34	0.38	0.04	Bsy 4	0.26	0.28	0.02
Bsy 2	0.33	0.36	0.03	Bsy 5	0.24	0.30	0.06
BSy 3	0.30	0.33	0.03	BSy 6	0.26	0.31	0.05

*where R_f – fracture resistance, R_s – crushing resistance ΔR_{fs} - the fracture – crushing interval

Based on mean values of the results obtained after the compression tests we could compare the three technological situations (BD, BS and Bsy) (Fig. 2).

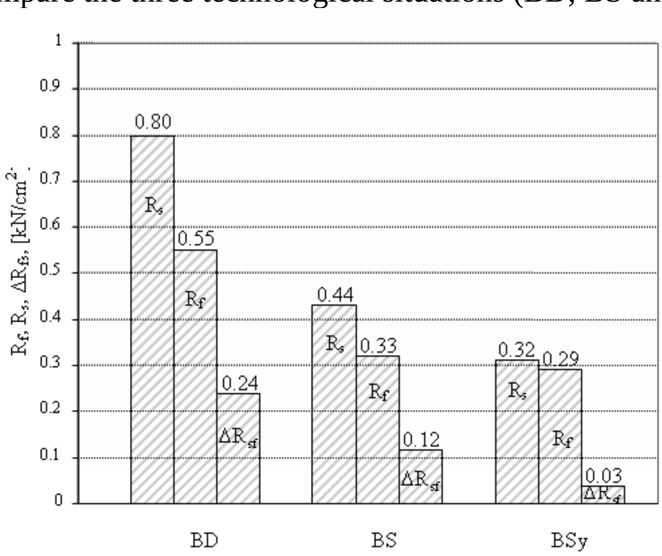

Fig.2. Hystogram for comparing the three situations by mean values

The experimental results for thermo compression for samples with 74%P, 6.5%B, 4%V, 0.5% C and 14% K are shown in table 5.

Table 5

Results of thermo compression tests

Temperature Parameter	20°C	200°C	300°C	400°C
R_f, [kN/cm^2]	0.43	0.18	0.12	0.05
R_s, [kN/cm^2]	0.70	0.25	0.10	0.07
ΔR_{fs}, [kN/cm^2]	0.27	0.07	0.02	0.02

Shatter test was realized on four categories of dust samples realized after the ones in table 6 at the temperatures of 20, 200, 300 and 400°C.

Table 6

Recipes for the samples subjected to Shatter test

Recipe Component	BD-S 1	BD-S 2	BD-S 3	BD-S 4
Dust	73	74	75	76
Bentonite	7	7	7	7
Lime	3.7	3.7	3.7	3.7
Chalk	0.8	0.8	0.8	0.8
Cocks	15.5	15.5	15.5	15.5

*where BD – S1 – BD – S4 – briquettes with dust for Shatter test.

The Shatter test results are shown in Fig. 3.

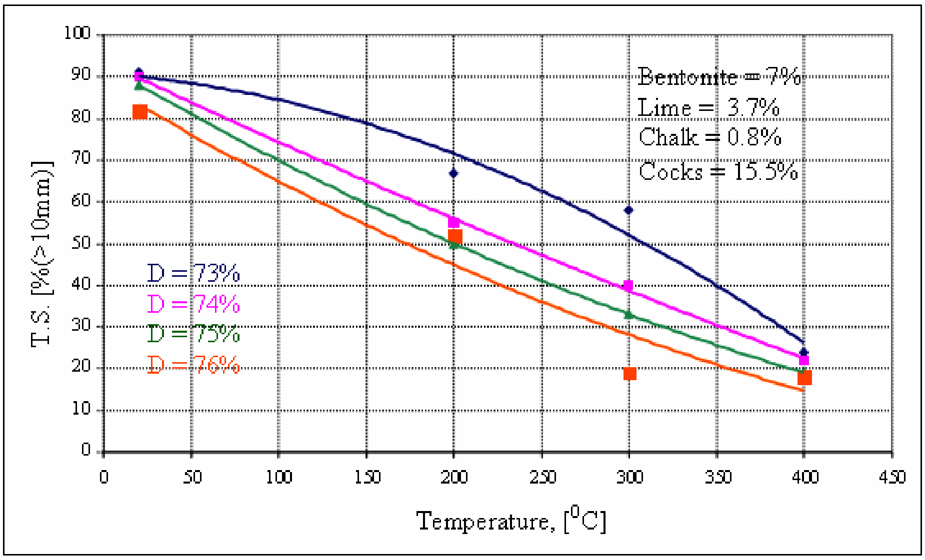

Fig. 3. Shatter coefficient variation

3. Results

We established the percent quantities of the components in manufacturing recipes function of the preliminary tests. Also, we took into consideration the zones where the manufacturing and using the briquettes has technological and economic signification.

Reading the results was realized function of the hypothesis advanced regarding the mechanism of briquettes behavior to subjected tests.

The quantitative and qualitative analyses resulted in:

- *Fracturing resistance* of the briquettes decreases when the EAF dust percent increases limited with the lime contend; so bentonite is a better binder than lime, lime being also the best basicity regulator;
- *Crushing resistance* of the briquettes is insignificantly influenced by the EAF dust content and bentonite content, but decreases with the lime content increasing; so in the crushing process after the fracture the briquettes resistance is lime dependent;
- *The fracture – crushing interval* increases with the EAF dust increasing and decreases with the lime and bentonite decreasing.
- To ensure the briquettes with a resistance of minimum 0.48 kN/cm^2 the EAF dust content should be 74%;
- The bentonite percent over 7% can be considered ensuring for obtaining a good crushing resistance over 0.6 kN/cm^2;
- Influence of the lime in the fracture process is reduced, having a deciding influence in the crushing procedure; a limitation of the lime content is the percentage of 3%.

4. Conclusions

From the analyses of briquettes compression tests, we can draw the following conclusions:

a) Briquettes are subjected, during transport and charging, to damaging processes; resistance to compression is influenced by the secondary powder materials as well as the binder (bentonite) and the lime content;
b) During damaging process there are 2 stages: I – the stage of fracture beginning (apparition of the first fracture) and II – crushing stage (destruction of the briquette). For the second stage the crushing resistance is essential, and this is function of lime and bentonite content;
c) After charging the briquettes in the electric arc furnace the briquettes structure disintegration processes are accelerated from the temperature of 200°C.

Shatter tests shows that the particles having a diameter of 10mm or smaller are the most representative for the reducing melting processes developing in the furnace.

We can conclude that ***the cold self-reducing briquettes*** can replace scrap iron in steel obtaining in EAF if the proper technologies are used, in order to foresee the use of the briquettes realized by EAF dust and scale.

Using and producing these briquettes has economical as well as ecological advantages:

- From the economical point of view, we used the simple eco - efficiency index, defined as the ration between the expenses from ecological technology (C_e) and the reference technology (C_m).

$$c_{ee} = \frac{C_e}{C_m} \qquad (3)$$

When c_{ee} is less than 1 we can say that the new procedure fulfill the *ecological – economical function* [6].

The ecological advantage resulted from the deposit spaces reduction and reducing the air – water – earth pollution.

R E F E R E N C E S

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