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RESEARCH ON THE USE OF DUSTS RESULTING FROM IRON AND STEEL PROCESSES

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Abstract: The powdery and fine ferrous waste, resulted in the various phases of the industrial processes (in most cases, siderurgical), represents an intrinsic value determined by the ferrous content (chemically bounded iron, sometimes metallic iron), which can adequately replace some of the raw materials used in siderurgy, i.e. the iron ore. In the experiments carried out, we considered the recycling of powdery ferrous waste (dust from steel plant, sinter plants and blast furnaces) and fine ferrous material (scale). The processing aimed obtaining self–reducing ferrous briquettes, which is why in the recipe composition we added graphite powder and, as binder, lime and bentonite. The quality of briquettes was assessed through their mechanical properties, resistance to cracking and crushing, and the crushing range, considered dependent parameters. As independent parameters, we considered the component percentages in the recipes. The data obtained were processed using Excel spreadsheet and MATLAB programs, and the obtained correlations were analytically and graphically expressed. The results were technologically and economically analyzed, resulting in a series of conclusions useful for the steelmaking practice.

Keywords: waste, dust, iron, carbon, briquettes, recovery, siderurgy

1. INTRODUCTION

In the industrial processes, in addition to the primary product are sometimes resulting secondary products and wastes. In the steel production flow, the economic operators generate continuously fine and powdery waste containing iron, carbon and iron & carbon, in appreciable amounts proportional to the obtained production.In the various stages of the technological processes within a steel company, besides the primary product, there are also generated significant amounts of materials, usually called wastes, but because of the possibilities to recover them through recycling and / or reuse they fall into the category of by–products. Depending on the circumstances of each steel unit, and according to the local market demand (time–variant) of each usable material, any waste can become by–product and any by–product can become waste. [1, 2, 3, 11]

Currently, the problem of recovery through recycling of the powdery and fine waste generated in siderurgy arises worldwide, being proposed the application of the integrated recycling concept. The entire quantity of powders, slurries and scale, steel plant slag – the ferrous fraction, generated within an integrated iron & steel plant, are recycled in the various stages of the technological flow, the mostly used processes being: sintering, pelletizing and briquetting.

Compared with the practices and trends worldwide, Romanian steel industry records backlogs in the collection, transport and storage of the powdery waste, as well in the technologies for recovery through recycling or reuse. In these conditions, we considered necessary and appropriate to approach the issue of higher recovery of the powdery waste generated within an integrated iron & steel plant, recovery achievable with minimal costs. [1, 11]

The higher recovery of siderurgical waste in general and of those fine and powdery in particular, represents an important issue, because turning them into by–products (i.e. in economic goods) can lead to a rational exploitation of the raw materials and energy resources, thus ensuring either the needs of human society or the environmental protection, major problem at the end of the second millennium and the beginning of the third millennium. [1, 2, 3, 6, 7]

2. STUDY OF THE ISSUE

In the experiments carried out, we assessed the possibilities to recover certain siderurgical wastes (i.e. dust from sinter plants & blast furnaces, dust from steel plant, and scale) through briquetting. We chose this method because the first two types of waste are powdery and the third is fine, which corresponds to this process. Since we chose the production of self–reducing briquettes, we used graphite powder as reducer and lime & bentonite as binder.

The waste chemical compositions are shown in the Tables 1 – 3, and the recipe compositions are shown in Table 4.

Table 1. Chemical composition of the slurry from sinter plants – blast furnaces (after drying) [1, 16]

Chemical composition, %											
FeO_{tot}	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	MnO	S	P	C	PC
30.40	8.84	33.61	10.35	9.33	10.47	2.47	0.89	1.38	0.13	22.04	1.272

Table 2. Chemical composition of the dust from steel plant electro–filter [1, 16]

Chemical composition, %											
Fe_{tot}	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	MnO	P_2O_5	S	ZnO	Others
53.67	2.98	73.37	3.49	1.07	5.11	2.34	4.80	0.74	0.34	0.84	4.918

Table 3. Chemical composition of the scale, % [1, 5]

FeO	Fe_2O_3	MnO	SiO_2	CaO	MgO	Al_2O_3	Others
63.0– 70.0	18.0– 30.0	0.8 – 1.5	1.0 – 3.5	0.1 – 0.40	0.3 – 0.5	(0.9 – 2.0	3.0– 4.0

Table 4. Composition of recipes, [%]

no	Used waste	Composition of recipes [%]									
		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
1	Dust from sinter plant and blast furnaces	25	30	35	35	40	45	50	55	60	65
2	Dust from steel plant	50	40	35	30	25	20	24	19	15	10
3	Scale	14	17	19	25	25	25	14	15	13	13
4	Bentonite	2	3	3	3	3	3	4	4	5	5
5	Lime	3	3	3	3	3	3	3	3	3	3
6	Graphite powder	6	7	5	4	4	4	5	4	4	4

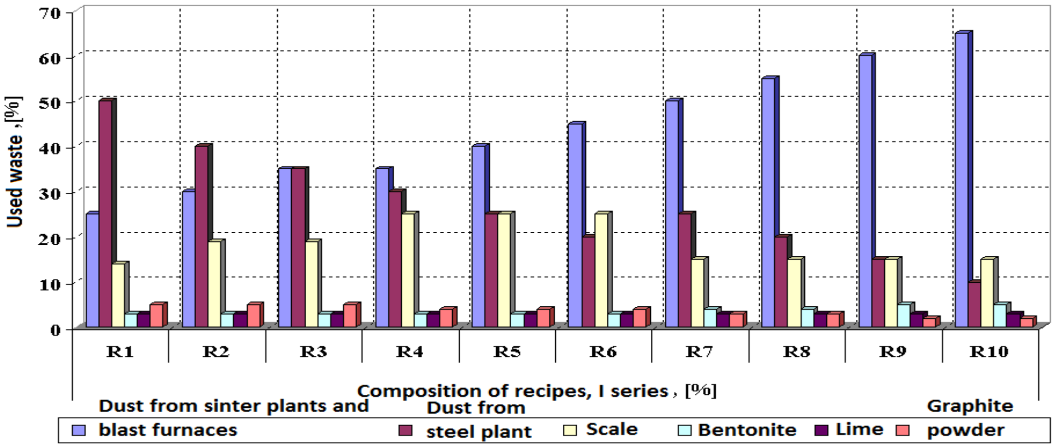

Figure 1. Composition of recipes

To assess the quality characteristics of resistance to handling and transportation of the briquettes, we found by experiments three technological proprieties:

- Resistance to cracking:

$$R_f = \frac{F_f}{A}, [kN/cm^2] \tag{1}$$

where: F_f – cracking force, [kN]; A – sectional area of the sample (briquette), [cm^2]

In case of the studied briquettes (cylindrical), the above relation can be written:

$$R_f = \frac{4 \cdot F_f}{\pi \cdot d^2}, \ [kN/cm^2] \tag{2}$$

The cracking force, $F_{f,}$ is considered to be the force at which the first visually detected cracks occur. Following a large number of preliminary tests and on the basis of literature data [1, 2, 6], this force is considered to have the value recorded at τ = 2 seconds.

- Crushing strength:

$$R_s = \frac{F_s}{A}, [kN/cm^2] \tag{3}$$

where: F_s – crushing force, [kN]; A – sectional area of the sample (briquette), [cm^2]

In case of the studied briquettes (cylindrical), the above relation can be written:

$$R_s = \frac{4 \cdot F_s}{\pi \cdot d^2}, \ [kN/cm^2] \tag{4}$$

Based on the literature data and the preliminary observations, the crushing force is considered to have the value recorded at $\tau = 12$ seconds.

- The crushing range:

$$\Delta R_{fs} = I_s = R_s - R_f, [kN/cm^2] \tag{5}$$

Regarding the possibility of using the material by recycling, any research must relate with the permissible values for the resistances mentioned above.

In the literature [1, 2, 3], we found information about the pellets to be loaded into the blast furnace, products that are in the same category with the briquettes subject to this research.

Given the fact that the briquettes for processing in the blast furnace undergo multiple handling operations, in many cases being transported over long distances (hundreds of kilometres), and taking into account the data found in the literature[1, 2, 6, 8, 9], we consider that, provided that the obtained briquettes will be used in a siderurgical company, located not far from the briquetting plant, the resistance to cracking must correspond to the relation:

$$R_f > 0.2, [kN/cm^2] \tag{6}$$

The literature [1, 2, 6] regarding the briquettes which contain more than 70% dust from electric steel plant (EAF) presents the following relation for the crushing strength R_s:

$$R_s = (1.2–1.35)\ R_f, [kN/cm^2] \tag{7}$$

Obviously, we are going to establish below a correlation relation of these resistances, for the briquettes produced according to our recipes.

In order to recover, as briquettes, the fine and powdery waste coming from the iron & steel, energy and mining industries, I considered the following types of waste: dust from the electric steel plant, dust (slurry) from the sinter plant & blast furnaces, scale (scale slurry), and as binder, we considered lime, bentonite and cement.

For each recipe, we produced a briquetting heat of 1.5 kg, to be possible to obtain a number of 5 briquettes.

After producing them, the briquettes were left to harden in the atmosphere for 15 days, after which they were tested for determining the quality characteristics.

The data from experiments were processed in Excel calculation program, for obtaining simple correlation equations, and in MATLAB for obtaining multiple correlation equations (triple and double). We mention that the same datawere processedin both programs. The correlations obtained are presented analytically and graphically. Below, I present the data about the production of briquettes.

The results of data, processing using the Excel program, are presented in the figures 1–8.

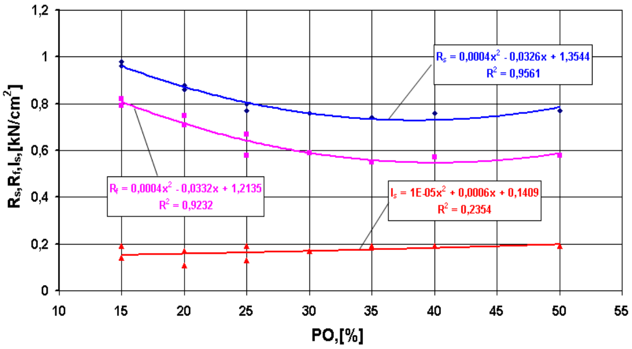

Figure 2. R_f, R_s, I_s versus the percentage of dust from steel plant

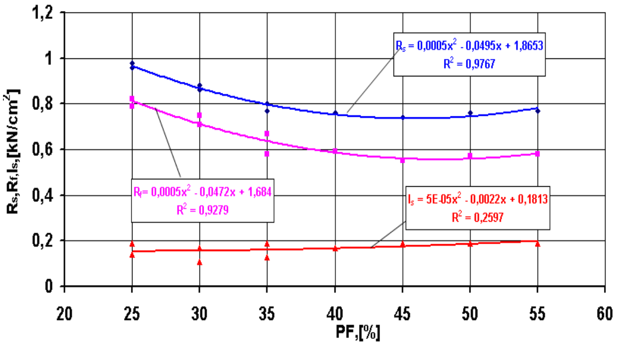

Figure 3. R_f, R_s, I_s versus the percentage of dust from sinter plant and blast furnaces

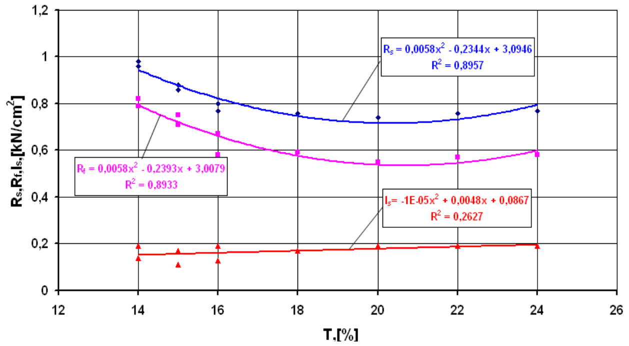

Figure 4. R_f, R_s, I_s versus the percentage of scale

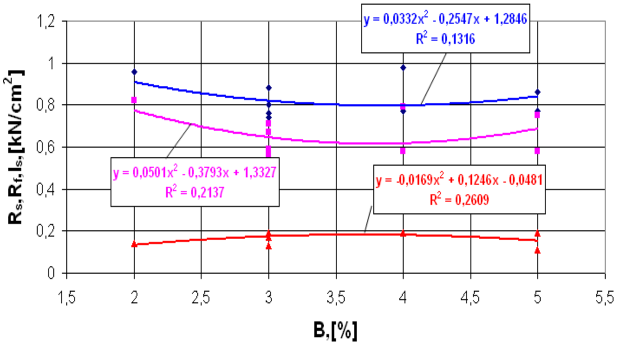

Figure 5. R_f, R_s, I_s versus the percentage of bentonite

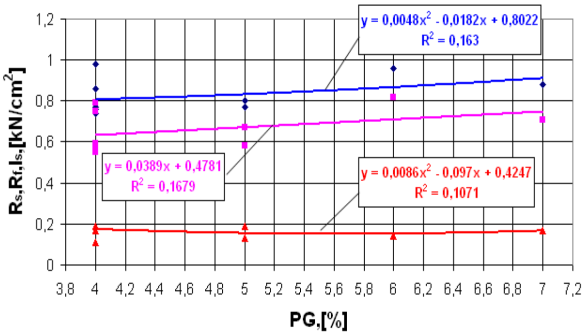

Figure 6. R_f, R_s, I_s versus the percentage of graphite dust

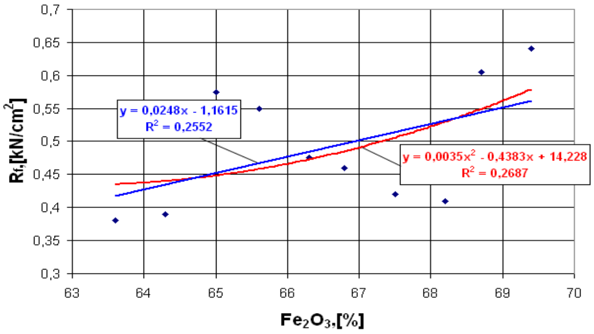

Figure 7. Influence of the Fe_2O_3 percentage on the cracking resistance

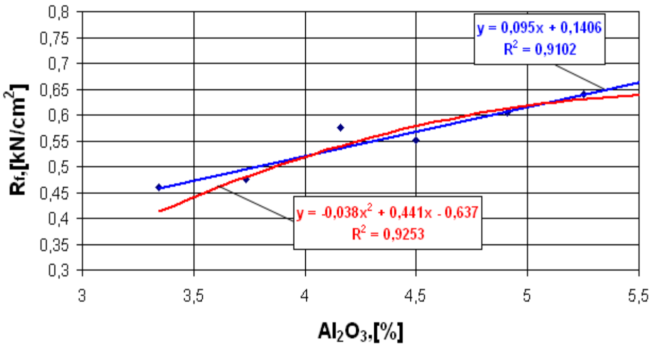

Figure 8. Influence of the Al_2O_3 percentage on the cracking resistance

The crushing strength:

$$R_s = 0.0003(PO)^2 - 0.0004(PF)^2 + 0.0073(T)^2 + 0.0004(PO)(PF) - 0.0024(PO)(PF) + 0.0001(PF)(T) + 0.0149(PO) + 0.0241(FF) - 0.2470(T) + 2.5680 \qquad (1)$$

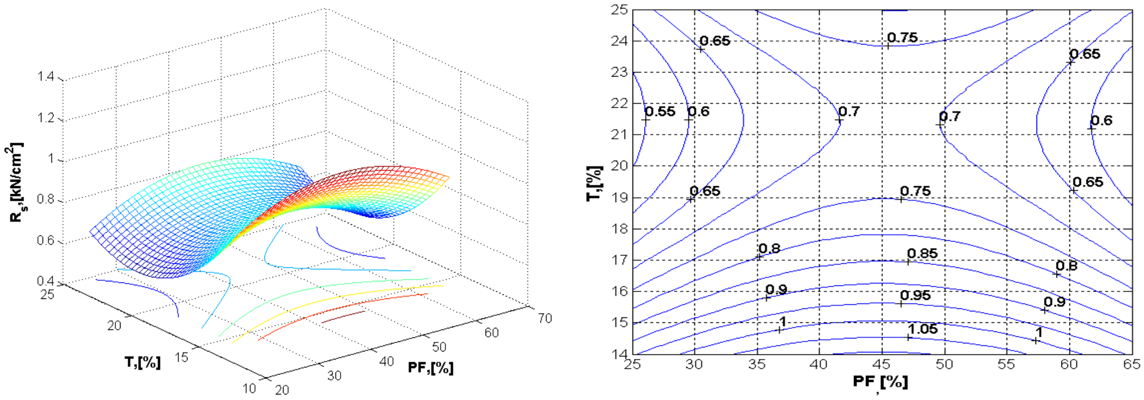

Figure 9. Crushing strength of briquettes versus the percentages of dust from sinter plant & blast furnaces and scale

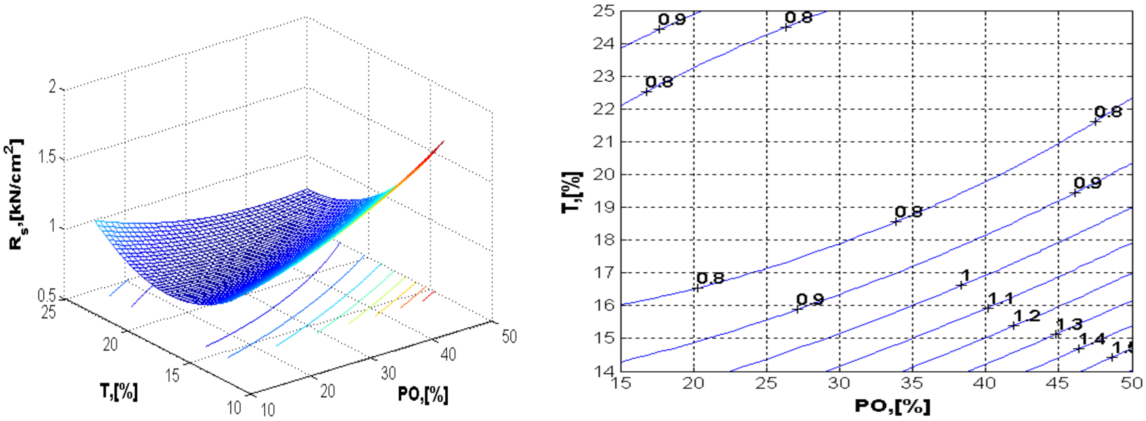

Figure 10. Crushing strength of briquettes versus the percentages of dust from steel plant and scale

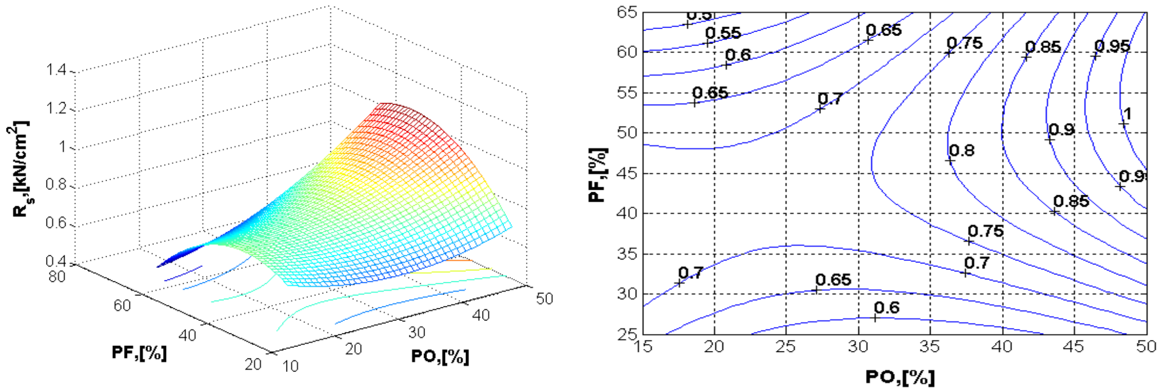

Figure 11. Crushing strength of briquettes versus the percentages of dust from steel plant and from sinter plant & blast furnaces

For $PO_{med} = 29.375\%$, it results:

$$R_s = -0.0004(PF)^2 + 0.0073(T)^2 + 0.0001(PF)(T) + 0.0357(PF) - 0.03171(T) + 3.2851 \quad (2)$$

For $PF_{med} = 43.125\%$, we have:

$$Rs = -0.0003(PO)^2 + 0.0073(T)^2 + 0.0024(PO)(T) + 0.0319(PO) - 0.212(T) + 3.6065 \quad (3)$$

For $T_{med} = 19.25\%$, we have:

$$Rs = -0.0003(PO)^2 - 0.0004(PF)^2 + 0.0004(PO)(PF) + 0.039(PO) - 0.039(PF) + 2.1875 \quad (4)$$

The cracking resistance of the briquettes R_f is given by the relation:

$$R_f = 0.0004(PO)^2 - 0.0005(PF)^2 + 0.0093(T)^2 + 0.0005(PO)(PF) - 0.0029(PO)(T) + \\ + 0.0002(PF)(T) + 0.0203(PO) + 0.0293(PF) - 0.3236(T) + 2.9856 \quad (5)$$

For $PO_{med} = 29.375\%$, we have:

$$R_f = 0.0005(PF)^2 + 0.0093(T)^2 + 0.0002(PF)(T) + 0.0426(PF) + 0.2398(T) + 3.5832 \quad (6)$$

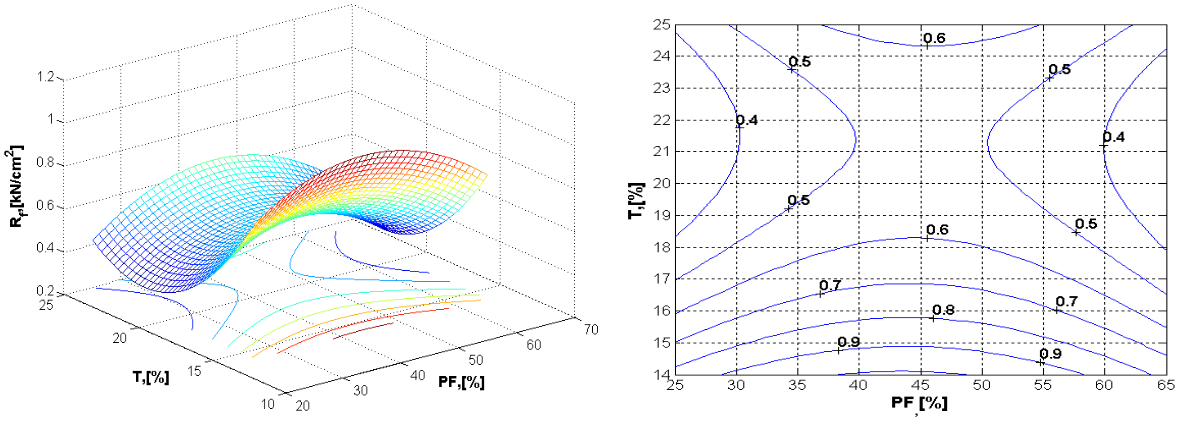

Figure 12. Cracking resistance of briquettes versus the percentages of dust from sinter plant & blast furnaces and scale

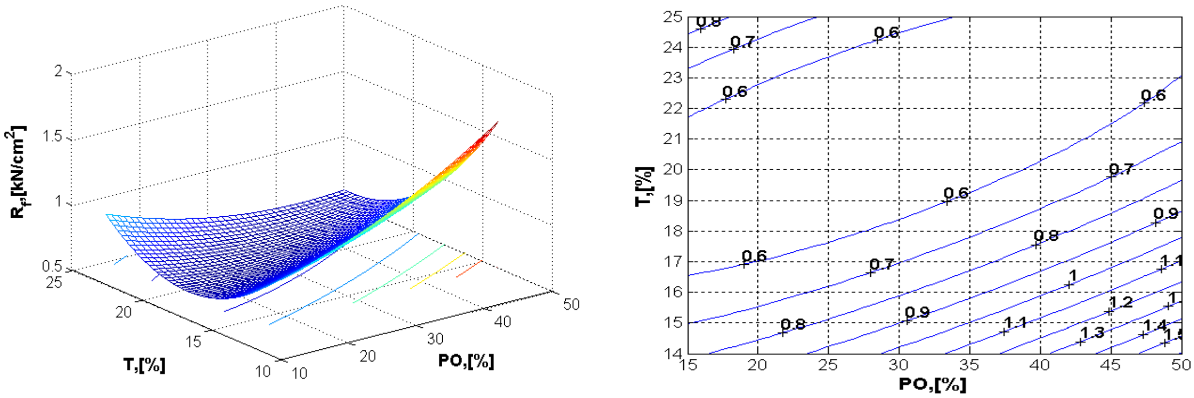

Figure 13. Cracking resistance of briquettes versus the percentages of dust from steel plant and scale

For $PF_{med} = 43.125\%$, it results:

$$Rf = 0.0004(PO)^2 + 0.0093(T)^2 - 0.0029(PO)(T) + 0.0418(PO) - 0.315(T) + 3.3193 \quad (7)$$

For $T_{med} = 19.25\%$, we have:

$$Rf = 0.0004(PO)^2 - 0.0005(PF)^2 + 0.0005(PO)(PF) - 0.0335(PO) + 0.0331(PF) + 5.8089 \qquad (8)$$

The crushing range I_s of the briquettes is given by the relation:

$$I_s = -0.0001(PO)^2 + 0.0001(PF)^2 - 0.0008(T)^2 + 0.0002(PO)(PF) - 0.0003(PO)(T) - 0.0017(PF) - 0.0061(PF) + 0.0474(T) - 0.2171 \qquad (9)$$

For $PO_{med} = 29.375\%$, we have:

$$I_s = 0.0001(PF)^2 - 0.0008(T)^2 - 0.0149(PF) + 0.0532(T) - 0.3532; \qquad (10)$$

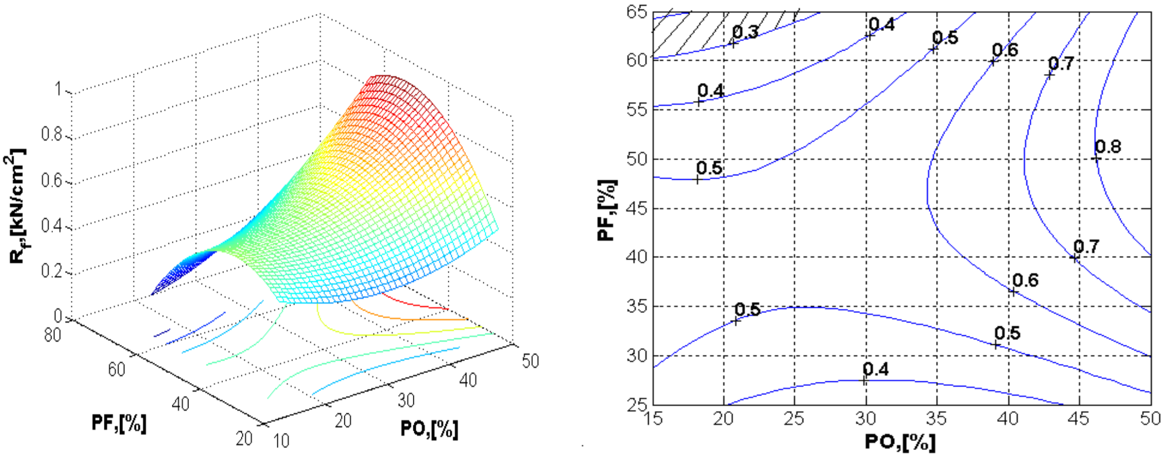

Figure 14. Cracking resistance of briquettes versus the percentages of dust from steel plant and blast furnaces

For $PF_{med} = 43.125\%$, we have:

$$I_s = -0.0001(PO)^2 - 0.0008(T)^2 + 0.0002(PO) * (T) - 0.0017(PO) + 0.0216(T) + 0.666 \qquad (11)$$

For $T_{med} = 19.25\%$, we have:

$$I_s = -0.0001(PO)^2 + 0.0001(PF)^2 + 0.0021(PO) - 0.0118(PF) + 0.3989 + 0.3989 \qquad (12)$$

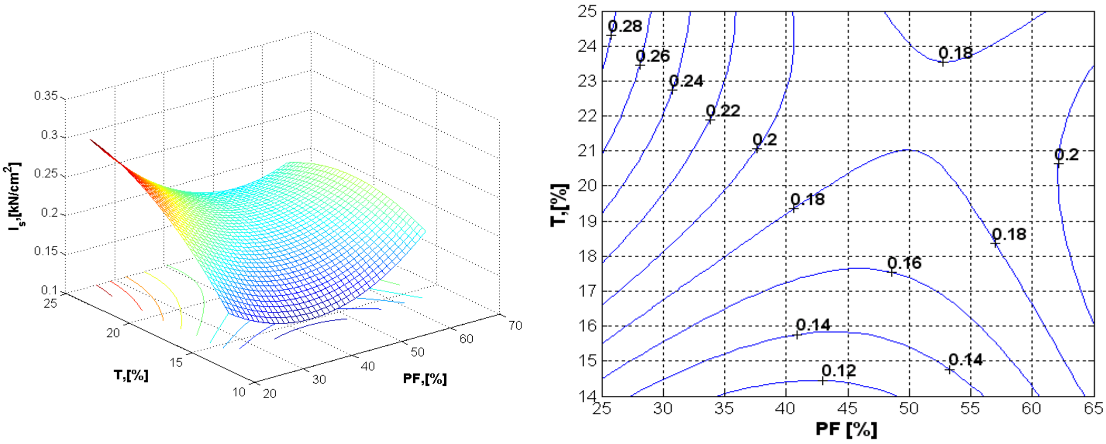

Figure 15. Crushing range of briquettes versus the percentages of dustfrom sinter plant & blast furnaces and scale

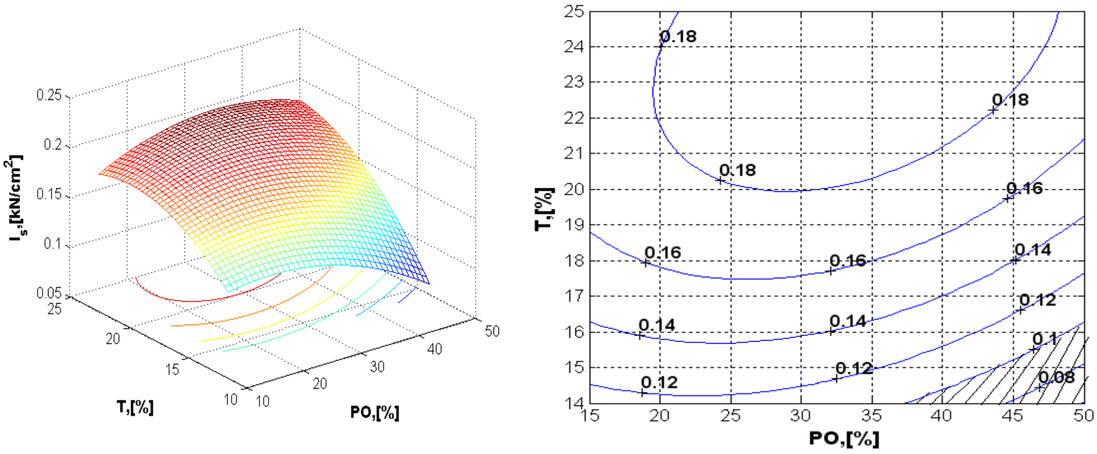

Figure 16. Crushing range of briquettes versus the percentages of dustfrom steel plant and scale

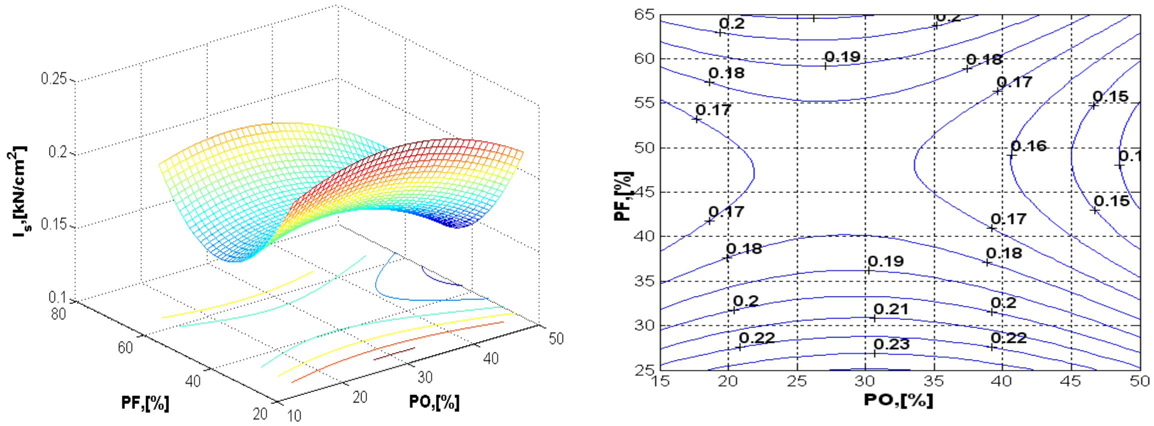

Figure 17. Crushing range of briquettes versus the percentages of dust from steel plant and blast furnaces

3. TECHNOLOGICAL ANALYSIS OF THE RESULTS

For a good behaviour in the process of handling and transportation, the literature [1, 2, 3] indicates, for the resistance to cracking, $R_f > 0.2$ kN/cm^2 (relation 6), and for the crushing strength $R_s > 0.3$ kN/cm^2 (relation 6.7). Regarding the crushing range, it is $I_s = \Delta R_{fs} = (0.2 - 0.35)R_f = (0.04 - 0.075)$, according to relation (5).

When analyzing the results, I considered, for a greater safety in the handling and transportation of the briquettes, to impose the following values for the strength properties: $R_f \geq 0.3$ kN/cm^2, $R_s \geq 0.4$ kN/cm^2, and $I_s \geq 0{,}1$ kN/cm^2.

Since we produced briquettes according to 5 recipes, in which the percentages of components with iron / iron & carbon varied, the technological analysis is presented separately for each recipe, taking into account either the results obtained in Excel calculation program or in MATLAB.

The results of the correlations obtained in EXCEL calculation program, led to the conclusion that the existing variation limits provided for the properties R_f, R_s and I_s higher values than those imposed as lower limit.The values obtained for the correlation coefficients confirmed their validity.

Regarding the double correlations, in most cases, for the variation limits of the load components, the values of resistance properties are higher than the imposed limits.The areas in which they do not fall are hachured; the values of independent parameters should vary so that the values of resistance properties to be always located within the unhachured area. For example, from the data shown in Figure 16, for the percentage of blast furnace dust of 5%, the scale content must be minimum 25%. For an increase in the steel plant dust content of 37–50%, the scale percentage must increase from 14% to more than 16% to obtain appropriate values for the crushing range. The other correlations shall be analysed similarly.

4. CONCLUSIONS

The following conclusions were drawn from those presented above:

- In the industrial processes, i.e. metallurgical and especially siderurgical, one or more secondary products (waste) are obtained in addition to the main product. The secondary products can, in terms of quality, be recycled in the iron & steel industry;
- The fine and powdery ferrous wastes, found in the western region of Romania (hence also in Hunedoara industrial area), the ones with basic character, as well as those with carbon content, can be reintroduced into the siderurgical economic circuit;
- The results obtained in the experiments lead to the conclusion that the analyzed wastes can be processed by briquetting (obtaining, for the mechanical strength properties, higher values than the minimum values associated with this process), this process allowing the recovery of waste materials with large variation limits in terms of grain size (desirable less than 2 mm);
- The recipe compositions will be determined based on the availability of fine and powdery waste and the final destination of the processed material (steel plant or blast furnaces);
- Under the locally existing conditions, due to a strong economic restructuring, a large amount of fine and powdery ferrous waste remained unused. Therefore, I consider necessary to intensify the recovery process of such wastes, mainly because they are a source of iron (scanty raw material), but also on technological considerations and, last but not least, ecological;
- I consider that either the waste routinely resulted from the process streams or those disposed in ponds and dumps can be successfully recovered.

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