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FERROUS WASTES RECOVERY POSSIBILITIES IN THE AREA OF STEEL INDUSTRY – EXPERIMENTS IN THE LABORATORY PHASE ON THE BRIQUETTES PRODUCTION FROM FINE AND PULVEROUS WASTES

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Abstract: *Life, in the form we all know, it exists because of air, water and earth, which are the main elements that underlie it. When one of these elements is disrupted by man and can no longer follow the natural cycles, the balance is destroyed, and we witness, without any right of reply, genuine environmental disasters. In the industrial sector, in most cases, in addition to the main product, there are one or more products which can be returned to the steel circuit after a quick processing. Reintroduction into the economic circulation of products/small and powdery ferrous wastes leads to reduction of water/air/soil pollution levels. Every tone of ferrous waste recovered and returned to steel production circuit leads to an economy of investments and operating costs. The paper approaches the problem of small and powdery wastes recovery from mining and steel industry in the western part of Romania. Research carried out shows that wastes can be used to produce pellets and briquettes.*

Keywords: *pollution, environment, steel industry, usage, wastes*

INTRODUCTORY NOTES REGARDING THE WASTES RECOVERY

Nowadays, among the main materials consumed worldwide (wood, steel, cement, and plastic), steel is in the first place and will still be there in the future. Steel and iron used as materials in many industrial fields, have the property to be recovered from manufactured products after their usage, regardless of period of time corresponding to those products´ life. During ferrous metallurgy processes by which iron ore is converted to steel (iron and steel) and continuing with the manufacturing processes of these products, there are different forms of iron and steel scrap that results, having the generic name ferrous scrap.

The steel industry uses large quantities of materials both in primary and secondary development process. The raw material used for primary development process in steel industry is iron ore [3-5,18,19].

By the late ´60s it began to develop the idea of nature and environmental protection on the premises that industrial development, raising the level of civilization and ensuring consumer's needs, all these, increasingly higher, lead to many forms of pollution.

The term `pollution` (to make dirty, to make impure) defines any action that, by itself or by its consequences, brings alteration to biological balances, influences negatively natural or/and artificial ecosystems having adverse consequences for economic activity, health and comfort of human species [7].

In most industrialized countries pollution of air, water and landscape has a common cause: discharge of manufacturing wastes in the environment without a real concern of avoiding it. Measures needed to combat pollution require considerable investment and significant operating expenses, especially in the steel industry.

For human communities and natural ecosystems in the steel industry and mining sites, pollution and risk do not disappear with the cessation of mining and processing of minerals, furthermore, it continues, the sites remain sources of pollution and risk.

The alteration of global ecosystems, because of consumption and production, shows how important is the process of rethinking the use of natural resources by the economy and society. For industry, the problem of managing the recovery (recovery, recycling) is an environmental and economic priority [1,4,10,20].

Industrial wastes include substances, materials, products, waste generated by industrial activity whose elimination from the production cycle is ensured through proper management, namely: recovery (conditioning) and/or storage for recycling; disposal, stabilization/ solidification (to store the final waste) or incineration.

Wastes contain substances resulting from industrial activity where they are produced and disposal of these wastes from the production cycle is achieved by a proper recovery: recovery and / or disposal for recycling and stabilization/solidification for storage in landfills [18,19].

Recovery includes the collection, transport, storage, selection and processing of certain waste; this waste can be returned to a flow sheet by internal and/or external recycling.

Internal recycling (direct recycling) consists of reintroducing the recovered industrial wastes in the same flow sheet that generated them, and external recycling (reuse) is the industrial activity that *reintroduces the recovered waste in a flow sheet that is completely different from the one which generated it.*

By combining economic imperative to maximize the recovery of scrap with the social aspect of action to combat environmental pollution in order to restore and maintain the ecological balance, a particular attention must be paid to waste recovery problem [7,9,12-22].

The flow of production in steel industry generates, on a continuous basis, wastes containing iron and carbon, in quantities directly proportional to the output. Within the manufacturing process, in addition to the main product there are sometimes secondary products, and there are always wastes: pulverous, small, large sizes, containing carbon, iron, alloying elements, and sometimes there are utile components for the formation and correction of the chemical composition of the slag, carbon powder.

Exploitation of iron ore deposits which are subjected to concentration operations, leads to obtaining fine grained iron concentrates which makes the process of agglomeration very difficult. Pulverous ferrous wastes can be processed by pelletizing and the fine and pulverous ones by agglomerating and briquetting.

MATERIALS / WASTES FROM THE STEEL INDUSTRY DESTINED TO THE BRIQUETTES PRODUCTION

From steel industry activities derive a wide range of wastes, that can be categorized as recyclable wastes (ferrous and nonferrous waste) and storable wastes, as well (slag, sludge, tar, oils). The flow of production in steel industry generates, on a continuous basis, wastes containing iron and carbon, in quantities directly proportional to the output [1,4]. On the platform of a steel mill virtually all sectors contribute to the pollution of at least one environmental factor.

Most frequent, ferrous scrap results from the steel industry while processing iron and steel, from industries where steel products are processed or used as such, and from the ferrous part recovery process. Ferrous scrap in the steel industry may be pulverous, deriving from exhaust gas treatment plant, from steel processes, or may be pieces, deriving from steel and iron making processes. Ferrous scrap can and should be reused, in their entirety, within steel industry. Every tone of ferrous scrap recovered and returned to steel production circuit leads to an economy of investments and operating costs.

Within the manufacturing process, in addition to the main product there are sometimes secondary products, and there are always wastes: pulverous, small, large sizes, containing carbon, iron, alloying elements, and sometimes there are utile components for the formation and correction of the chemical composition of the slag, carbon powder.

Ferrous materials, pulverous or mud, are generated from the exhaust gas and wastewater treatment plants within steel technological processes. Their collection is performed for ecological purposes, to avoid air and water pollution, and for economical purposes also, to capitalize their intrinsic value, in the form of raw material substitute of that obtained in the country or imported.

Rolled steel industry sector constitutes the most significant source of industrial water pollution because of scale (iron oxide) and oil in suspension resulted in the different cooling and cleaning operations that occur in the process of rolling. Thus, the waste water from rolling contain iron oxide particles - scale - an amount that can vary between 1 g/l for hot strip mills and heavy plate and 5 g/l in the case of oil skimmer mills.

Ferrous material, as reusable powder, is about 20 thousand tons, containing about 70% iron at 1 million tons of steel. In addition, there are iron oxides that occur during flame cleaning process applied to ensure the quality of semi-finished rolled surface [8].

Ferrous material, as pieces, represents the most important quantity within mill sector. It starts with oil skimmer rolling mills, (bloom or slab) it continues with semi-finished rolling mills, and it ends with finishing mills of flat products, profiles, pipes, wire, etc. In all these rolling mill sectors obtaining quality products requires removal by cutting of ends or sides, areas where frequently occur rolling defects.

Among the sources for the production of ferrous recyclable materials, some pulverous wastes containing iron have to be mentioned, wastes resulted within technological processes in other industries and which can be used in steel industry after a prior processing. These are: pyrite ashes and red mud/sludge. Pyrite ashes result from roasting pyrite in the production of sulphuric acid. There are different methods to extract non – ferrous metals and the waste which can constitute a ferrous agglomerate can be used for furnace load.

Red mud is a waste product generated in the industrial production of aluminum oxide from bauxite. Containment of these industrial wastes can cause great difficulties in terms of water pollution. Oily scale comes from former coke plant, after the removal of liquid and oily ammonia fraction coming from coal volatile components.

Romanian steel industry is currently experiencing technological gaps regarding the collection, transport, storage and, especially, the use of all categories of waste.

EXPERIMENTS IN THE LABORATORY PHASE ON THE BRIQUETTES PRODUCTION FROM FINE AND PULVEROUS WASTES

Based on the documentation in literature, this paper will describe one of these three methods, namely briquetting.

Briquetting is the method by which pieces of spherical, oval or rectangular forms are obtained from fine/small and pulverous waste during compressing operations on specialized equipment, followed by a drying-roasting process in order to increase their mechanical characteristics [12-22].

Briquetting applies to pulverous wastes (powder resulting from dedusting plants) and also to fine products obtained by precipitation. For waste briquetting (at 50-60^{0}C) inorganic binders are used (limewash, Na_2SiO_3) and sometimes organic binders (sulphite liquor, heavy tars, etc.) Briquetting operation consists of:

- *preparation, mixing and homogenizing waste with binder to ensure optimum moisture and granulation;*
- *compression of the mixture;*
- *hardening;*
- *transport and storage of briquettes.*

Mixing and homogenization of the mixture is performed in mixture drums, screw mixers, paddle mixers. Compression is performed on presses with rotating cylinders and piston presses. Hardening is performed by cooling and sintering.

Experiments on the production of briquettes were conducted within the laboratory of the Doctoral School of the Faculty of Engineering Hunedoara, University Politechnica Timişoara. Determination of waste chemical composition was carried out in the laboratories of ArcelorMittal SA Hunedoara Company.

To obtain briquettes, the raw material is subjected to fine grinding, which usually is performed in ball mills. Wastes which are substandard in terms of grain size are ground with these mills. Recipes with pulverous wastes are prepared. Homogenization of waste is done manually or in mixing plant with the addition of binders, and to obtain briquettes, the press is equipped with a mold chosen in accordance with the type of desired briquette. The proportions of waste were determined in 4 recipes, compliance with these recipes is mandatory in order to obtain briquettes with appropriate quality standards [10,11,14,17,19].

Recipes composition and chemical composition of briquettes obtained were displayed in Table 1 and Table 2 [10,11]. Once the briquettes are obtained, they are subjected to hardening processes after a diagram heating/holding/cooling, and then dried and tested to determine the qualitative characteristics (compression tests to determine resistance to cracking, crushing and grinding interval).

For recovery of small and pulverous wastes as briquettes from steel industry, energy and mining, we considered the following wastes: dust from electric steel mill, dirt (sludge) from agglomeration–furnaces, scale (scale slurry) and as binder: limewash, bentonite, cement [10,11,17].

Table 1. Composition recipes (%)

Nr. crt.	Waste used	Composition recipes (%)			
		R1	R2	R3	R4
1.	Sintering furnace dust	25	35	40	50
2.	Steel mill dust	50	35	25	24
3.	Scale	14	19	25	15
4.	Bentonite	3	3	3	4
5.	Limewash	3	3	3	3
6.	Graphite powder	5	5	4	4

Table 2. Chemical composition of lighters (%)

Number recipe	Chemical composition (%)					
	SiO_2	FeO	Fe_2O_3	P_2O_5	S	C
R1	5.02	3.60	63.81	0.18	0.28	9.33
R2	5.70	4.44	57.27	0.14	0.39	11.10
R3	6.01	5.09	54.78	0.12	0.44	11.00
R4	7.51	5.06	48.79	0.13	0.56	11.79
	Al_2O_3	CaO	MgO	MnO	Other oxizes	
R1	2.33	5.36	0.67	2.60	6.84	
R2	3.00	6.13	0.85	2.03	8.95	
R3	3.33	6.51	0.94	1.66	10.13	
R4	4.16	7.39	1.15	1.64	11.83	

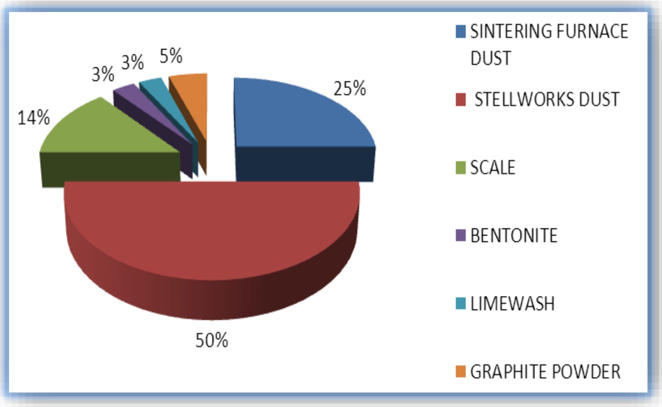

Figure 1. Composition of recipe R1

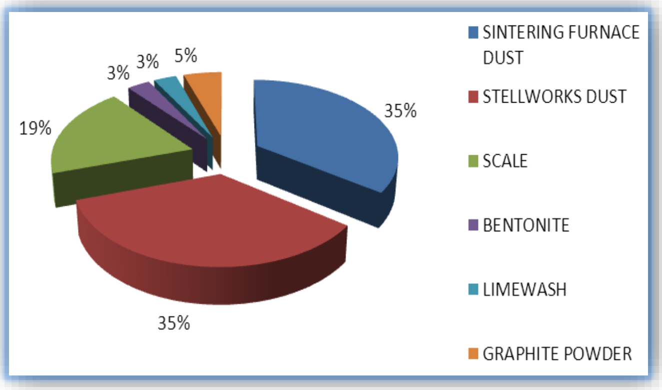

Figure 2. Composition of recipe R2

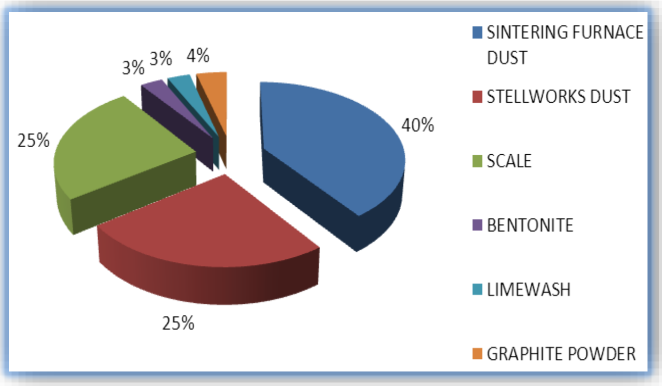

Figure 3. Composition of recipe R3

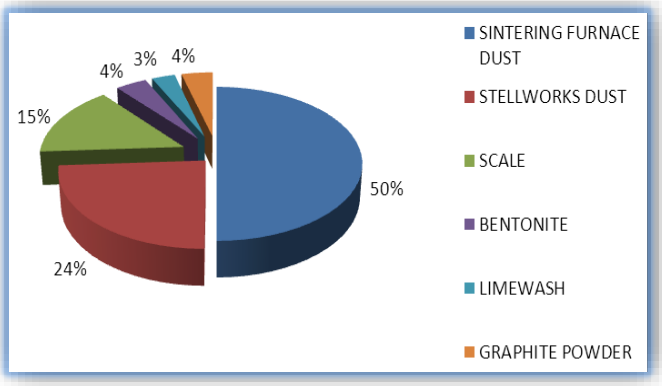

Figure 4. Composition of recipe R4

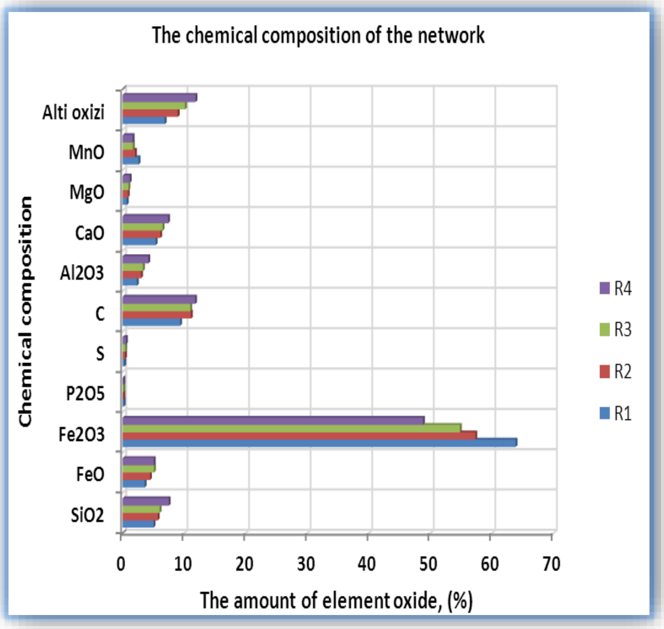

Figure 5. The chemical composition of recipes

For the determination of the quality characteristics were determined the resistance to cracking and crumbling, respectively, were also calculated between experimental crushing briquettes.

With the data obtained, we conducted several dependencies that demonstrates the influence of the composition of briquetting load on these indicators. A number of correlations are shown in the figures 6-26, so we plotted the variation in resistance to cracking, crushing and milling the respective range according to the proportion of the electric steelmaking dust, dirt (sludge) from the cluster, and that the scale furnaces. Analyzing these diagrams, it is found that the optimum proportion of the steel dust varies between 30-50%, powder-sintering furnaces 25-40% and 18-24% of scale.

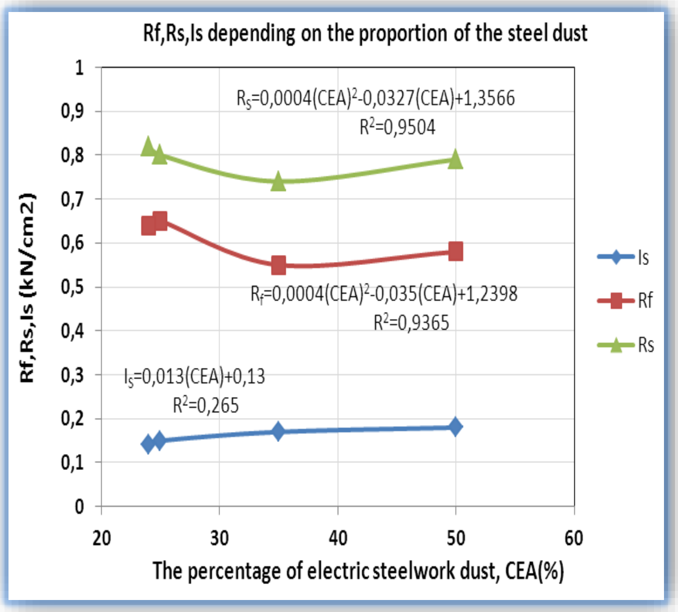

Figure 6. Resistance to cracking, crushing and milling range, depending on the proportion of electric steelwork dust, CEA

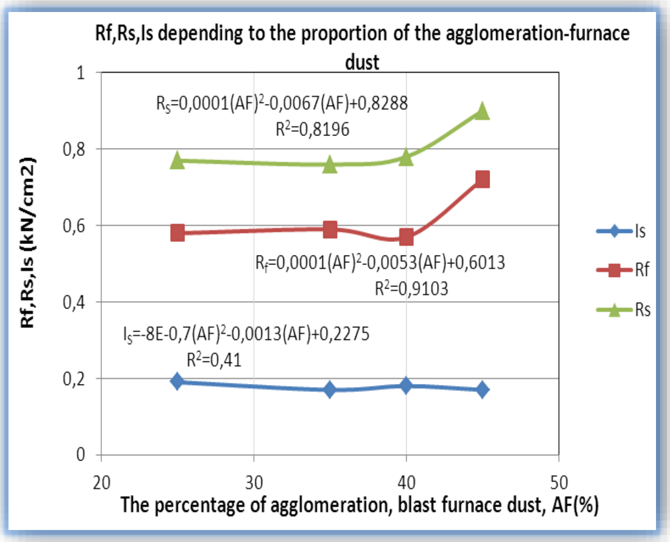

Figure 7. Resistance to cracking, crushing and milling range, depending on the proportion of agglomeration, blast furnace dust AF

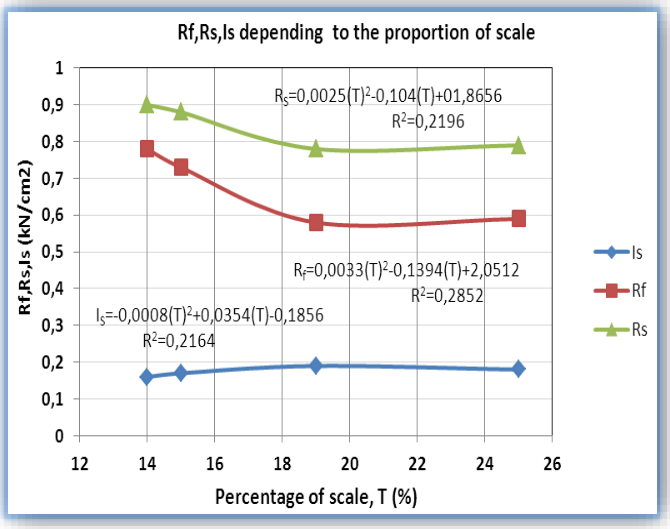

Figure 8. Resistance to cracking, crushing and milling range, depending on the proportion of the proportion of tunder

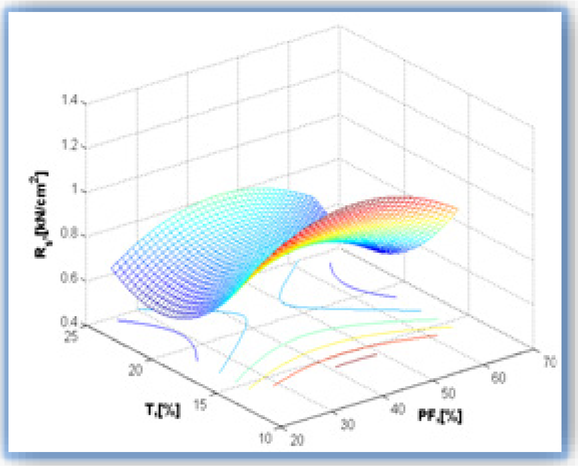

Figure 9. Resistance to cracking depending on the proportion of agglomeration, blast furnace dust AF of tunder (the regression surface)

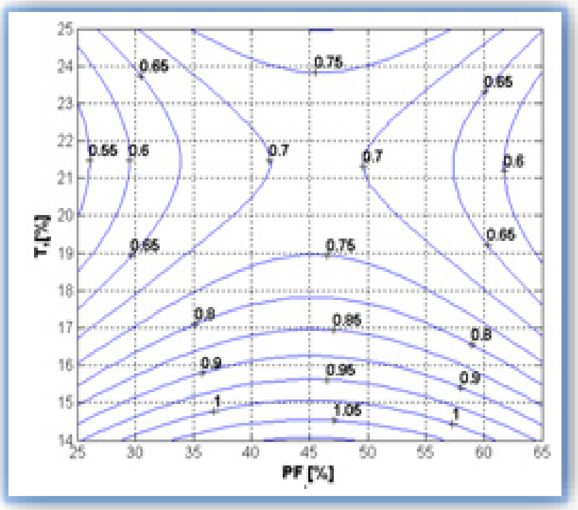

Figure 10. Resistance to cracking depending on the proportion of agglomeration, blast furnace dust AF of tunder (the correlation diagram)

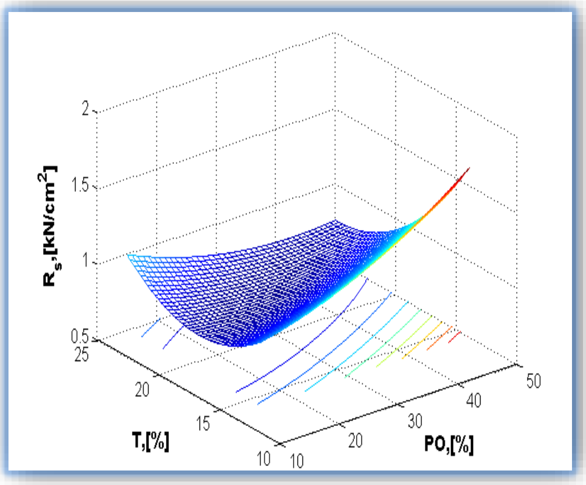

Figure 11. Resistance to cracking depending on the proportion of electric steelwork dust, CEA of tunder (the regression surface)

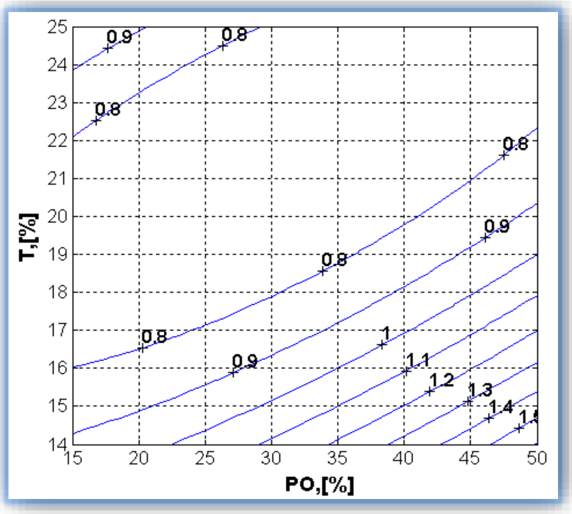

Figure 12. Resistance to cracking depending on the proportion of electric steelwork dust, CEA of tunder (the correlation diagram)

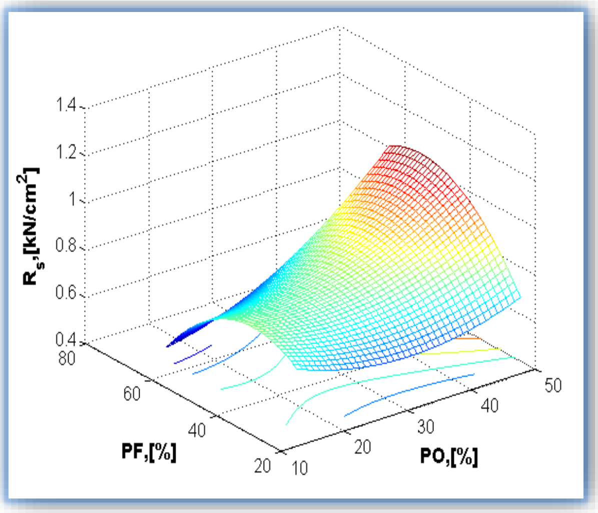

Figure 13. Resistance to cracking depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the regression surface)

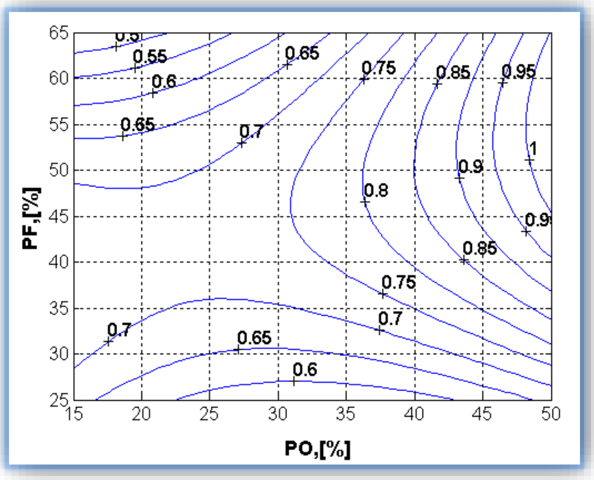

Figure 14. Resistance to cracking depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the correlation diagram)

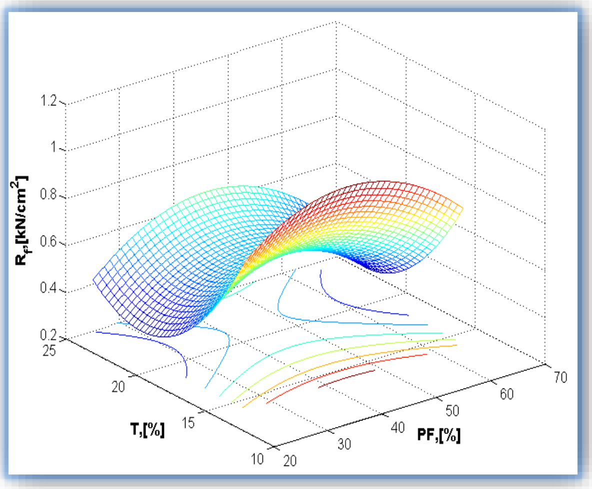

Figure 15. Resistance to crushing depending on the proportion of agglomeration, blast furnace dust AF of tunder (the regression surface)

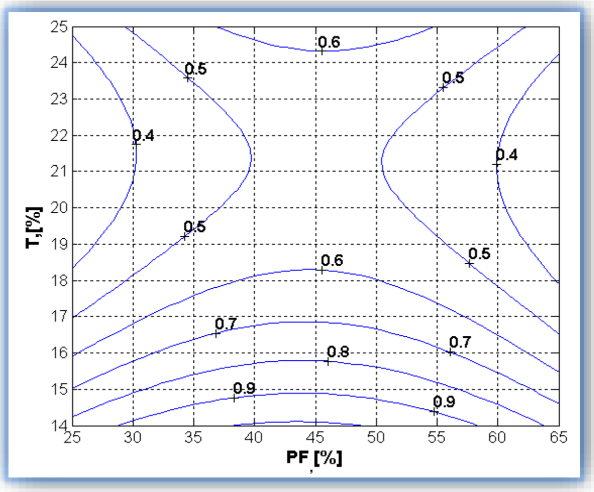

Figure 16. Resistance to crushing depending on the proportion of agglomeration, blast furnace dust AF of tunder (the correlation diagram)

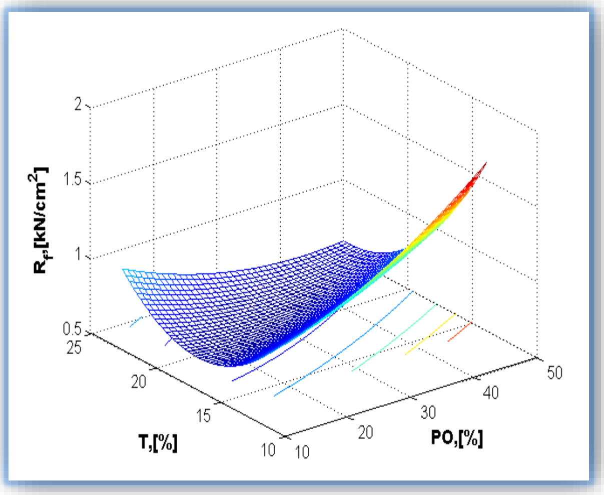

Figure 17. Resistance to crushing depending on the proportion of electric steelwork dust, CEA of tunder (the regression surface)

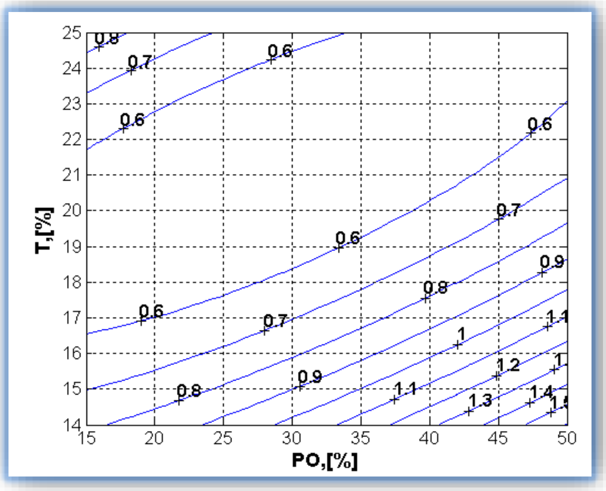

Figure 18. Resistance to crushing depending on the proportion of electric steelwork dust, CEA of tunder (the correlation diagram)

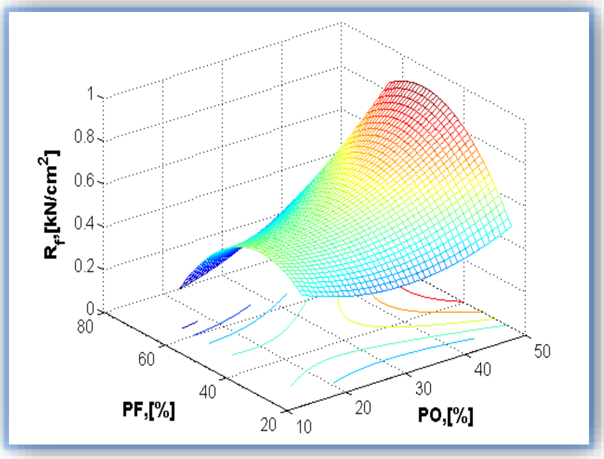

Figure 19. Resistance to crushing depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the regression surface)

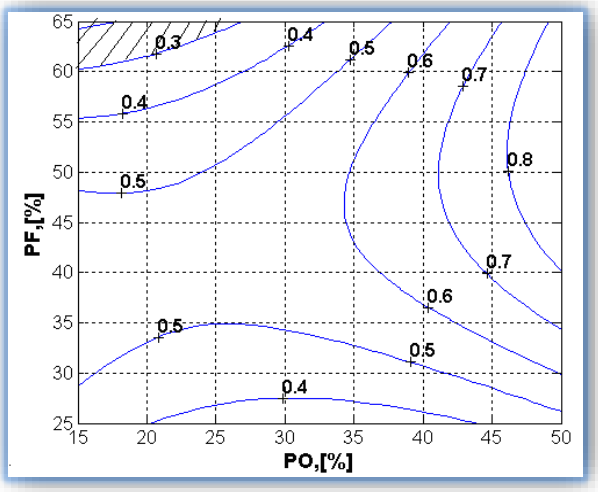

Figure 20. Resistance to crushing depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the correlation diagram)

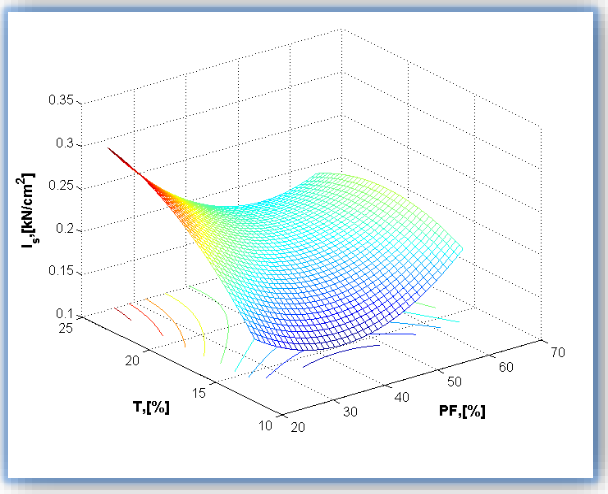

Figure 21. Resistance to milling range depending on the proportion of agglomeration, blast furnace dust AF of tunder (the regression surface)

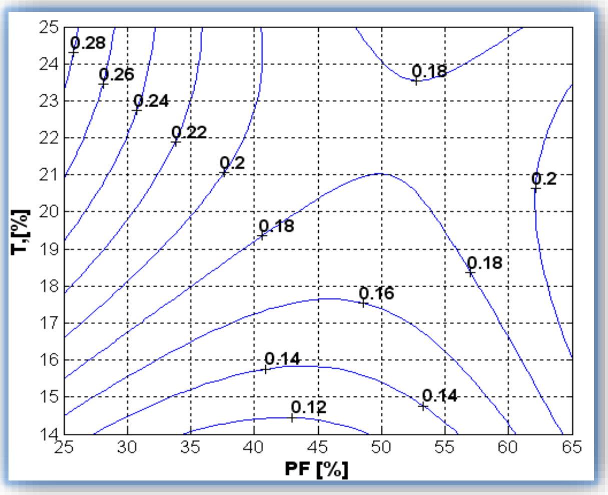

Figure 22. Resistance to milling range depending on the proportion of agglomeration, blast furnace dust AF of tunder (the correlation diagram)

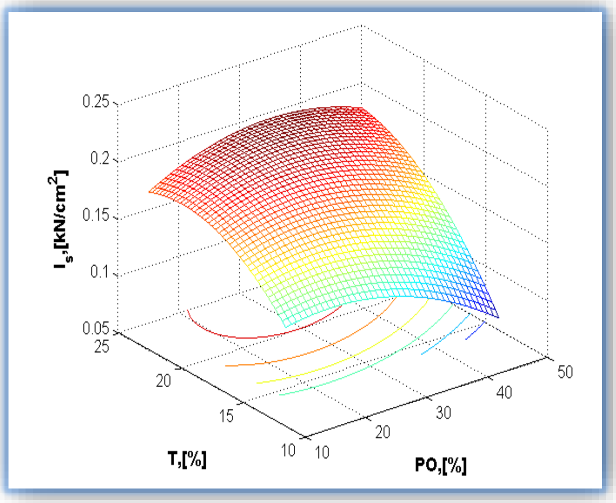

Figure 23. Resistance to milling range depending on the proportion of electric steelwork dust, CEA of tunder (the regression surface)

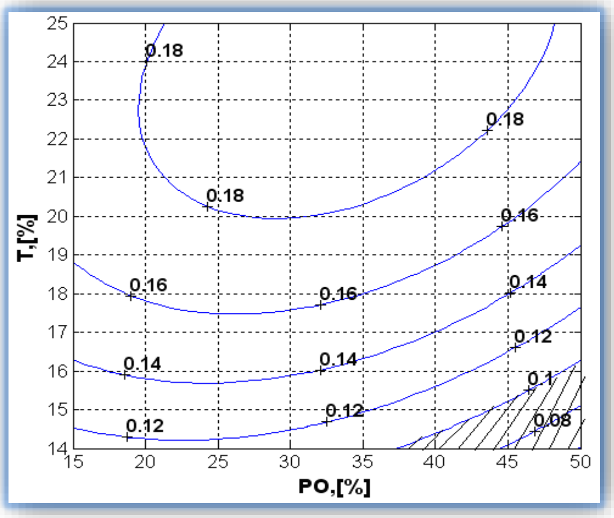

Figure 24. Resistance to milling range depending on the proportion of electric steelwork dust, CEA of tunder (the correlation diagram)

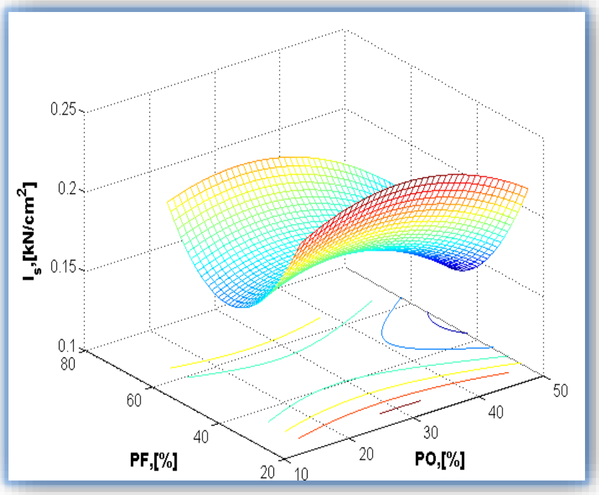

Figure 25. Resistance to milling range depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the regression surface)

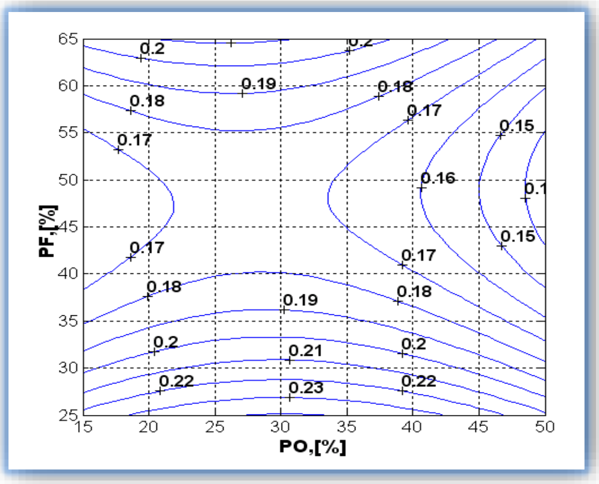

Figure 26. Resistance to milling range depending on the proportion of agglomeration, blast furnace dust AF of electric steelwork dust, CEA (the correlation diagram)

CONCLUSIONS

The paper presents results of research on the strength of briquettes from recycled materials, research conducted to acknowledge:

- *alteration of briquettes resistance in accordance with quantity of waste used for recipe preparation;*
- *influence upon resistances of some chemical compounds from materials recovered by briquetting.*

As a result of analyses performed on products obtained by processing small and pulverous wastes from industrial steel and mining areas and the experiments conducted in the laboratory stage, we consider the following:

- *wastes studied in the experiments can be processed by using the available technologies and can be reintroduced into the steel circuit with minimum investment costs;*
- *reintroduction of wastes into economic circuit has both economic and ecological effects, by releasing the occupied terrains (ponds,*

landfills, disused buildings) in case of deposited wastes, vacancy of areas for waste resulting routinely on technology flows.

≡ *the results of the experiments lead to the conclusion that the analyzed wastes can be processed by briquetting (to provide mechanical strength characteristics superior to those minimum values for this method), this method allows recovery of waste with high variation limits in terms of grain size (desirably under 2mm);*

Taking into consideration the existing local conditions, as a result of the strong economic restructuring, a large amount of pulverous and small ferrous wastes remained, it is necessary to intensify the wastes recovery process, both because it represents a source of iron, poor raw material, and because of technological and ecological considerations. We consider that can be processed both the wastes resulted in technological flows and those deposited in ponds or landfills.

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