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THE Datafit ANALYSIS OF SMALL AND POWDERY FERROUS WASTES DESTINED FOR THE PRODUCTION OF BRIQUETTES IN SOME LABORATORY EXPERIMENTS

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Abstract: From steel industry activities derive a wide range of wastes, that can be categorized as recyclable wastes (ferrous and nonferrous wastes) and storable wastes, as well (slag, sludge, tar, oils). 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. Reintroduction into the economic circulation of products of small and powdery ferrous wastes (fine and pulverous ferrous wastes) lead 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 fine and pulverous wastes recovery from mining and steel industry. In fact, our research carried out shows that wastes can be used to produce briquettes.

Keywords: pollution, environment, steel industry, usage, wastes, briquetting, the Datafit analysis

INTRODUCTION

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 [1,2,10,11,13]. 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.

From steel industry activities derive a wide range of wastes, that can be categorized as recyclable wastes (ferrous and nonferrous wastes) and storable wastes, as well (slag, sludge, tar, oils). 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. 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 (powdery), small (fine) or large sizes, containing utile components like carbon, iron and alloying elements. Ferrous scrap can and should be reused, in their entirety, within steel industry. In fact, the pulverous ferrous wastes can be processed by pelletizing and the fine and pulverous ones by agglomerating and briquetting technologies. Every tone of ferrous scrap recovered and returned to steel production circuit leads to an economy of investments and operating costs. Romanian steel industry is currently experiencing technological gaps regarding the collection, transport, storage and, especially, the use of all categories of waste.

LABORATORY EXPERIMENTS

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 [5–13].

Briquetting applies to pulverous wastes (powder resulting from dedusting plants) and also to fine products obtained by precipitation. For waste briquetting (at 50–60°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 Politehnica Timişoara. Determination of waste chemical composition was carried out in the laboratories of ArcelorMittal 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 wastes were determined in 13 recipes, compliance with these recipes is mandatory in order to obtain briquettes with appropriate quality standards [5–13].

Recipes composition and chemical composition of briquettes obtained were displayed in Table 1 and Table 2, respectively in Table 3 and Table 4, [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: agglomeration–furnaces dust, steel dust, galvanic sludges (two different types) and red mud from bauxite refining (bauxite residue). As binder for the manufactured briquettes we considered the following three types of powdery materials: limewash, bentonite and graphite [5,6,10–13].

Table 1. The used wastes and the composition of briquetting recipes (%) – Recipes R1 – R6

Wastes type	Composition of briquetting recipes, [%]					
	R1	R2	R3	R4	R5	R6
Steel dust (P.O.)	40	36	33	30	27	24
Agglomeration–furnaces dust (P.A.F.)	30	33	36	39	42	45
Galvanic sludge 1 (N.G.–O)	2	2	3	4	5	6
Galvanic sludge 2 (N.G.–B)	8	9	7	7	6	4
Red mud from bauxite refining (N.R.)	10	10	10	10	10	10
Graphite powder (G)	2	2	2	2.5	2.5	3
Bentonite powder (B)	4	4	3.5	3.5	3.5	3
Limewash powder (V)	4	4	4.5	4	4	4

Table 2. The used wastes and the composition of briquetting recipes (%) – Recipes R7 – R13

Wastes type	Composition of briquetting recipes, [%]						
	R7	R8	R9	R10	R11	R12	R13
Steel dust (P.O.)	20	17	15	13	8	5	2
Agglomeration–furnaces dust (P.A.F.)	48	51	54	57	60	63	66
Galvanic sludge 1 (N.G.–O)	7	5	6	6	5	7	8
Galvanic sludge 2 (N.G.–B)	5	6	5	4	7	5	4
Red mud from bauxite refining (N.R.)	10	10	10	10	10	10	10
Graphite powder (G)	3	3.5	3.5	4	4	4.5	4.5
Bentonite powder (B)	3	3	2.5	2.5	2.5	2	2
Limewash powder (V)	4	3.5	4	3.5	3.5	3.5	3.5

Table 3. Chemical composition of the recipes, (%) – Recipes R1 – R6

	R1	R2	R3	R4	R5	R6
Fe_2O_3	37.16	40.26	39.66	36.47	40.08	36.10
SiO_2	16.95	17.52	15.70	19.30	18.29	18.01
ZnO	10.82	8.47	8.56	9.54	8.42	9.76
CaO	10.56	9.42	10.64	9.92	11.23	11.62
Al_2O_3	7.16	7.40	10.14	8.55	7.68	6.1
Na_2O	4.10	4.80	3.75	4.66	3.80	5.16
MgO	2.47	2.13	2.04	2.19	2.27	1.41
MnO	1.63	1.28	1.37	1.44	1.41	1.13
P_2O_5	1.54	1.87	1.18	1.21	1.21	1.10
Other oxides	7.6	6.8	6.9	6.7	5.6	9.6

Table 4. Chemical composition of the recipes, (%)– Recipes R7 – R13

	R7	R8	R9	R10	R11	R12	R13
Fe_2O_3	39.20	43.15	33.57	38.42	40.02	34.73	36.02
SiO_2	18.58	17.28	16.84	16.52	18.68	11.15	10.37
ZnO	8.40	9.13	9.47	8.76	5.81	16.99	16.73
CaO	10.32	11.56	11.08	10.96	9.56	7.57	7.44
Al_2O_3	9.14	8.14	8.33	7.54	7.26	2.80	2.43
Na_2O	7.23	4.13	4.20	5.32	6.12	7.33	7.67
MgO	1.57	1.15	2.08	1.89	2.37	2.60	2.56
MnO	1.08	1.04	1.33	1.62	1.13	2.20	2.14
P_2O_5	1.93	1.34	1.45	1.28	3.11	2.41	2.53
Other oxides	2.55	3.08	11.65	7.69	5.9	12.0	12.0

The quality characteristics the resistance to crushing and the resistance to cracking of obtained briquettes, are calculated. With the data obtained, we conducted several dependencies that demonstrates the influence of the composition of briquetting load on these indicators, using Datafit and Matlab programs.

Firstly, in our mathematical analysis, we plotted in Datafit program the variation in resistance to cracking and resistance to crushing of obtained briquettes, according to the proportion of the small and pulverous wastes used in the recipes (steel dust, agglomeration–furnaces dust, galvanic sludges). The obtained mathematical correlations, the regression equations (polynomial regression model type:

$$y = a + b\cdot x1 + c\cdot x12 + d\cdot x13 + e\cdot x14 + f\cdot x15 + g\cdot x2 + h\cdot x22 + i\cdot x23 + j\cdot x24 + k\cdot x25)$$

and the regression surfaces are shown in the Figures 1–6. Conveniently, these models are all linear from the point of view of estimation, since the regression function is linear in terms of the unknown parameters a, b, ...

Therefore, for least squares analysis, the computational and inferential problems of polynomial regression can be completely addressed using the techniques of multiple regression, done by treating x, x2, ... as being distinct independent variables in a multiple regression model.

RESULTS OF THE Datafit ANALYSIS

DataFit is a simple and efficient science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis. The data were processed in DataFit programs to obtain correlations between the main characteristic of the obtained briquettes – resistance to crushing and resistance to cracking – and the proportion of components in the recipe (small and pulverous wastes quantities).

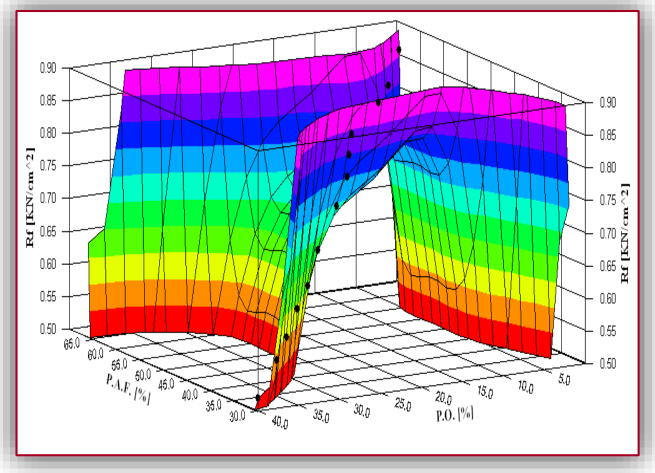

Figure 1. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9996349716, the polynomial regression equation coefficients are: a=–205.6158; b=23.8851; c=–1.0830; d=0.02397; e=–0.0002; f=1.1140; g=0.7284; h=–0.0802; i=0.0041; j=–0.0001; k=9.2884)

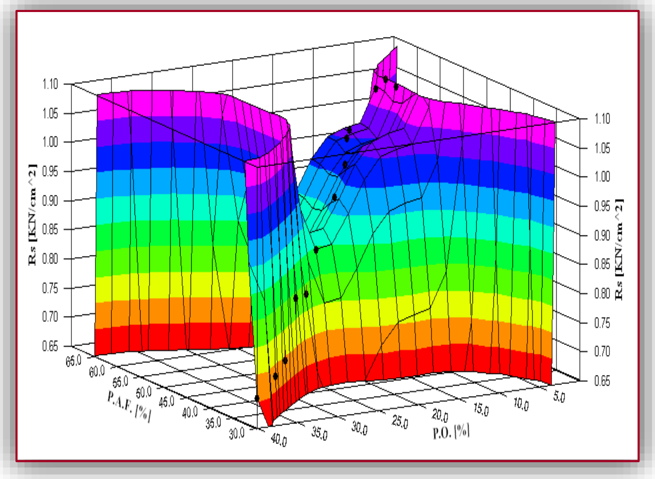

Figure 2. The regression surface determined by the briquettes resistance to cracking depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9920884722, the polynomial regression equation coefficients are: a=440.0762; b=–51.3919; c=2.3642; d=–0.0530; e=0.0006; f=–2.5292; g=–1.9088; h=0.2059; i=–0.0105; j=0.0002; k=–2.2424)

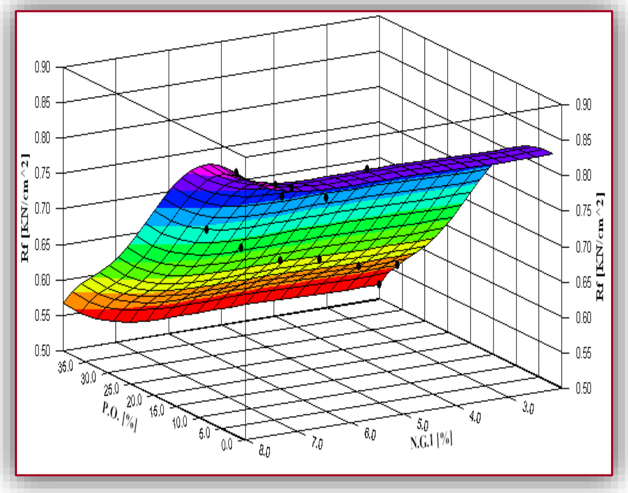

Figure 3. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9996578109, the polynomial regression equation coefficients are: a=0.8178; b= –0.0009; c=0.0004; d=–0.0001; e=2.4959; f=–2.6265; g=0.0215; h= –0.0186; i=0.0065; j=–0.0010; k=0.0001)

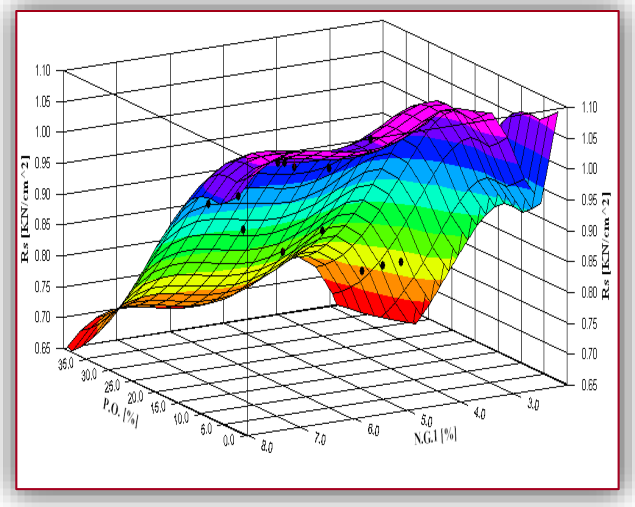

Figure 4. The regression surface determined by the briquettes resistance to cracking depending on the proportion ofsteel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9975716124, the polynomial regression equation coefficients are: a=18.0641; b=2.3436; c=–2.8285; d=1.5497; e=–0.3915; f=0.0364; g=–70.6418; h=107.5958; i= –78.7594; j=27.8951; k=–3.8446)

The accuracy of DataFit has been verified with the Statistical Reference Datasets Project of the National Institute of Standards and Technology (NIST). DataFit is a science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis. With the combination of the intuitive interface, online help and wide range of features, it is a tool that is used effectively by both engineers and scientists.

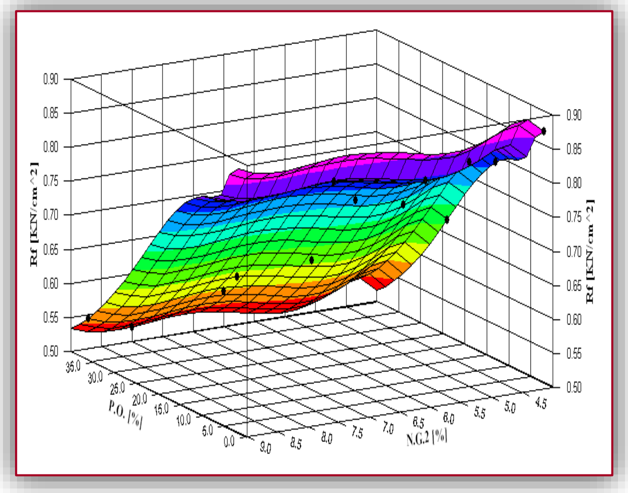

Figure 5. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9999509001, the polynomial regression equation coefficients are: a=–244.5798; b=2.6814;c= –3.0316; d=1.5452; e=–0.3655; f=0.0321; g=693.4561; h=–780.7115; i=436.4224; j=–121.1669; k=13.3702)

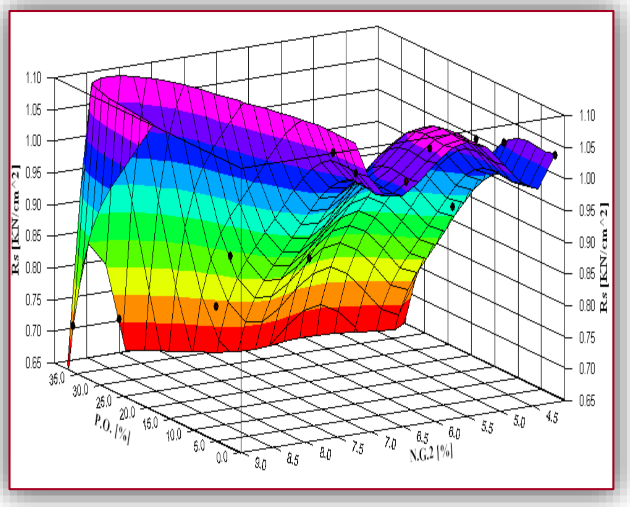

Figure 6. The regression surface determined by the briquettes resistance to cracking depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9968434407, the polynomial regression equation coefficients are: a=116.5405; b=–0.0161;c=0.0036; d=–0.0003; e=0.0001; f=–1.2262; g=–101.6929; h=35.1393; i=–5.9538; j=0.4944; k=–0.0161)

CONCLUSIONS

Waste recycling represents one of the economic solutions of environment ecology. In this sense the group of authors has made a series of experimentations regarding their transformation in used products in the iron-and-steel industry.

To obtain the products in forms of briquettes many series of receipts have been tested and according to qualitative characteristics of the obtained products the processing receipts have been chosen.

The data obtained has been processed in Datafit program, which that allowed the establishing of optimal domains of variations of the technological parameters in view of obtaining some products with superior technological characteristics.

The paper presents results of research on the strength of briquettes obtained from recycled ferrous wastes – through resistance to crushing and the resistance to cracking –, research conducted to acknowledge the following two technical problems:

- the alteration of the experimental briquettes resistance, in accordance with the quantity of various ferrous wastes (steel dust, agglomeration–furnaces dust, galvanic sludges) used for the experimental recipes preparation;
- the influence upon the 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:

- the studied small and pulverous wastes (steel dust, agglomeration–furnaces dust, galvanic sludges) can be processed by using the available technology like briquetting and can be reintroduced into the steel circuit with minimum investment costs;
- reintroduction of small and pulverous 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.

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.

For Romania the recovery of ferrous wastes represents a priority for the durable development strategy because the natural resources of some raw materials categories are poor or insufficient and the resources can substitute part of the raw materials with significant low costs.

Comparatively with the practice and the world wide manifested tendencies, the Romanian industry registers gaps in the powder wastes collection, transportation and storage area, as well as in that of the recovery technologies area by their recycling or reusing. Thereby, the approach of the superior recovery of small and powder ferrous wastes problem was considered necessary and convenient.

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