Research on quality of pellets

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Abstract:—Besides the humidity, the granulometric composition and the specific surface of the pelleted material, the compressive strength of the pellets is also influenced by some additions with binding proprieties (bentonite, lime, limestone, dolomite, etc.). During the hardening process, these additions form a resistant slag that contributes to the binding of the granules of ferrous raw materials and, finally, to the increasing of the compressive strength of the pellets. The paper presents the results of the laboratory experiments on the production of pellets by using secondary materials (steel plant dust, sludge from sintering and blast furnace plants, red mud, etc.) as raw materials, and lime/dolomite as a binder along with the bentonite.

Key-words:-pellets, compressive strength, bentonite, lime, dolomite, binder, steel plant dust

I. INTRODUCTION

To determine the influence of the addition of lime and dolomite on the compressive strength of pellets, we performed a series of experiments in the laboratory phase, consisting of the production of pellets based on various recipes, by adding bentonite and lime or bentonite and dolomite, as in Table I.

Table I. Recipe for pelletising

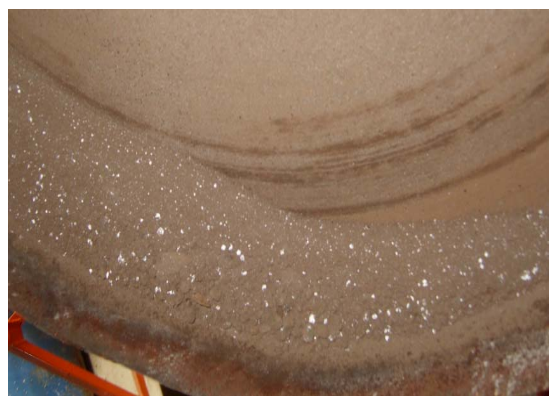
Set	Lot	Set	Lot	Remarks
A	**A1** with 1% lime	B	**B1** with 1.5% dolomite	In each set, the addition of bentonite ranged between 0 and 1% (i.e. 0%; 0.5% and 1%), and the addition of water ranged between 7.5 and 11.5%, (i.e. 7.5%, 9.5% and 11.5%)
	A2 with 3% lime		**B2** with 3.5 dolomite	
	A3 with 5% lime		**B3** with 5% dolomite	

II. PROBLEM FORMULATION

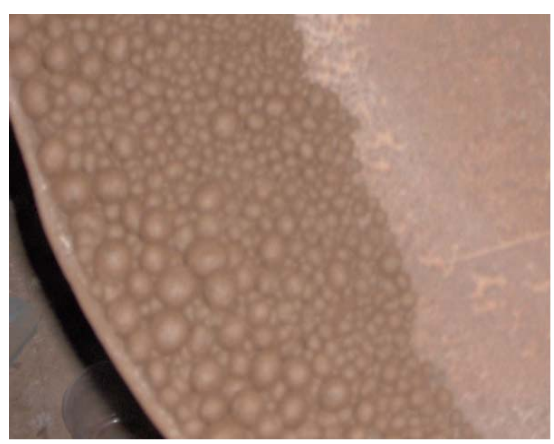
The experiments regarding the producing of pellets were performed in the laboratory "Energy and raw material base in industry", at the Engineering Faculty of Hunedoara. This laboratory is endowed with the installations required for producing pellets (volumetric ranking device, mixing drum, pellet making machine and hardening installation). The compression resistance has been determined by using the tension-compression test machine found in the "Strength of materials" laboratory of the faculty. The raw material used to produce pellets consisted of steel plant dust and red mud (resulted from alumina production). The compositions are presented in Table 1. We produced two sets of pellets, each set consisting of 3 lots.

Pellet production process and equipment used are illustrated in the figures below.

(a)



(b)



(c)

(d)

Fig.1. pellet production process and equipment: (a). introduction mixture, (b). formation of small pellets, (c). final form of raw pellets, (d). raw pellets hardening by firing in the kiln

(a)

(b)

(c)

Fig.2. facillities and equipment used during the laboratory experiments: (a). pellets making machine, (b).balance Sartorius ,(c). volumetric ranking device

The weight of the pellet batch was 2 kg (ferrous raw material, bentonite, lime/dolomite). The hardening of the pellets respected the combustion diagram of hematite ferrous materials [1,2] . From each batch, we selected three pellets to determine their compression resistance, [3]. To establish the correlations, we took into account the average value. By processing the data obtained in the laboratory phase, we obtained equations of correlation between the binder additives and water (considered as independent parameters) and the pellet compression resistance (considered as dependent parameter). The data were processed in Excel and MATLAB programs, the results being presented hereunder, in graphical and analytical forms.

III. PROBLEM SOLUTION

The correlations obtained by processing the data in the Excel program are presented in Figs. 1-9, in graphical and analytical forms, and the correlations obtained by processing the data in the Matlab program are presented in graphical form in Figs. 10-15. Analyzing these correlations, we could establish the optimum domains for the flux, bentonite and water additions, in order to obtain higher pellet compression resistance values in case of flux addition, [5].

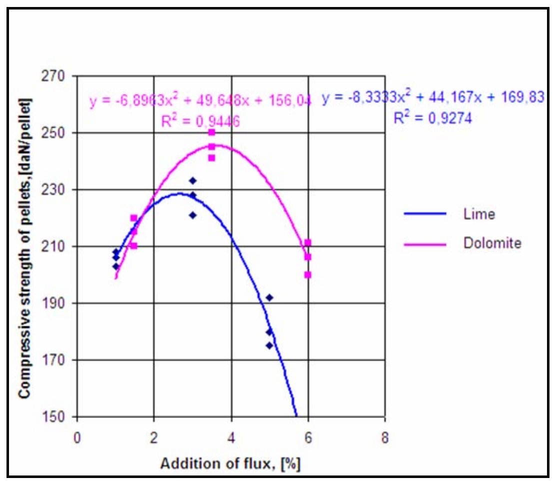


Fig.3.variation of compressive strength of pellets (7. 5 % water, 1% bentonite)

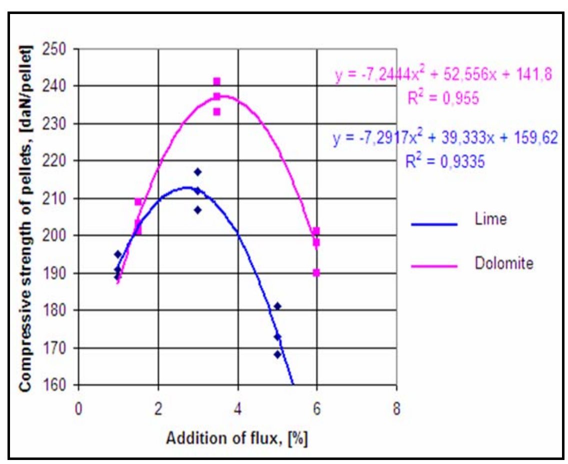


Fig.4.variation of compressive strength of pellets (7. 5 % water, 0. 5% bentonite)

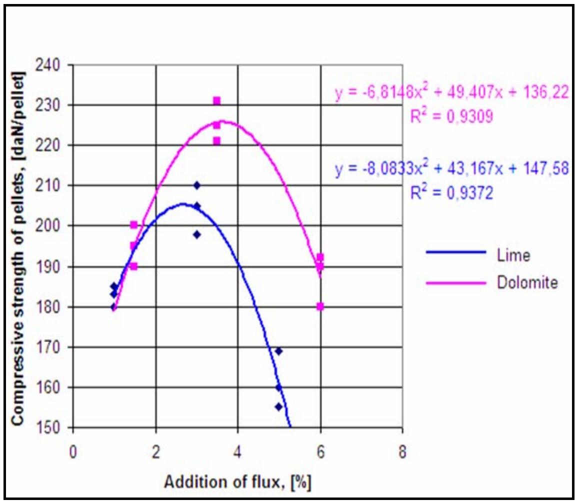


Fig.5.variation of compressive strength of pellets (7. 5 % water, 0.% bentonite)

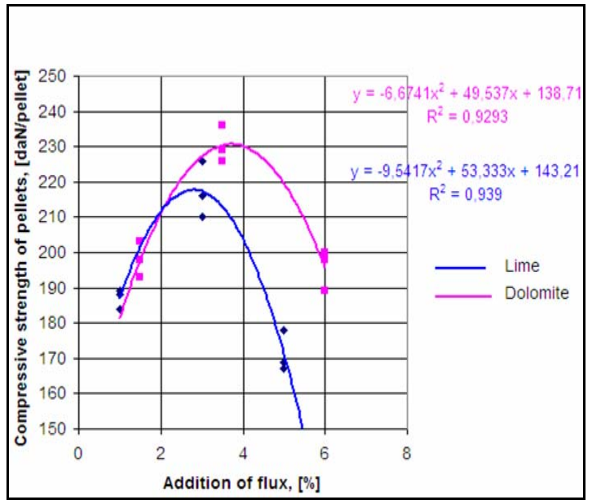


Fig.8.variation of compressive strength of pellets (9. 5 % water, 0% bentonite)

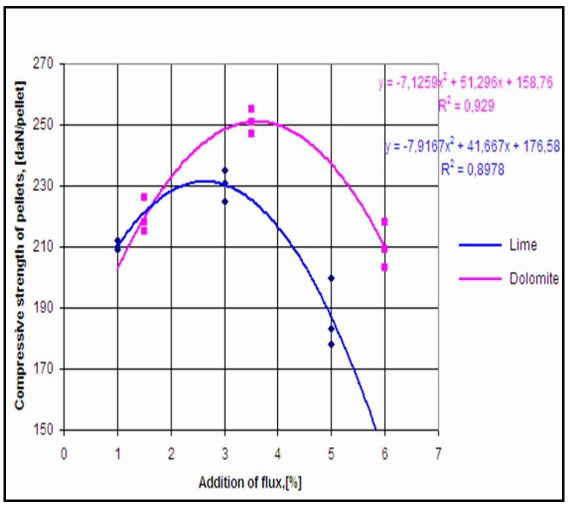


Fig.6.variation of compressive strength of pellets (9. 5 % water, 1% bentonite**)**

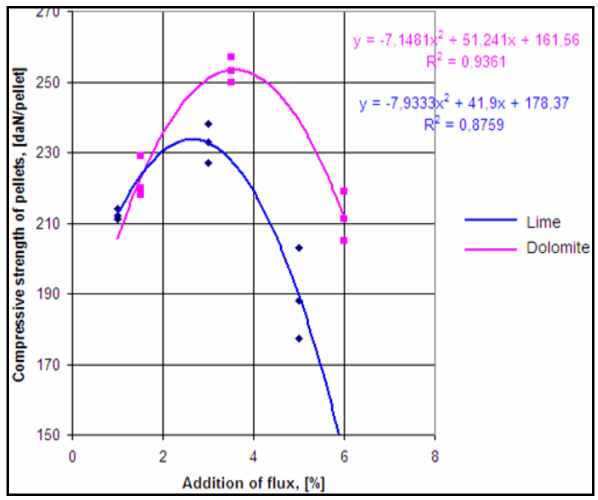


Fig.9. variation of compressive strength of pellets 11. 5 % water, 1% bentonite**)**

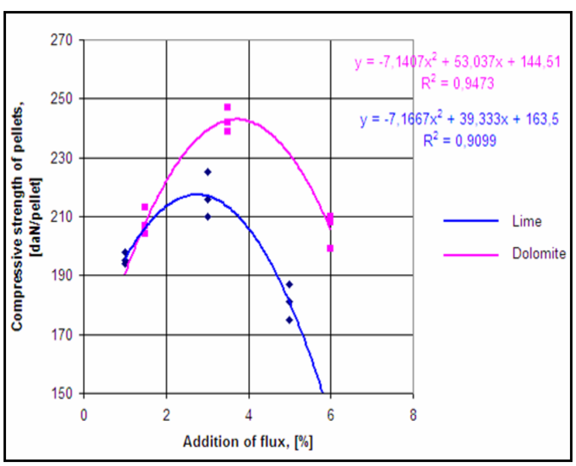


Fig.7.variation of compressive strength of pellets (9. 5 % water, 0. 5% bentonite)

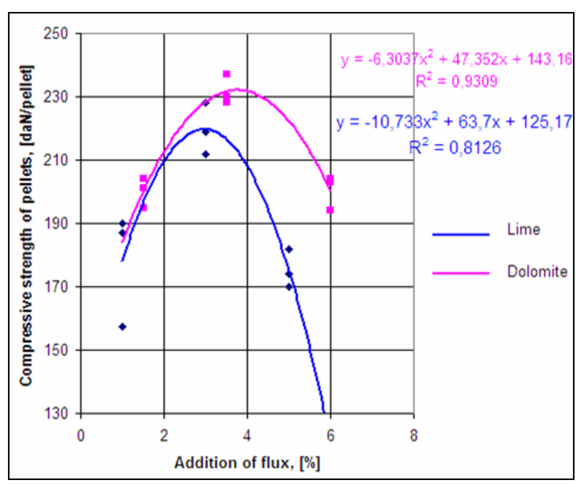


Fig.10.variation of compressive strength of pellets (11. 5 % water, 0. 5% bentonite)

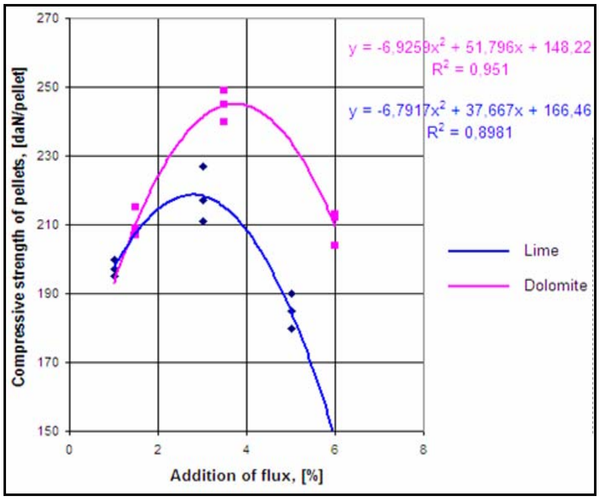
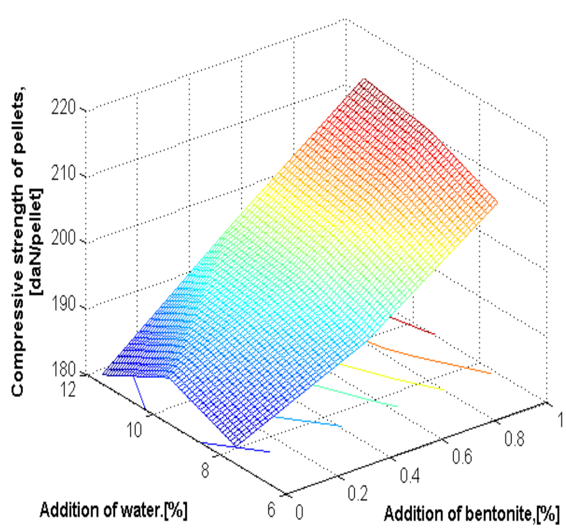


Fig.11.variation of compressive strength of pellets
(11. 5 % water, 0 % bentonite)

Analyzing the above figures it appears:
- whether bentonite is used with the addition of lime or dolomite, pellets hardened compressive strength increases with increasing addition of up to 2.5-3% for lime, dolomite respectively for 3 to 3.5, regardless of the addition of bentonite and water over these limits compressive strength decreases with increasing margins;
-regardless of the addition of flux and water resistance to compression of the pellets increases with the addition of bentonite;
-addition of water increased from 9.5 to 10.5% within the values increases the compressive strength of pellets.

Correlations resulting from data processing in Matlab program are presented graphically in Fig.10-15. Analyzing these correlations we were able to establish the optimal addition of flux, bentonite and water, so as to obtain higher values for compressive strength of the pellets with the addition of flux.

$$z = 6.6667 \cdot x^2 - 0.625 \cdot y^2 + 2 \cdot x \cdot y + 0.1111 \cdot x + 11.7917 \cdot y + 129.7188 \quad (1)$$



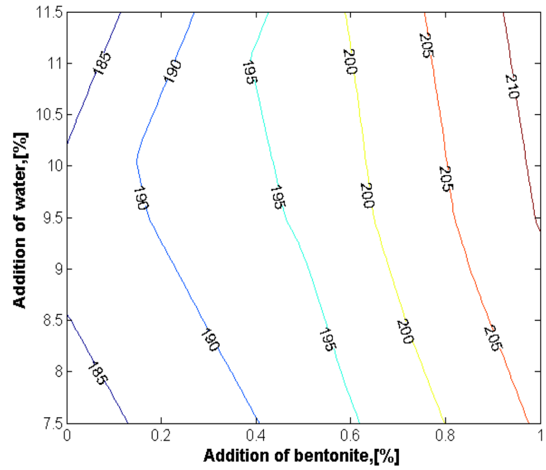
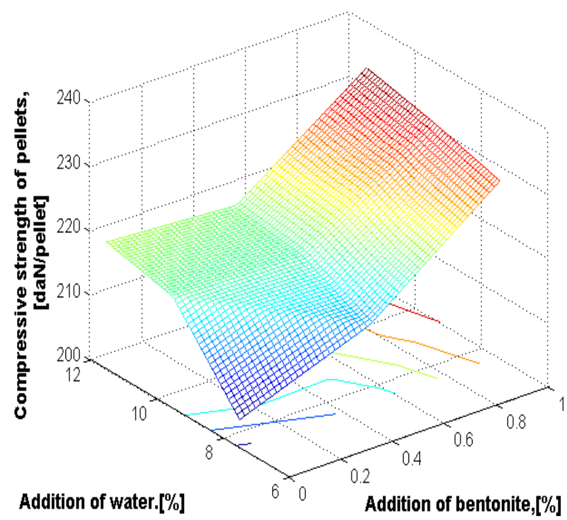


Fig.12. variation of compressive strength of pellets
to a concentration of 1% lime

$$z = 24.6667 \cdot x^2 - 0.625 \cdot y^2 - 2.5 \cdot x \cdot y + 15.4167 \cdot x + 15.3750 \cdot y + 125.7882 \quad (2)$$



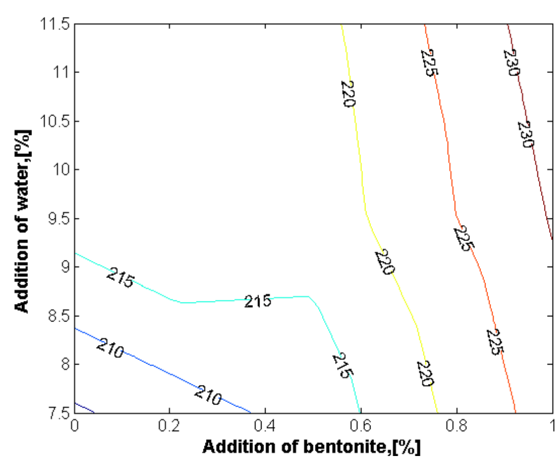
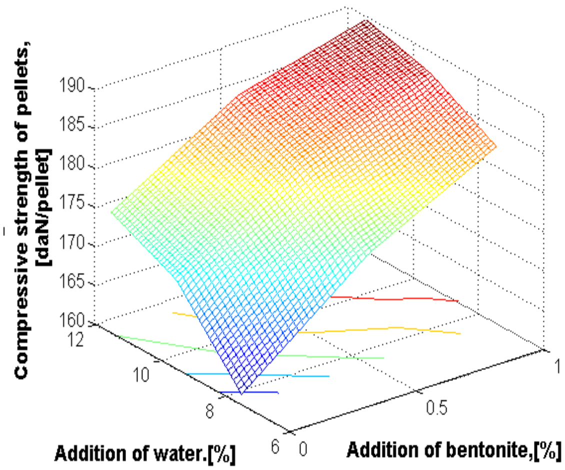


Fig.13. variation of compressive strength of pellets
to a concentration of 3% lime

$$z = -8.8889 \cdot x^2 - 0.4722 \cdot y^2 - 1.75 \cdot x \cdot y + \\ + 42.40 \cdot 28 \cdot x + 12.1539 + 94.3287 \quad (3)$$



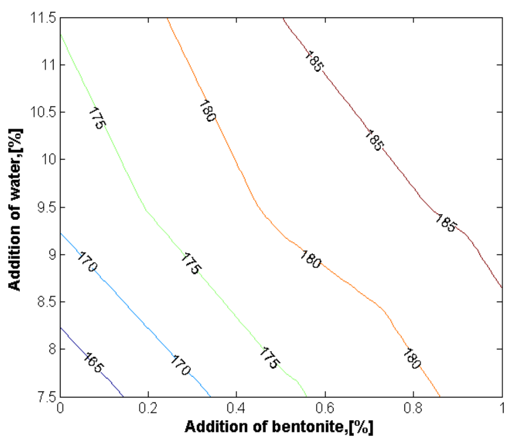
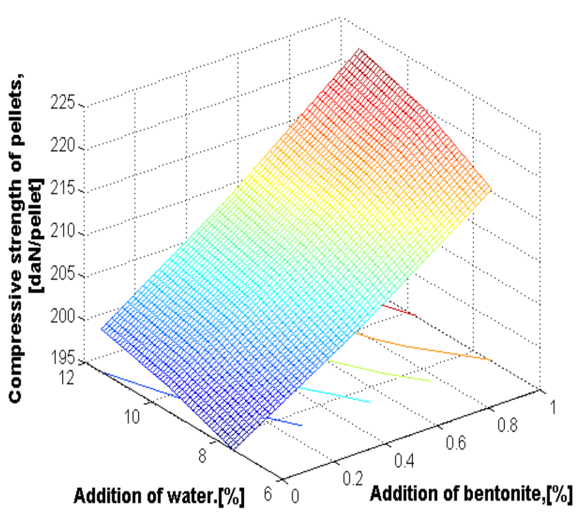


Fig.14.variation of compressive strength of pellets to a concentration of 5% lime

$$z = 62.4444 \cdot x^2 - 0.1806 \cdot y^2 + 0.3333 \cdot x \cdot y - \\ - 54.1667 \cdot x + 4.7917 \cdot y + 178.8113 \quad (4)$$



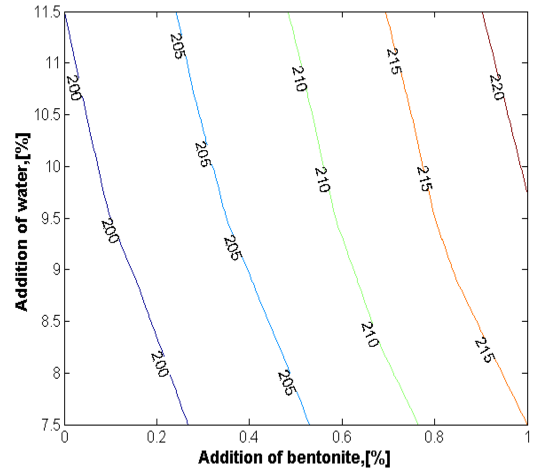
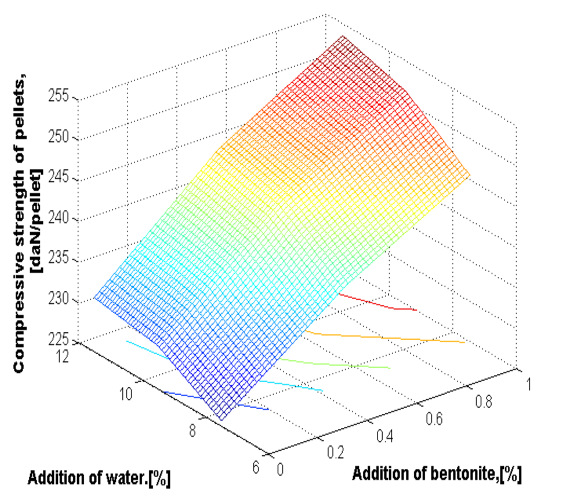


Fig.15. variation of compressive strength of pellets to a concentration of 1. 5% dolomite

$$z = 65.7778 \cdot x^2 - 0.4306 \cdot y^2 + 0.0833 \cdot x \cdot y \\ - 58.1250 \cdot x + 9.94444 \cdot y + 189.9880 \quad (5)$$



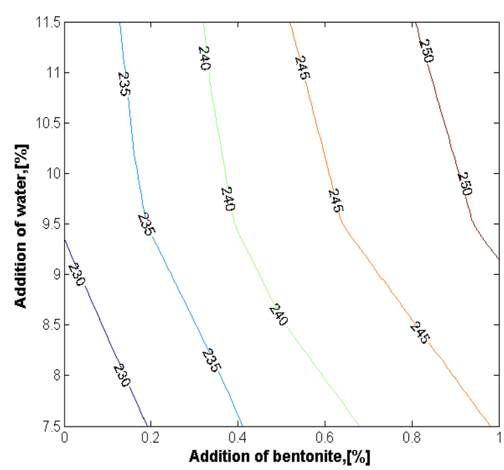


Fig.16. variation of compressive strength of pellets to a concentration of 3. 5% dolomite

$$z = 48.2222 \cdot x^2 - 0.4861 \cdot y^2 - 1.8333 \cdot x \cdot y - 25.5833 \cdot x + 12.8472 \cdot y + 127.0081 \quad (6)$$

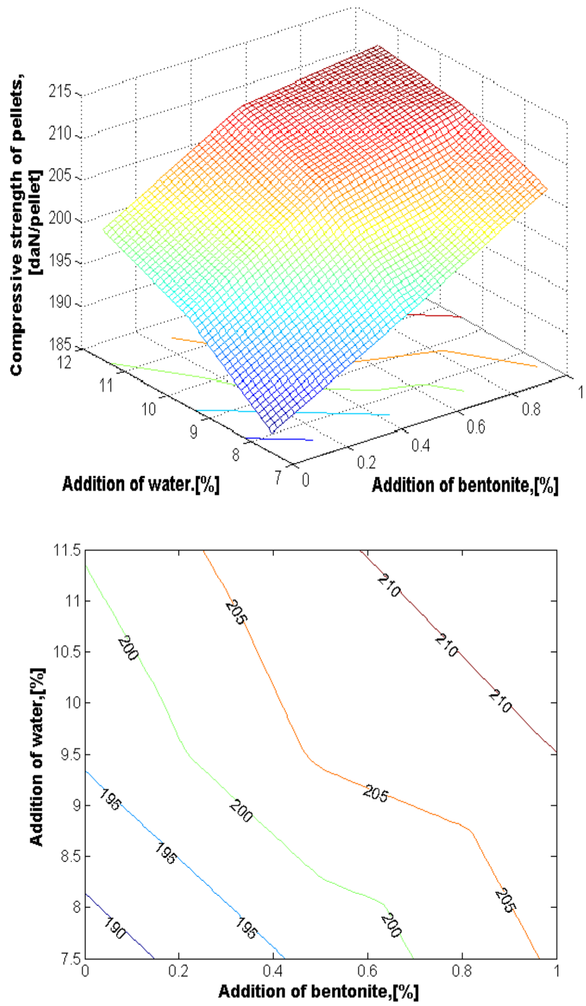


Fig.17. variation of compressive strength of pellets to a concentration of 6 % dolomite

To obtain the cumulative influence of technological factors on the compressive strength of the pellets have made correlations with three independent parameters: the addition of water, the addition of bentonite, the addition of lime. Using MATLAB software, we determined the mathematical formula between the compressive strength of the pellets and the three parameters above presentation.
If we note x- addition of bentonite, y- addition of water, z- addition of lime, w- compressive strength of pellets the following equation for compressive strength of pellets is:

$$w = 7.4815 \cdot x^2 - 0.5741 \cdot y^2 - 8.1574 \cdot z^2 - 0.7500 \cdot x \cdot y - 2.2222 \cdot x \cdot y + 0.4375 \cdot y \cdot z + 25.9769 \cdot x + 11.9144 \cdot y + 41.5289 \cdot z + 87.1948 \quad (7)$$

To view graphic dependence of the compressive strength of the pellets and the three parameters for each of the three pametrii in formula 7 we replaced by one average value of each parameter.
For the average value of bentonite (0.5%) we have:

$$z = -0.5741 \cdot x^2 \cdot 8.1574 \cdot y^2 + 0.4375 \cdot x \cdot y + 11.5394 \cdot x + 40.4178 \cdot y + 102.0526 \quad (8)$$

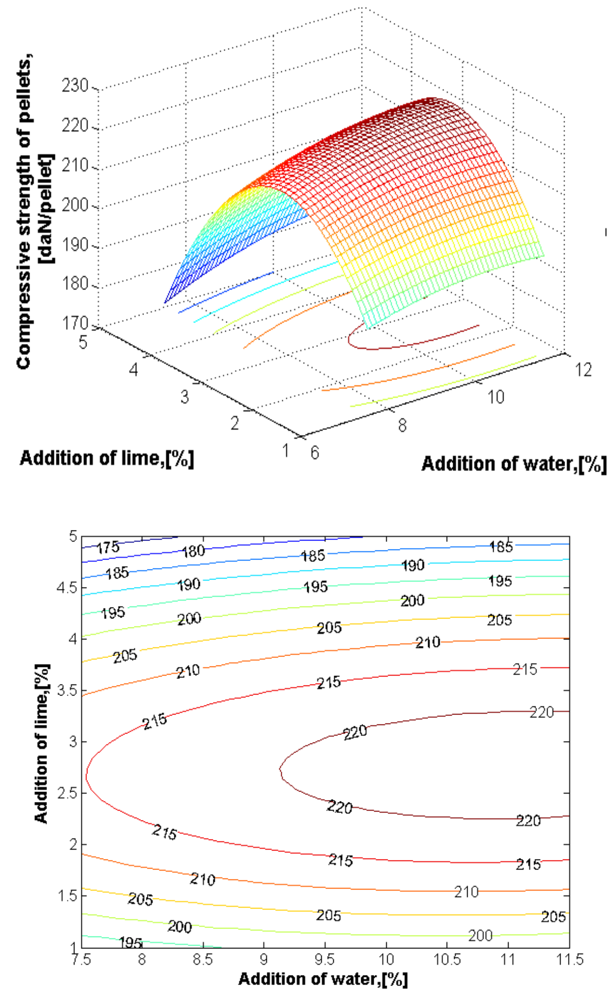
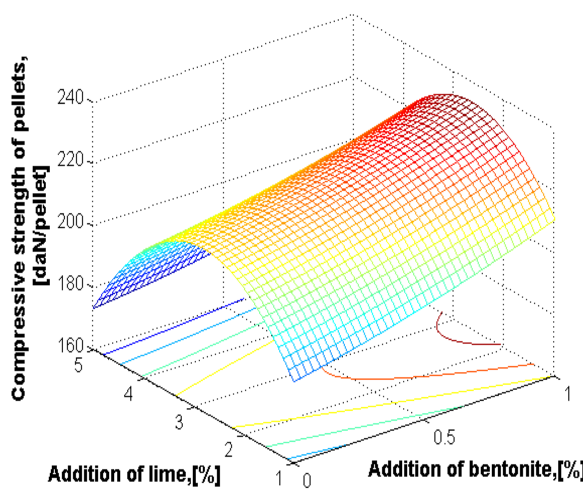


Fig.18. variation of compressive strength of pellets for the average value of bentonite

For the average value of water (9.5%) we have:

$$z = 7.4815 \cdot x^2 - 8.157 \cdot y^2 - 2.2222 \cdot x \cdot y + 18.8519 \cdot x + 45.6851 + 194.9274 \quad (9)$$



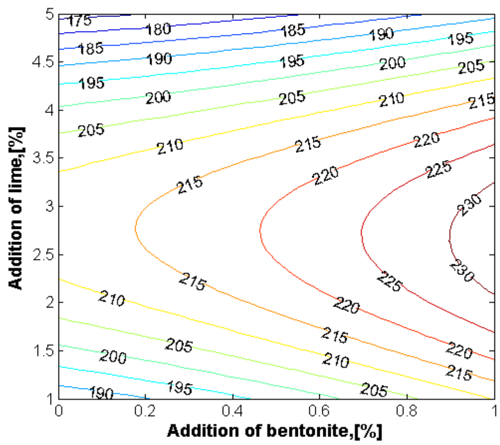


Fig.19. Variation of compressive strength of pellets for the average value of water

For the average value of lime (3%) we have:

$$z = 7.4815 \cdot x^2 - 0.5741 \cdot y^2 - 0.7500 \cdot x \cdot y + 19.3102 \cdot x + 10.39191 \cdot y + 187.3094 \quad (10)$$

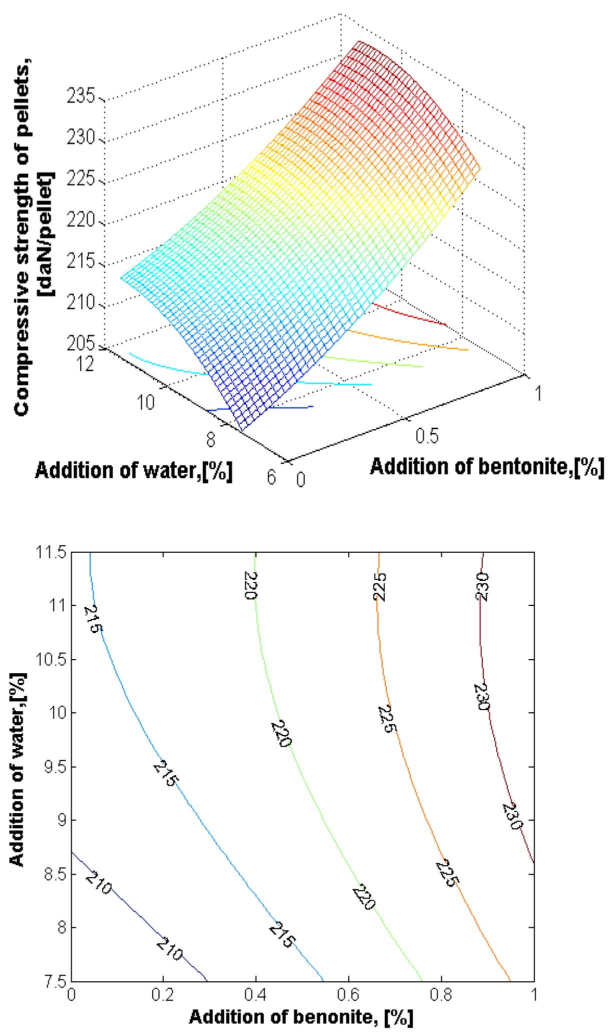


Fig.20. Variation of compressive strength of pellets for the average value of lime

Next we repeat the same operations for pellets having in their composition dolomite instead lime.
If we note x- addition of bentonite, y- addition of water, z- addition of dolomite, w- compressive strength of pellets the following equation for compressive strength of pellets is:

$$w = 58.8148 \cdot x^2 - 0.3657 \cdot y^2 - 6.9194 \cdot z^2 - 0.4722 \cdot x \cdot y - 1.3789 \cdot x \cdot z + 0.2632 \cdot y \cdot z - 40.9025 \cdot x + 8.2294 \cdot y + 48.8412 \cdot z + 101.6598 \quad (11)$$

For the average value of bentonite (0.5%) we have:

$$z = -0.3657 \cdot x^2 - 6.9193 \cdot y^2 + 0.2632 \cdot x \cdot y + 7.9933 \cdot x + 48.1518 \cdot y + 95.9093 \quad (12)$$

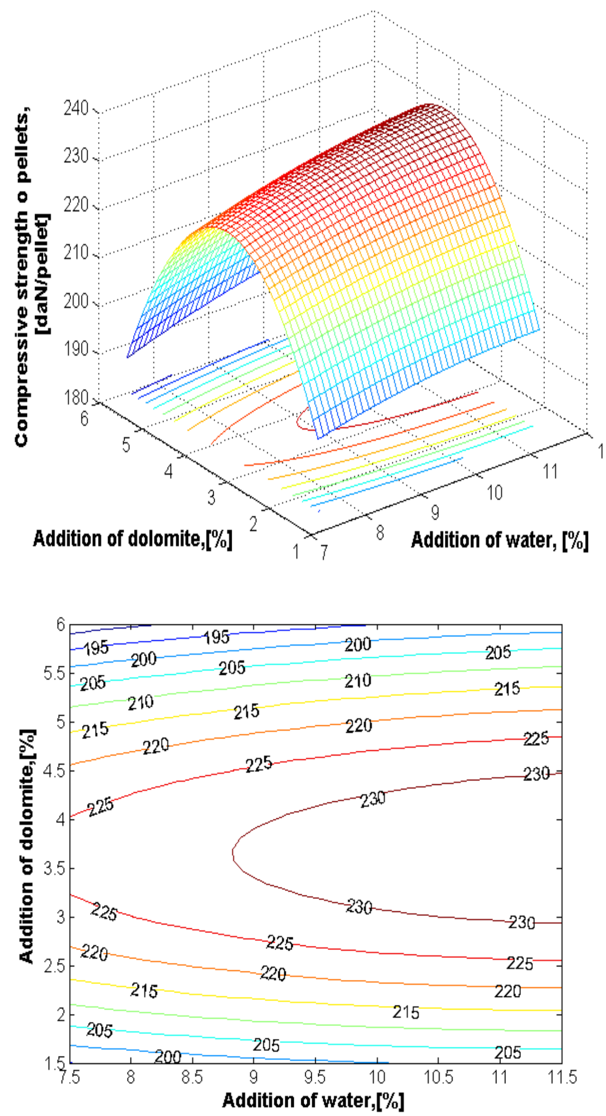
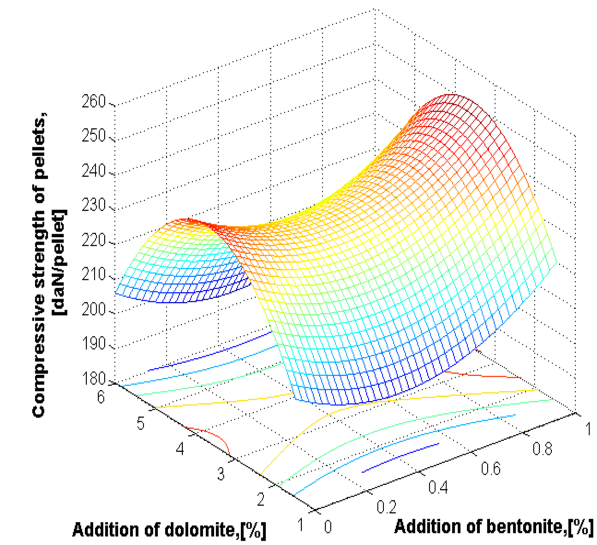


Fig.21. variation of compressive strength of pellets for the average value of bentonite

For the average value of water (9.5%) we have:

$$z = 58.814 \cdot x^2 - 6.9193 \cdot y^2 - 1.3789 \cdot x \cdot y - 45.3886 \cdot x + 51.3417 \cdot y + 117.4899 \quad (13)$$



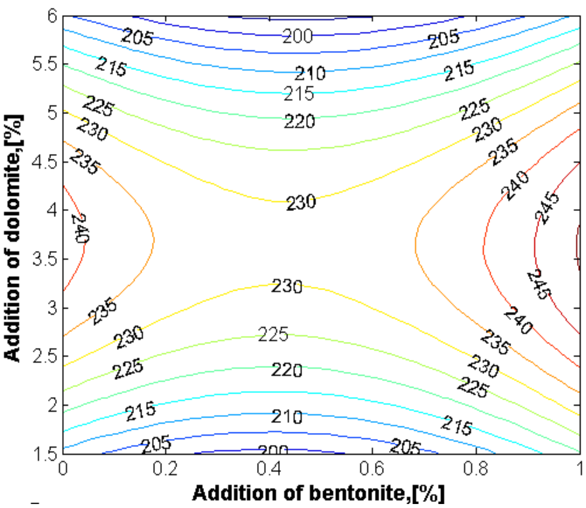
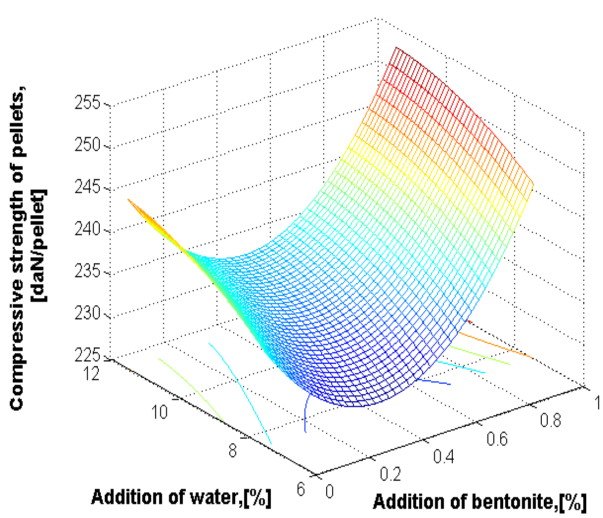


Fig.22. Variation of compressive strength of pellets for the average value of water

For the average value of dolomite (3.67%) we have:

$$z = 58.8148 \cdot x^2 - 0.3657 \cdot y^2 - 0.4722 \cdot x \cdot y - 459.584 \cdot x + 9.1945 \cdot y + 87.7147 \quad (14)$$



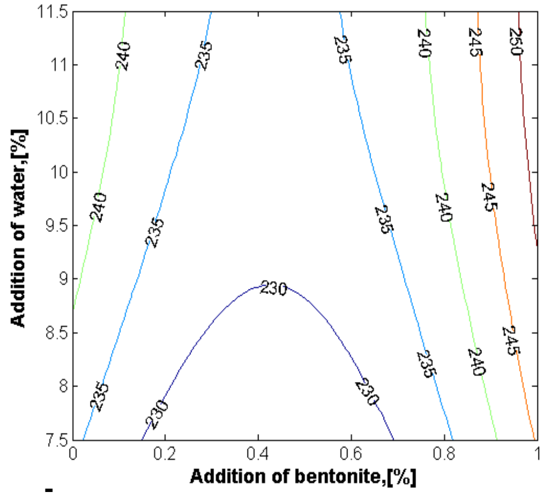


Fig.23. Variation of compressive strength of pellets for the average value of dolomite

IV. CONCLUSION

Based on the experiments, on the results obtained from data processing and on the technical analysis of these data, the following conclusions resulted, in a nutshell:

- the two types of ferrous wastes (steel plant dust and red mud), both resulted from metallurgical processes, can be processed through pelleting. This means they can be used in the iron and steel industry;
- by adding flux, or lime or dolomite, the compression resistance of the hardened pellets increases when adding 2.5-3,5% flux;
- it is advisable to add 1% bentonite and 10-11% water, the upper limit corresponding to the higher limit of the added flux;

By processing these wastes and transforming them in pellets fit to be used as raw or auxiliary materials in the iron and steel industry, the areas current covered by them can be given back to nature, contributing in this way to the greening of the environment.

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