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RESEARCH ON THE INFLUENCE OF BASIC ADDITIVES ON THE COMPRESSIVE STRENGTH 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. 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 & lime or bentonite & dolomite. During the research, we aimed to establish correlations between the compressive strength of pellets and the additions of water, bentonite, lime or dolomite. The data obtained in the experiments were processed in Excel and MATLAB programs, resulting simple or multiple correlation equations. Based on these equations, we could establish the optimum addition of materials with basic character.
KEYWORDS: pellet, compressive strength, lime, dolomite, iron oxide, calcium oxide

❖ INTRODUCTION

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. By using the lime as additive, simultaneously with the hardening process can appear various chemical combinations between the iron oxide and the calcium oxide, obtaining calcium ferrites, or between the iron oxide, silica and lime, obtaining calcium and iron silicates. In case of CaO additive in excess and basicity ration up to 1.8, we obtain calcium di-ferrite, $2CaO_2Fe_2O_3$, which becomes friable in case of reduction at low temperatures.

When using dolomite as basic additive, the formation of calcium diferrite is avoided mostly due to the reduction of the CaO content. From the reaction between CaO and SiO_2 that takes place in the gangue of the pelleted raw material, it results calcium silicates of $CaOSiO_2$ or $2CaOSiO_2$ types, which ensure a good binding of the material during the low temperature reduction process.

Regarding the influence of MgO, we have to mention the fact that this compound presents a very high melting temperature versus the pellet hardening temperature. As a consequence, MgO diffuses in the lattice of Fe_3O_4 and forms, in the solid phase, during the increasing of the magnetite grains, a magnetic magnesium compound called magnesioferrite, (Mg, Fe)O Fe_2O_3, which plays the role of a very strong binder and has a good oxidation stabilisation. Due to this quality, during the hardening treatment, the Fe_2O_3 remains mostly untransformed in Fe_3O_4. For this reason, at the low temperatures found in the upper zone of the blast furnace, the transformation of Fe_2O_3 in Fe_3O_4 stops. In these conditions, the pellets present a good breaking resistance.

Moreover, MgO increases the softening under load temperature of the pellets and the melting temperature.

The use of additives for increasing the resistance of the pellets should be made respecting an optimal proportion, this being the subject of the present research.

❖ LABORATORY EXPERIMENTS

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.

Table 1. The compositions of raw materials used to produce pellets

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	

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. From each batch, we selected three pellets to determine their compression resistance. To establish the correlations, we took into account the average value.

❖ RESULTS OBTAINED FROM PROCESSING THE EXPERIMENTAL DATA

By processing the data obtained in the laboratory phase, we obtained equations of correlation between the binder additives & 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.

The correlations obtained by processing the data in the Excel program are presented in Figs. 1-9, in graphical and analytical forms.

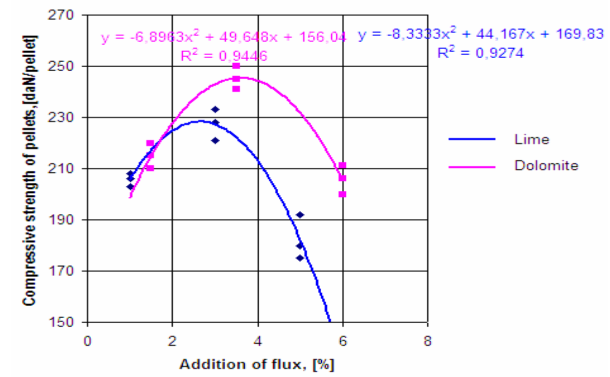

Fig.1. Variation of compressive strength of pellets (7.5 % water, 1% bentonite)

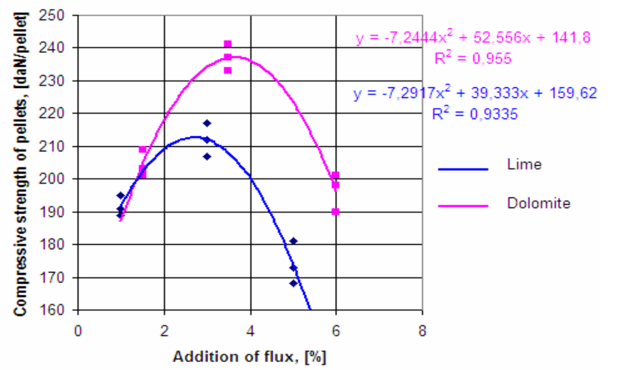

Fig.2. Variation of compressive strength of pellets (7,5% water, 0.5% bentonite)

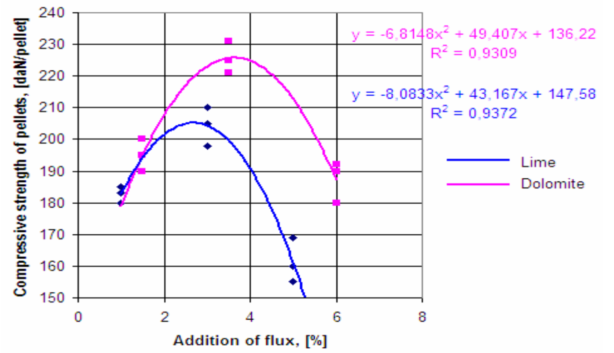

Fig.3. Variation of compressive strength of pellets (7.5 % water, 0% bentonite)

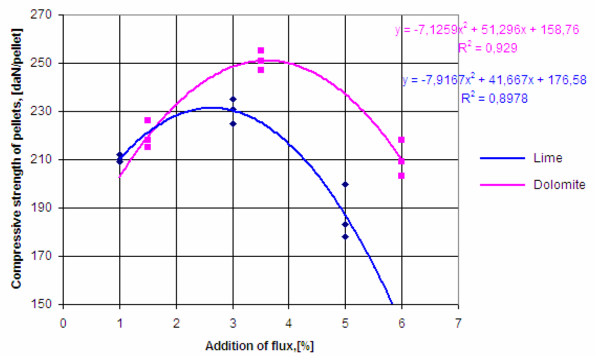

Fig.4. Variation of compressive strength of pellets (9,5% water, 1% bentonite)

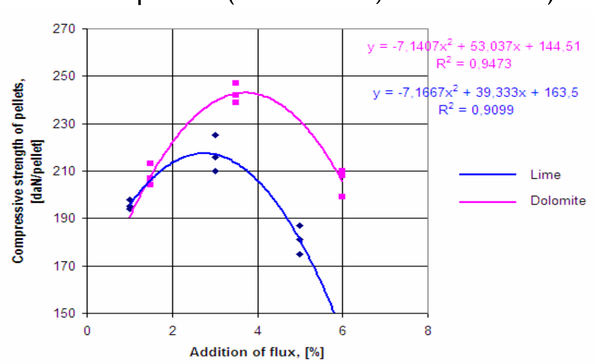

Fig.5. Variation of compressive strength of pellets (9.5 % water, 0.5% bentonite)

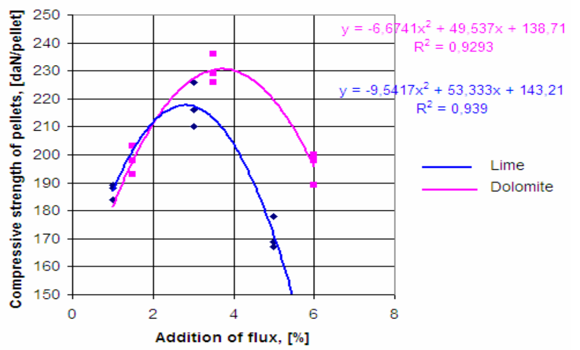

Fig.6. Variation of compressive strength of pellets (9,5% water, 0% bentonite)

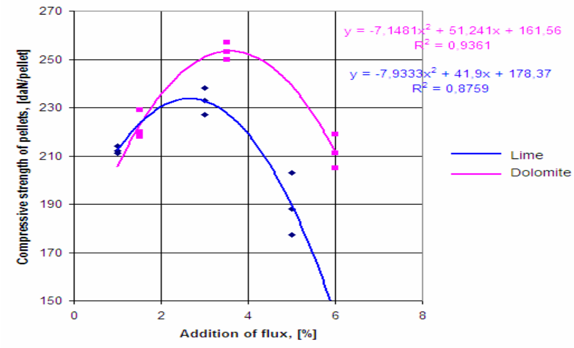

Fig.7. Variation of compressive strength of pellets (11.5 % water, 1% bentonite)

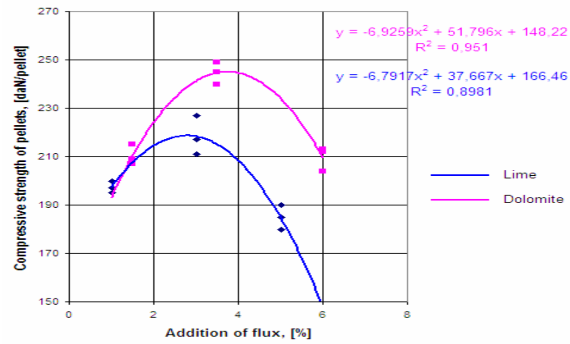

Fig.8. Variation of compressive strength of pellets (11.5% water, 0.5% bentonite)

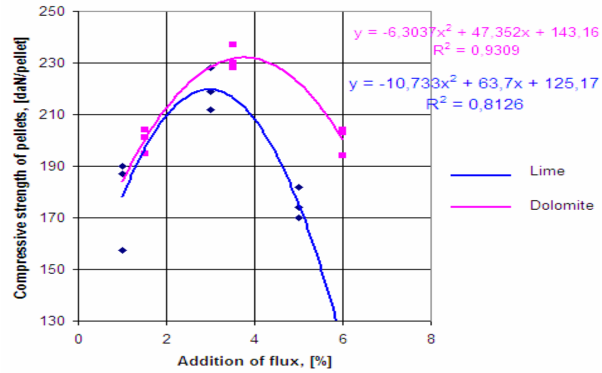

Fig.9. Variation of compressive strength of pellets (11.5% water, 0% bentonite)

Following the technical analysis of these data, it resulted:

- no matter whether we add lime or dolomite beside the bentonite, the compression resistance of the hardened pellets increases with increasing additive quantity, up to 2.5-3% (lime) and 3-3.5 (dolomite), indifferent of the bentonite and water additions; over these limits, the compression resistance decreases with increasing additive quantity;
- no matter whether we add flux or water, the compression resistance of the pellets increases with increasing bentonite addition;
- an increase of the water addition with 9.5-10.5% determines an increase of the compression resistance of the pellets.

The correlations obtained by processing the data in the Matlab program are presented in graphical form in Figs. 10-12.

$$z = 6{,}324 \cdot x^2 + 6{,}422 \cdot x + 1{,}542 + 39{,}021 \cdot y - 2{,}031 \cdot y^2 - 1{,}39 \cdot x \cdot y$$

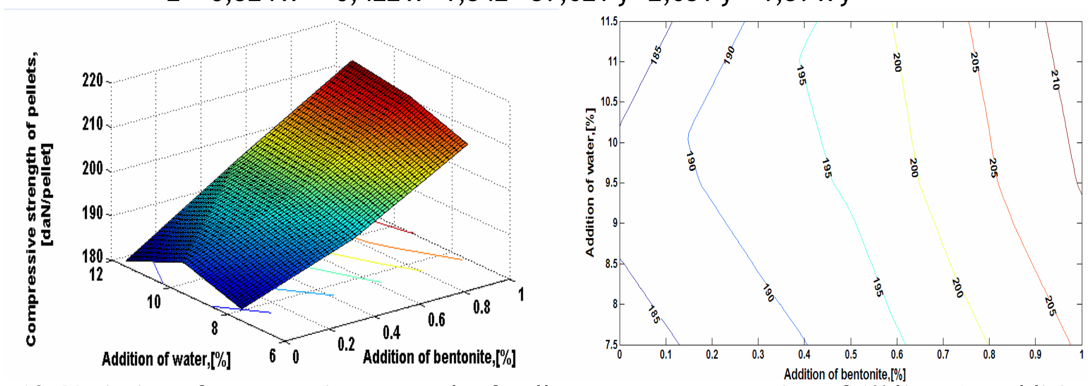

Fig.10. Variation of compressive strength of pellets to a concentration of 1% lime (x- addition of bentonite [%], y- addition of water [%], z-compressive strength of pellets, [daN/ pellet])

$$z = 24{,}334 \cdot x^2 + 21{,}536 \cdot x + 1{,}495 + 41{,}78 \cdot y - 1{,}989 \cdot y^2 - 3{,}092 \cdot x \cdot y$$

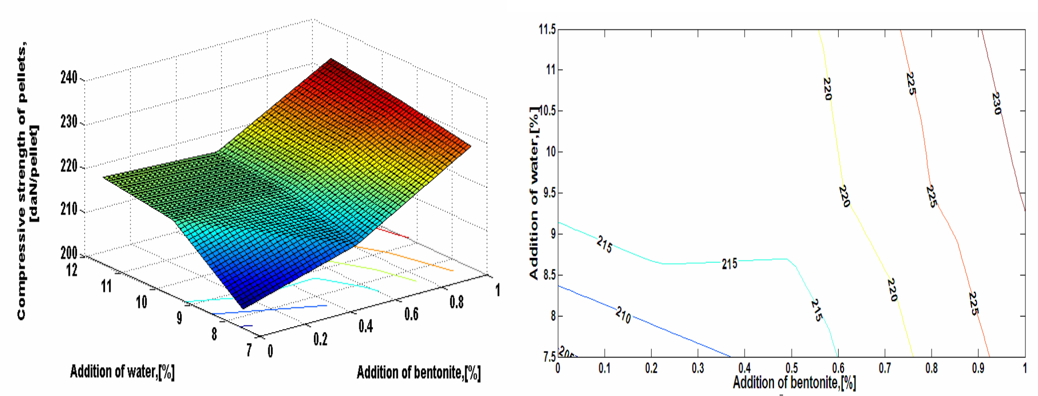

Fig.11. Variation of compressive strength of pellets to a concentration of 3% lime (x- addition of bentonite [%], y- addition of water [%], z- compressive strength of pellets, [daN/ pellet])

$$z = -9,138 \cdot x^2 + 46,992 \cdot x + 1,121 + 32,315 \cdot y - 1,495 \cdot y^2 - 2,194 \cdot x \cdot y$$

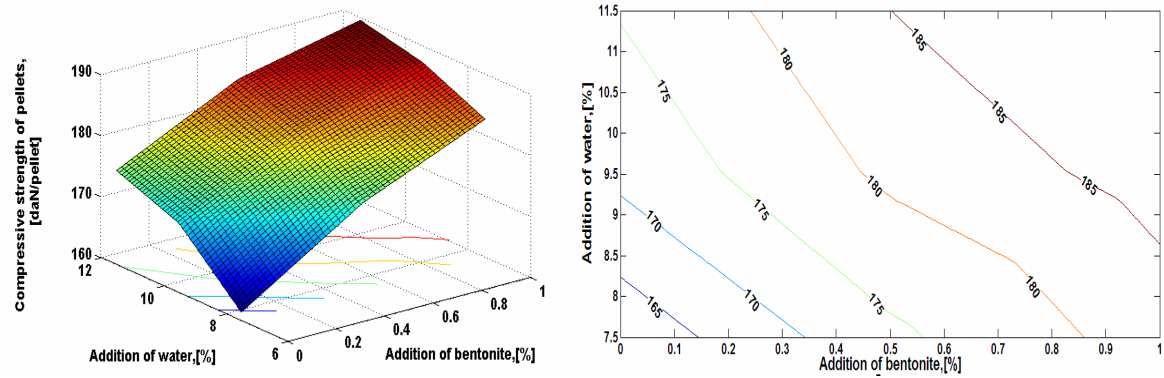

Fig.12. Variation of compressive strength of pellets to a concentration of 5% lime (x- addition of bentonite [%], y- addition of water [%], z- compressive strength of pellets, [daN/ pellet])

Analysing 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.

CONCLUSIONS

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 & 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 & steel industry, the areas currently covered by them can be given back to nature, contributing in this way to the greening of the environment.

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