Researches regarding pulverous ferrous waste processing by pelletizing

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***Abstract*—**The paper presents the results obtained in laboratory experiments, regarding the obtaining of pellets, produced from ferrous pulverous waste. The pellets produced within the experiments are made of fine and powder scrap, come as waste material from the iron & steel industry, i.e. steel plant dust, sludge agglomeration, siderite wastage concentrate, red mud, limestone dust, dolomite dust, blast furnace slag and coke dust.

***Keywords*—** sludge agglomeration, recycling, steel plant dust, siderurgy, waste.

I. INTRODUCTION

NATURAL resources constitute the support of sustainable development, as they offer the elementary conditions of life and supply the basic raw materials.

The extraction of non-renewable resources such as coal, oil and minerals can have a negative impact upon the environment and biodiversity unless adequate steps are taken towards waste management. Under normal conditions, there should be a balance between the exploitation of such resources and environment protection. At the same time, some non-renewable resources are estimated in terms of their commercial potential. But price increase stimulates the development of new, alternative technologies, which cut down the quantities of resources used.

Waste recycling is at present a most important field of interest and it is part of the strategy of sustainable development.

Wastes are to be recycled only if this process and the manufacturing of the resulting new products have a lower impact upon the environment than in the case of waste final dumping and the costs are lower than those involved by the use of usual raw materials. Thus, recycling is preferred to waste dumping if it meets both economical and ecological conditions [1].

Recycling is economically profitable only if the recyclable materials have a lower cost than the usual raw materials and if their use does not imply modifications of technology or of the product quality. Recycling must also to be correlated with the environmental and waste management laws.

Re-usage of industrial wastes is a topic of paramount interest in the context of sustainable development in terms of industrial recycling technologies correlated with their impact upon the environment. The recycling potential represents at present the main criterion in approaching waste management. Fig.1. shows a classification of industrial wastes according to their re-usage potential [2].

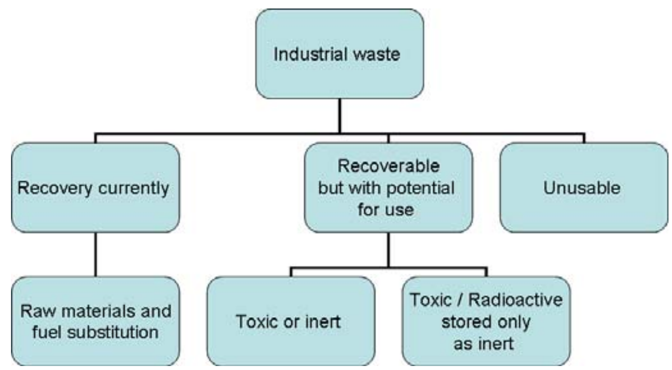


Fig.1. Industrial wastes according to the potential for recovery

Besides the ever growing need of raw materials for steel making, there are areas that have to face the problem of industrial wastes, whose dumping is most of the time incompatible with environment protection. These wastes are accumulated in dumping areas whose capacity is more and more restricted. Hence the significant lack of dumping possibilities which, through their negative impact upon the environment, lead to a rapid growth of taxes imposed by environmental laws [3].

In order that recycling be sustainable, the principles that should be used are "the polluter pays" and "the user pays". Both involve establishing the transaction price in terms of total cost, i.e. polluters pay the entire cost of the damage and the waste processors pay the overall cost of their storage and elimination.

The strategies of steel making development are oriented in two directions [4]-[5]:

- a drastic cut down of emissions by applying efficient technologies;
- an increase of the output in recovering and recycling by-products.

Ferrous powdery wastes resulting from the steel making industry come from gas and industrial water filtering installations. Their collection has both an ecological dimension, i.e. it avoids air and water pollution and an economical one, considering the intrinsic value of such materials that can replace traditional raw materials. For 1,000000 t steel/year, the resulting 25,000-35,000 ton of ferrous powdery wastes has a content of 60-70%Fe [6]-[12].

Pulverous ferrous wastes are present in all cases in the form of oxides. For the recovery of iron, they must be objects in a reduction process, either in a furnace, case in which these wastes are components of the raw material (previously processed as pellets, briquettes or agglomerate), or in electric arc furnaces, as secondary material with a complex fusing - oxidizing character or as a slag foaming agent.

Based on the study regarding the recovery possibilities of pulverous ferrous wastes in siderurgy, and also the conditions present in the area of Hunedoara (fig.2), we consider that the processing technology through pelletizing is viable on economical basis [6].

Fig.2.Distribution of pulverous waste in Hunedoara area

II. Testing in Pilot Phase

Finding economically and ecologically efficient solutions for the technological fluxes in steel making constitutes a major issue at present. The structure of raw material basis for steel elaboration is unconditionally imposed by the quality of the material that is going to be produced [7].

The research we have carried out focused on the processing of by products, consisting in ferrous small grain and powdery wastes and their use in steel making. In order to turn them into account, several technologies can be used, namely: agglomeration, palletizing, briquetting or their use through the Carbofer method [6]-[16].

The paper presents the laboratory and the pilot tests we carried out in order to asses the possibilities of using ferrous powdery wastes in steel making, after their pelleting. We took samples of the ferrous powdery wastes (steel plant dust, sludge agglomeration, siderite wastage concentrate, red mud, limestone dust, dolomite dust, blast furnace slag and coke dust) in order to determine their quality characteristics.

Fig. 3-6show their chemical composition and fig.7 shows their grain-size structure. The waste samples (consisting in sub-micronic almost spherical particles) have been analyzed by means of a scanning electronic microscope (SEI), the morphological aspects related to the steel plant dust and sludge agglomeration being shown in 8 and 9. The particles have various dimensions and shapes, some being round, others poliedrical [9].

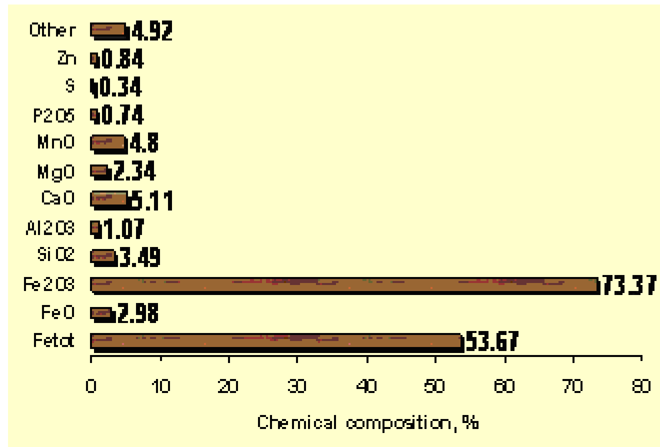


Fig.3. Average chemical composition of steel plant dust

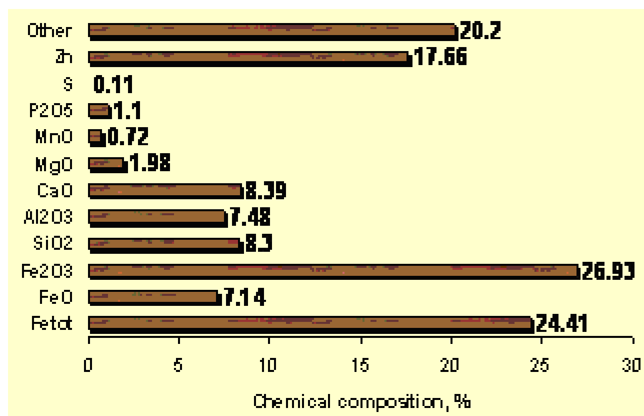


Fig.4. Average chemical composition of sludge agglomeration

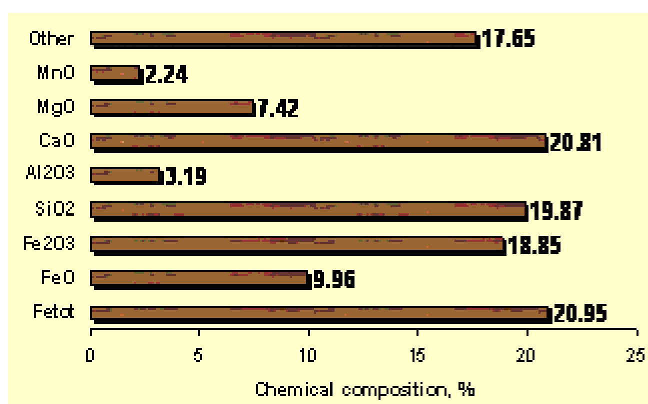


Fig.5. Average chemical composition of siderite wastage concentrate

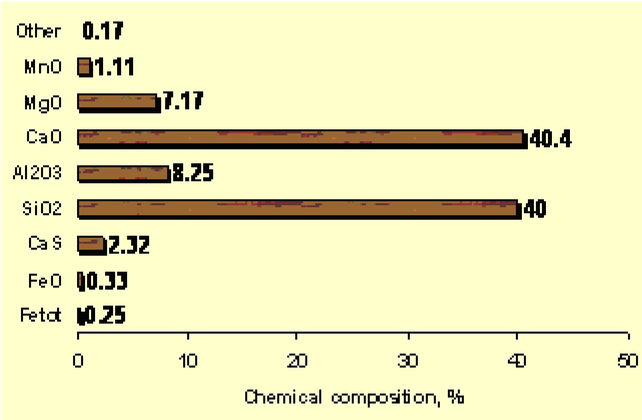


Fig.6. Average chemical composition of blast furnace slag

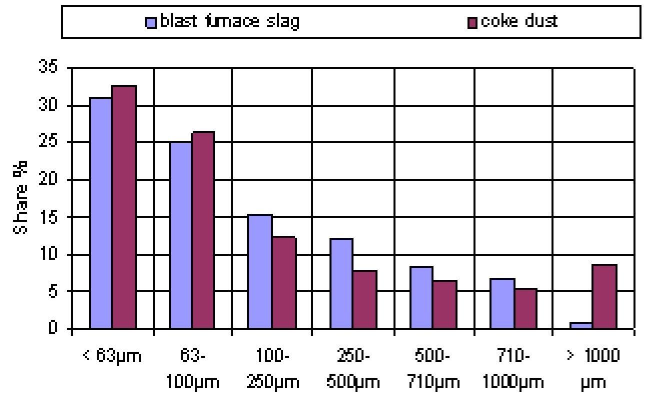
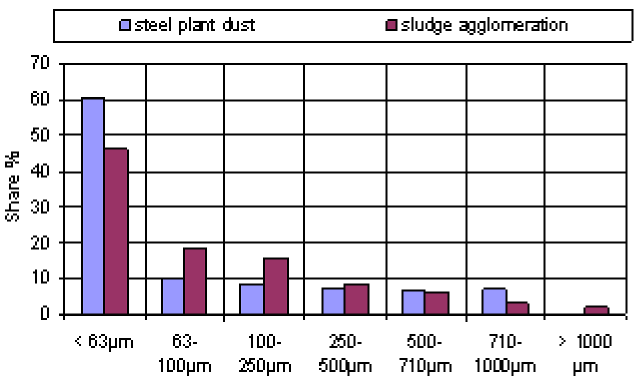
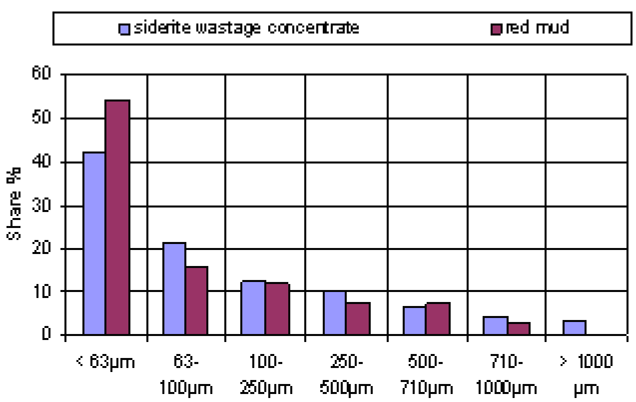
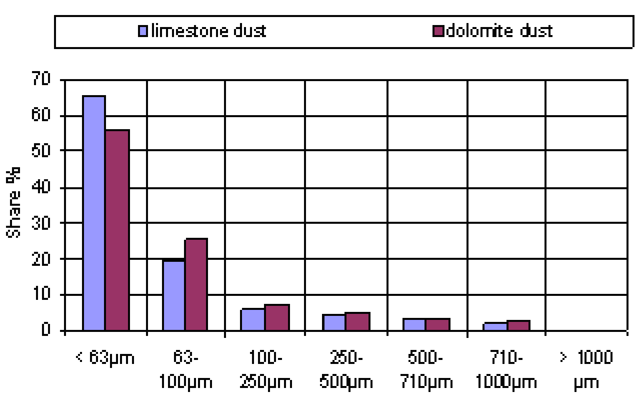


Fig.7. Granulometric composition of the waste







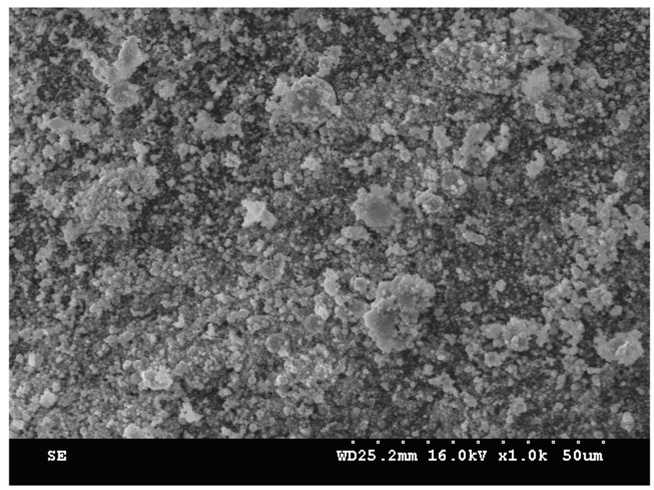


Fig.8. Scanning electron microscopy images (SEI) of steel plant dust, x 1000

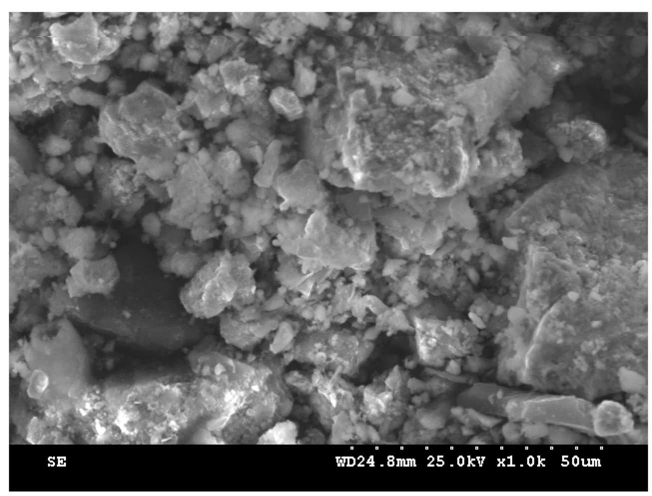
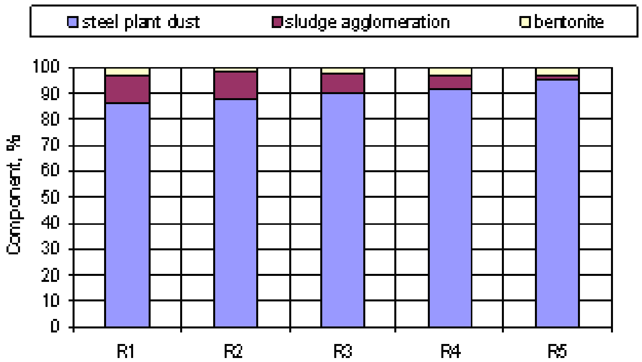
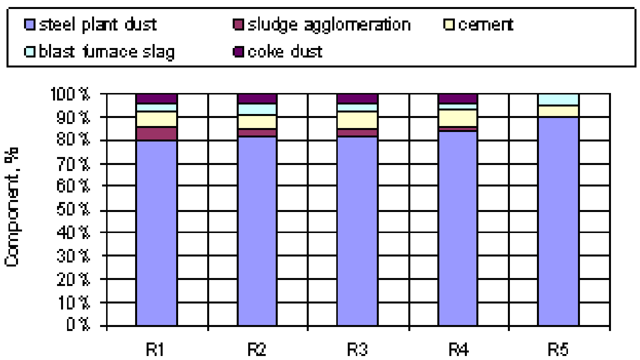


Fig. 9. Scanning electron microscopy images (SEI) of sludge agglomeration, x 1000

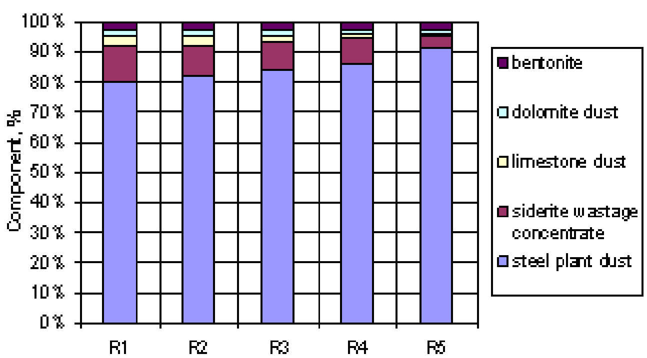
We produced pellets according to 5 recipes / 4 variant (A, B, C and D), their structure being shown in fig.10.



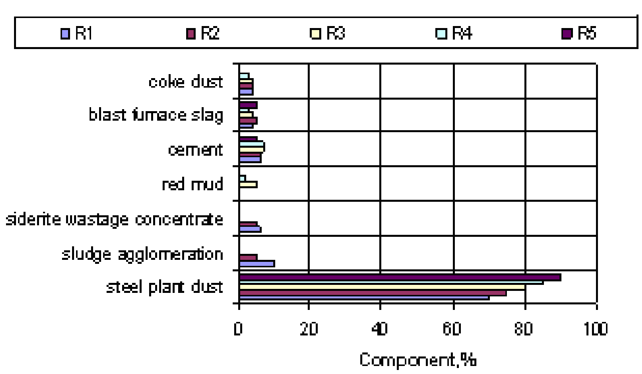
Variant A



Variant B



Variant C



Variant D

Fig.10. Recipes

We used 80-95% steel plant dust, 2-11% sludge agglomeration, 4-12% siderite wastage concentrate, 2-5% red mud, 1-3% limestone dust, 1-2% dolomite dust and 3-5% blast furnace slag and as bonding material 2-3% bentonite and 5-7% cement.

The determinations we made have lead to the conclusion that these materials meet the conditions requested by their processing into pellets, particularly if we consider their use in steel making.

The pelletizing operation lasted 25-30 min. During the entire process we focused on the charge moisturizing and pellet formation. Water flow rate was corrected according to the humidity of the material.

After the pelletizing operation was ended, the pellets were screened for various grain sizes. Hardening was done by burning in electric (resistance) ovens, observing the heating diagram (fig.11). For each batch of pellets we determined: the chemical composition, the grain size structure (fig.12) and the resistance to compression (fig.13), in [daN/pellet].

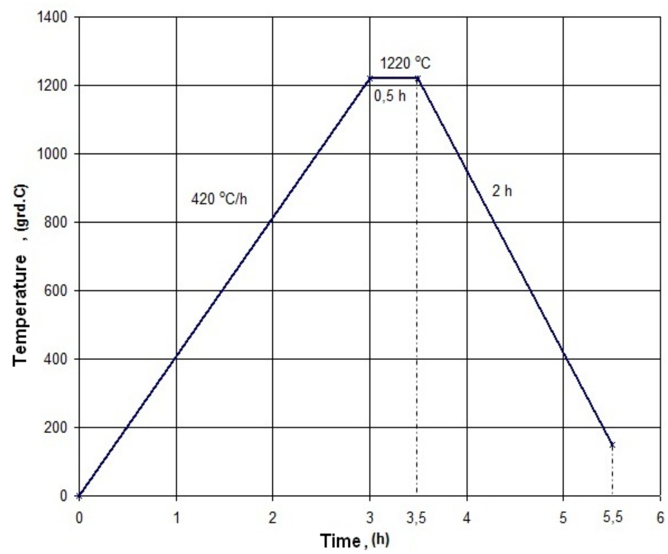


Fig.11. Diagram of hardening

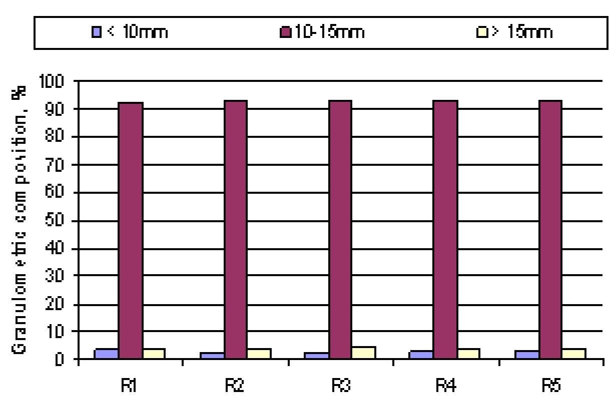
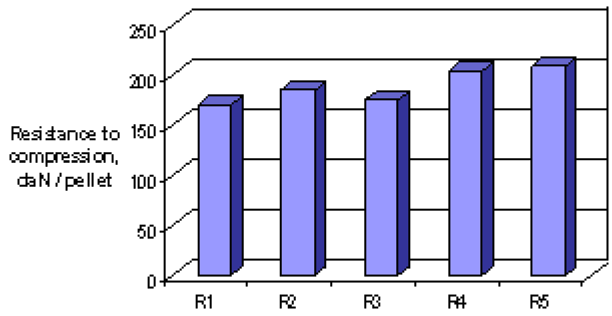
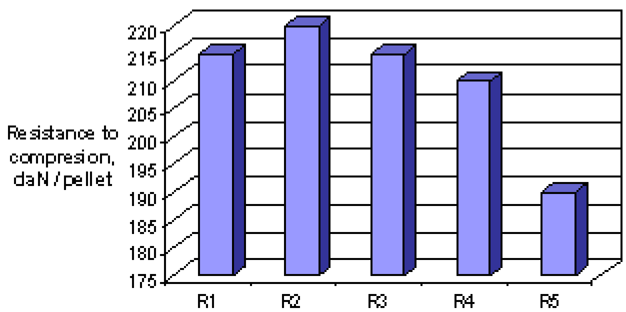


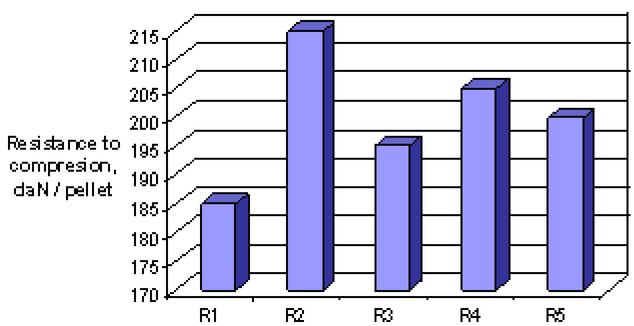
Fig.12. Granulometric composition of pellets.



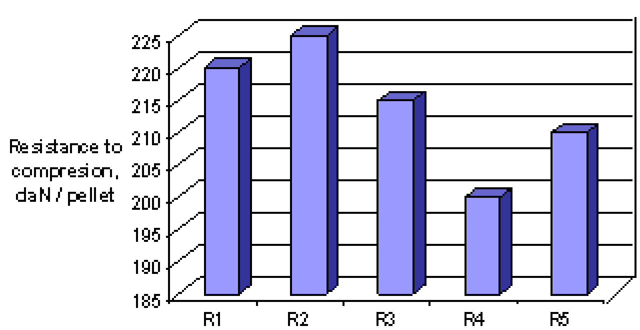
Variant A



Variant B



Variant C



Variant D

Fig.13. The resistance to compression of pellets

III. Results. Discusion

We determined the degree of iron reduction. For each variant we performed 5 determinations (one for each recipe). The reduction degree was calculated by relation [3]:

$$R = \left(1 - \frac{Q_r}{Q_i}\right) \cdot 100, [\%] \tag{1}$$

Q_r – stands for the content of residual oxygen, [%];

Q_i – stands for the initial content of oxygen, [%].

The results are shown in fig.14.

The analysis of the data shows a good degree of reduction for the pellets containing a large quantity of blast furnace-agglomeration slam, as after burning they acquire a less dense structure, which is favorable to reduction by a gaseous reducing agent.

We also tested the carbon reduction in the Tamman oven in order to determine the degree of metallization [3]:

$$G.R._{Fe} = \frac{Fe_{met}}{Fe_{tot}} \cdot 100\ , [\%] \tag{2}$$

Fe_{met} – metallic iron content, %

Fe_{tot} – total iron content, %.

For each variant we performed five determinations (one for each recipe). The contents of the samples were: 1.5kg pellets; 0.5kg graphite powder; 0.2kg blast furnace slag and 0.1kg lime. Graphite powder had a reduction role and the blast furnace slag and lime were meant to form and correct the chemical composition of the slag. The results we obtained are shown in fig.15.

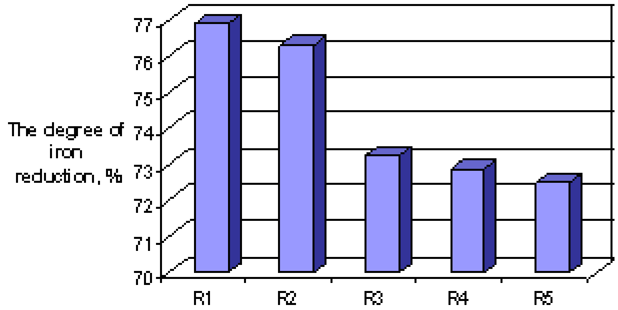
The analysis of the data shown above leads to the conclusion that the process of carbon reduction (similar to the one in the steel plant) is taking place in good conditions. The pellets we obtained are shown in fig.16.

Taking into consideration the fact that the pellets are going to be processed in electric arc ovens, they can be considered as corresponding from the point of view of their resistance to compression.

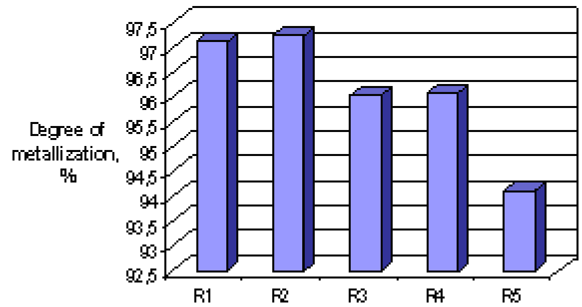
The industrial testing was made using a direct heating furnace having the capacity 5 tones. Pellets addition had the purpose to replace partially (25%) the iron ore used for decarbonisation. Thereby from total addition 4.2 kg/100kg(steel), the iron ore was replaced 1.05 kg with an equivalent of 1.2 kg of pellets (it was calculated for iron equivalent, respectively oxygen), which demand a specific addition of 12kg/t, that means 60kg/charge.

From the performed determinations regarding the oxygen consumption used for carbon oxidation it resulted that mean utilisation grade of oxygen was between 73-77%.

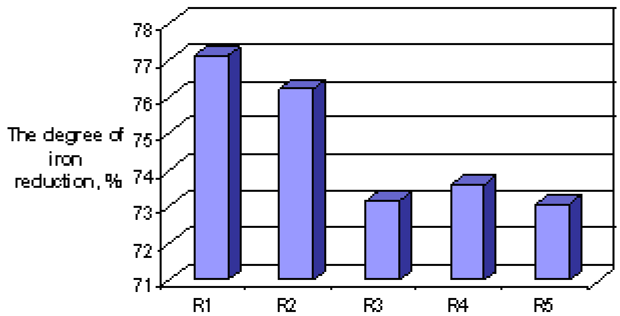
Also it was observed that in case of using the pellets produced after the recipes R5/Variant B and R5/VarianrD it wasn't produced skimming, because these pellets does not contain the components which produce skimming.



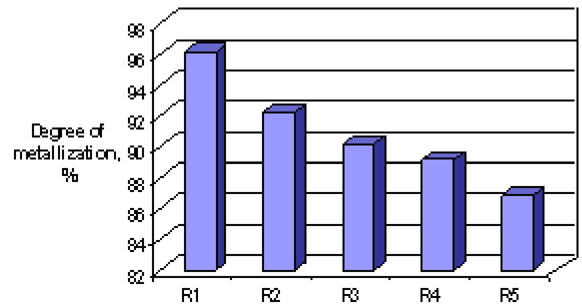
Variant A



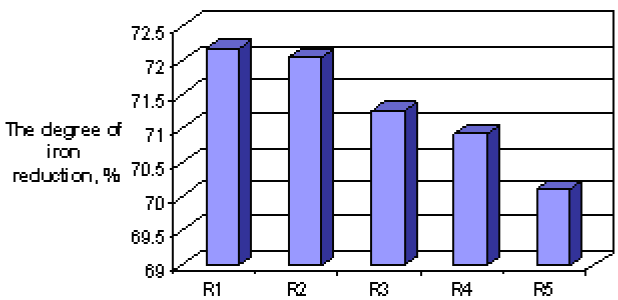
Variant A



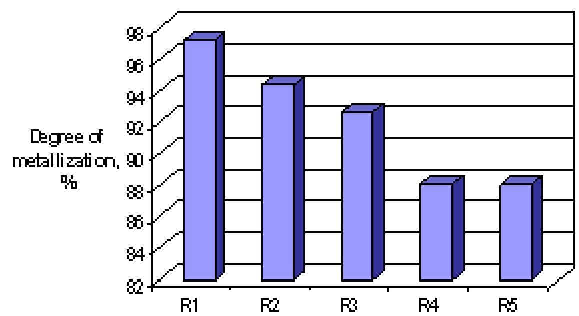
Variant B



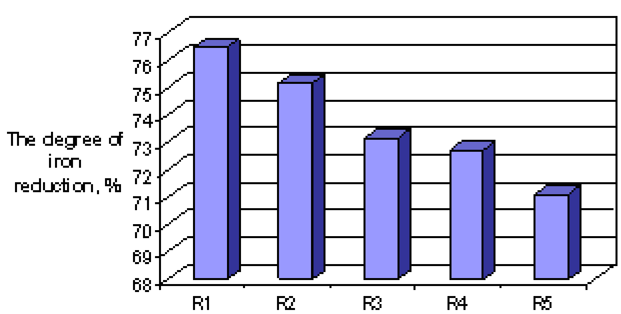
Variant B



Variant C

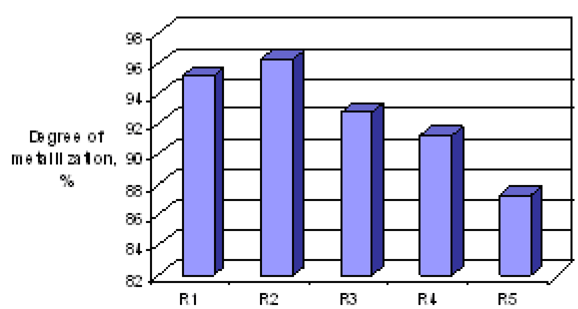


Variant C



Variant D

Fig.14. The degree of reduction



Variant D

Fig.15. Degree of metallization.

Fig.16. Pellets

A good skimming was obtained in case of using the pellets produced after the recipes R1, R2 and R3/Variant A and R2/Variant D, these having as foamer the carbon from lime residue, and recipe R1/variant D and the coke dust and the siderite concentrate, which lead to the best skimming.

An acceptable skimming was observed in case of utilisation of pellets produced after the recipes R4/Variant A, R1-R4/Variant B and R3/Variant D.

A slightly skimming was observed for recipes having small content of foamer elements (R5/Variant A, R1-R4/Variant C, R4/VariantD).

IV. Conclusion

The remarkable results obtained in modern iron factories were possible through implementation of management systems into industrial activity, systems which imposed the analysis, evaluation and selection on changes at the level of technologies/equipments, respectively alternative technologies, from the perspective of its specific instruments, among which one of the most complex is undoubtedly the life cycle analysis

At industrial level, sustainable development supposes modeling the activities that optimize the economical and social profits, without jeopardizing the potential corresponding to benefices meant for the future generations.

In the industrial areas and especially in the iron & steel making areas, which are frequently subject to a strong economical restructuring, we consider the recovery through the fine scrap pelletizing to be one of the most viable technological solution, suitable to be introduced in the economic circuit.

On the basis of the results we have obtained and the technological observations we have made during the experiments, one can consider that these materials can be processed in good conditions into pellets.

Pellets can be submitted to reduction in view of their usage as raw material in electric arc ovens.

Pellets show enough resistance to compression, so they can be used in blast furnace charges.

The presence of carbon brought by the blast furnace-agglomeration dust into their composition, speeds up the reduction process.

Because of the natural product crisis, correlated with the increase of waste storage costs, industrial companies are bound to take steps towards processing and delivering, under advantageous conditions, of their own wastes to the users who turn them into account, or towards accepting external wastes to be used in their technologies as substitute raw materials.

The use of wastes is convenient if the sum of material, production and storage costs is lower than the cost of using traditional materials.

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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