U.P.B. Sci. Bull., Series B, Vol. 83, Iss. 1, 2021 ISSN 1454-2331

EXPERIMENTAL RESEARCH ON A SEMI-INDUSTRIAL PILOT SCALE FOR OBTAINING CARBOFER PELLETS IN ROTARY TUBULAR FURNACE

Nicolae CONSTANTIN[1], Ana Virginia SOCALICI[2], Radu BUZDUGA[3], Alina Cristina MIHAIU[4], Cristian DOBRESCU[5*], Octavian Nicolae STANASILA[6], Elisa-Florina PLOPEANU[7], Elena Madalina VLAD[8]

The authors present in this paper an unconventional technology through which mixed iron-carbon pellets are obtained, pre-reduced, with a high degree of metallization. The raw material is made up of fine ferrous waste and brown coal. From this, mixed iron-carbon pellets are obtained in a pelletizing installation with rotating tray and later they are reduced in an unconventional installation of rotary tubular furnace existing at SC CCPPR SA Alba Iulia, modernized, and specially adapted for carrying out this research.

The final products obtained through this technology are Carbofer type pellets that contain at least 85% metallic iron. They can be used as raw material in the blast furnace and steel sectors. The work also represents an important contribution to the improvement of the environmental conditions in the areas where the waste from which the pellets were made is currently stored.

Keywords: ferrous waste, pellets, carbofer, rotary furnace, iron sponge

1. Introduction

Among the industrial branches, some are responsible for the generation of the largest parts of waste: extraction and preparation of ores and coal, energy production, metallurgy, chemistry, etc. For industrial products, whose manufacture involves the generation of large quantities of waste such as coking coal, pig iron and crude steel, physical production has had a general downward

[1] Ph.D. engineer, University POLITEHNICA of Bucharest, Romania,e-mail: nctin2014@yahoo.com
[2] Ph.D. engineer, University POLITEHNICA of Timisoara, Romania,e-mail: virginia.socalici@fih.upt.ro
[3] Ph.D. engineer, SC CCPPR SA Alba Iulia, e-mail: radu_buzduga@yahoo.com
[4] Ph.D. economist to University POLITEHNICA of Bucharest, Romania,e-mail: mihaiu_alina@yahoo.com
[5] *Ph.D. engineer, University POLITEHNICA of Bucharest, Romania,e-mail: cristiandobrescu@yahoo.com
[6] Ph.D. mathematician, University POLITEHNICA of Bucharest, Romania,e-mail: ostanasila@hotmail.com
[7] Doctoral engineer, University POLITEHNICA of Bucharest, Romania,e-mail: elisaplopeanu@yahoo.com
[8] Doctoral engineer, University POLITEHNICA of Bucharest, Romania,e-mail: madalinavlad920131@gmail.com

trend. [1, 2, 3]. In these products, there is a trend of stabilizing production at levels of about 30% of those recorded in 1989.

In Romania, as in other countries, the impact of waste on the environment has increased alarmingly in recent years, improper management of them generating soil and groundwater contamination, as well as emissions of methane, carbon dioxide and toxic gases, with direct effects on health population. [4, 5, 6]

Storage spaces have reached saturation and finding new ones has become a big problem. [7, 8] In the countries with developed steel industry, the powdery ferrous waste is recovered in proportion of over 90%, by their reintroduction in the steel circuit. From the study of the specialized literature [9-11] it results that for their capitalization several technologies are practiced, namely capitalization by agglomeration, capitalization by pelletization, capitalization by briquetting, capitalization by reduction without an initial processing. [6, 11,] Among the previously mentioned variants, in Romania, in the steel units, the small and powdery ferrous waste were reintroduced in the steel circuit only by agglomeration and not more than 10% of the total waste.

The ferrous waste resulting from the chemical industry (pyritic ash - Turnu Măgurele) was also processed by pelletization. [1]. The aim of the research was to finalize an alternative technology for the recovery of small and powdery ferrous waste, existing in steel areas where there has been strong economic restructuring, the recovery of both existing waste in dumps and ponds and those currently resulting in flows technology.

2. Experimental

To achieve the direct reduction of pellets from ferrous waste, the design and execution of the adaptations necessary for the application of the technology for direct reduction of iron oxides in pellets using carbon reducer, embedded in pellets and indirectly with carbon monoxide formed inside the reduction furnace, on a pilot installation consisting of a rotary tubular oven of direct reduction with electric heating existing at SC CCPPR SA Alba Iulia.

To carry out the experiments, the oven was modified so that it could be easily loaded with pellets; the heating, rotation and tilting installations, as well as all the oven seals were overhauled.

Special ceramic channel bricks have been partially replaced, on which a new resistance has been introduced, mineral wool and asbestos used for thermal insulation and sealing against the environment have been replaced.

The rotating and tilting devices, the power supply device, the raw material supply device were reviewed, lubricated and pre-checked.

The main component part of the reduction installation, the rotary tubular furnace is presented in Fig. 1, and the images of the rotary tubular furnace captured during the experimental research are presented in Figs. 2 and 3.

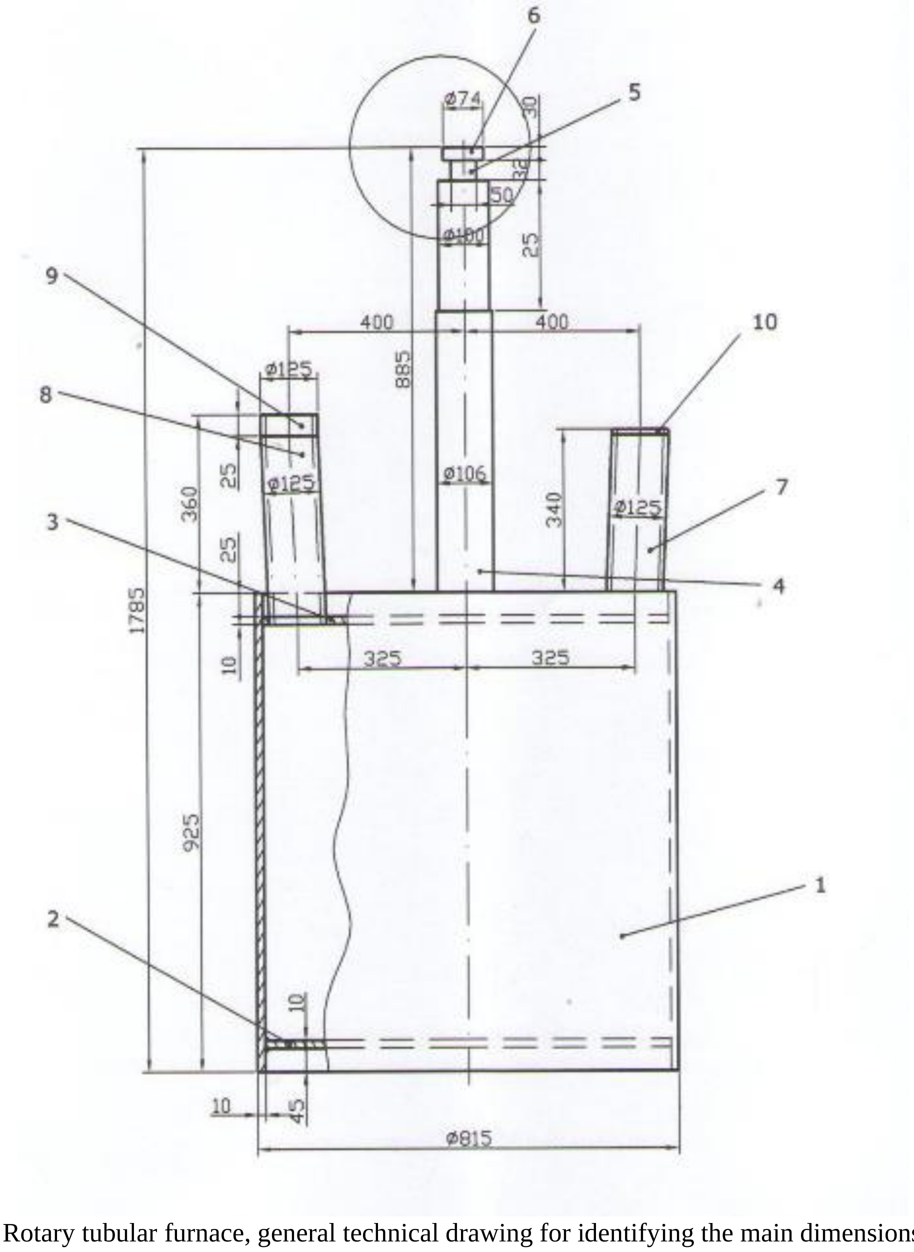

Fig.1 Rotary tubular furnace, general technical drawing for identifying the main dimensions.
1. Rotary fournace 2. Lower lid 3. Upper lid 4. Central reaction tube
5. Collar 6. Ring 7. Right section 8. Left section, 9. Hood, 10. Cover [1]

Fig.2 Rotary tubular furnace assembly
1 outer outer jacket 2 roller for supporting and guiding the rotational movement,
3 gear and transmission chain from the electric motor of the rotational movement,
4box power supply and control of the oven movements [1]

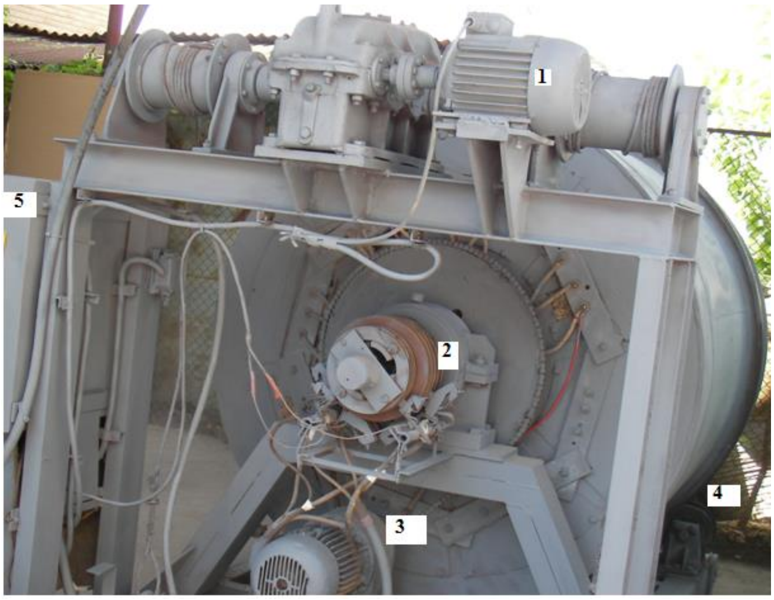

Fig.3 Rotary tubular furnace assembly with motorized gearboxes for rotational and tilting driving, as well as circular copper rings and contact brushes for the transmission of electricity from the mains to the resistors inside the furnace
1.Driver motor group for vertical tilting 2. Cu rings and contact brushes for power supply
3. Electric motor, chain and toothed ring for rotary motion of the rotary kiln
4. Support frame and roller guidance 5. Oven control panel [1]

The experimental research of direct reduction of the special pellets of carbofer type, in this rotary tubular furnace took place at SC CCPPR SA Alba Iulia, location where the pilot installation is located, in a specially made space, with direct access to the supply network electricity and ensuring total security for people and the environment.

The pellet samples were placed in the thermal chamber of the oven after it was heated to about 350 OC. The furnace was rotated, and the gaseous phase removed through the central shaft was closely monitored to prevent carbon monoxide poisoning resulting from direct carbon reductions of iron oxides in the pellet content. After 45 minutes the oven temperature reached about 950-975 ^oC.

Ignition of the gas discharged from the furnace confirms the presence of carbon monoxide in it. Direct reduction and metallization of the pellets was considered completed when the standby flame was no longer lit. Of course, this mode of protection against the released carbon monoxide was the safest, but it no longer allows a complete analysis of the gas phase discharged from the furnace. The oven could cool naturally in the air stream, this being one of the reasons why the installation was made in a special enclosure without side walls built at SC CCPPR SA Alba Iulia.

The evacuation of the pre-reduced pellets was done at an interval of 24 hours in order to be evacuated cold and thus protected from reoxidation. The operations were repeated for the five types of pellets and from the pellets reduced to metallic and sterile iron samples were taken from which the content of metallic Fe was determined and by calculations the degree of metallization Gm, Gm = metallic Fe from the reduced pellet was obtained / Total faith in the initial test. The results are presented in table1.

Table 1

Centralization of experimental results [1]

Sample number	Component of recipes from raw materials subject to palletizing , [%]				Micro pelletisin gduration [min]	Chemical composition of pellets ,[%]				Metallization degree after reduction [%]
	Dust steel	Blast furnace sinter sludge	Gra-phite pow-der	Bentonite		Fe_2O_3	SiO_2	CaO	C	
R1	82	10	5	3	12	77,21	4,41	1,58	7,13	92
R2	78	15	4	3	6	75,28	4,88	2,09	7,27	88
R3	74	20	3	3	10	73,35	5,35	2,60	7,41	84
R4	65	30	2	3	9	68,58	6,29	3,62	8,66	85
R5	55	40	2	3	10	62,92	7,23	4,64	10,89	75

It can be observed that the pellets from sample R1 have the highest degree of metallization, in which steel dust predominates 82%, but in which graphite with about 5% is present in the recipe. The lowest degree of metallization has the pellets made in the recipe with the most sludge from the agglomeration of furnaces 40% but also with the lowest percentage of graphite 3%. A slight disintegration was observed in all samples due to the surface friction forces between the pellets and between them and the walls of the thermal chamber of the furnace.

Electron microscopy research.

In this study, eight samples encoded sample R1 - sample R5 were investigated by the SEM / EDS method using a scanning electron microscope model XL 30 ESEM (3.5 nm resolution), coupled with an EDAX Sapphire energy dispersion spectrometer (128eV resolution). The results are materialized by obtaining morpho-compositional images (secondary and scattered electrons) and EDS spectra with adjacent quantitative results. The samples were analyzed directly in the crack, in perpendicular incidence, for morphological characterization by identifying deposits. SEM images were taken in different magnifications (25x, 100x, 250x, 500x) and were sufficient to identify the details and morphic aspects of the compounds [1].

Compositional analyzes involve the identification of microvolumes. Consequently, the compositional deviations can be significant even within the same analyzed sample. The results are shown in Figs. 4-8.

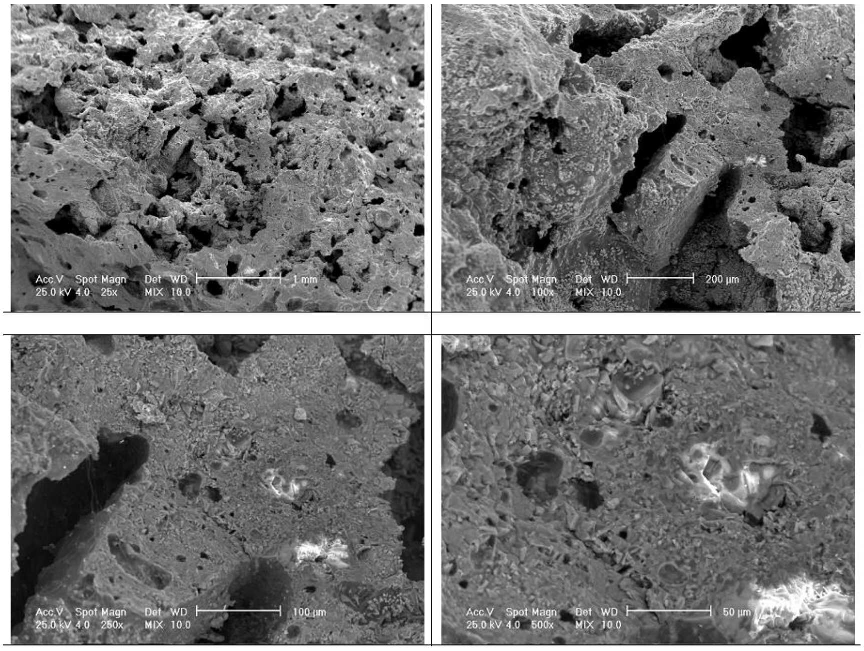

Fig.4 SEM images for R1 sample pellets at different magnification orders [1]

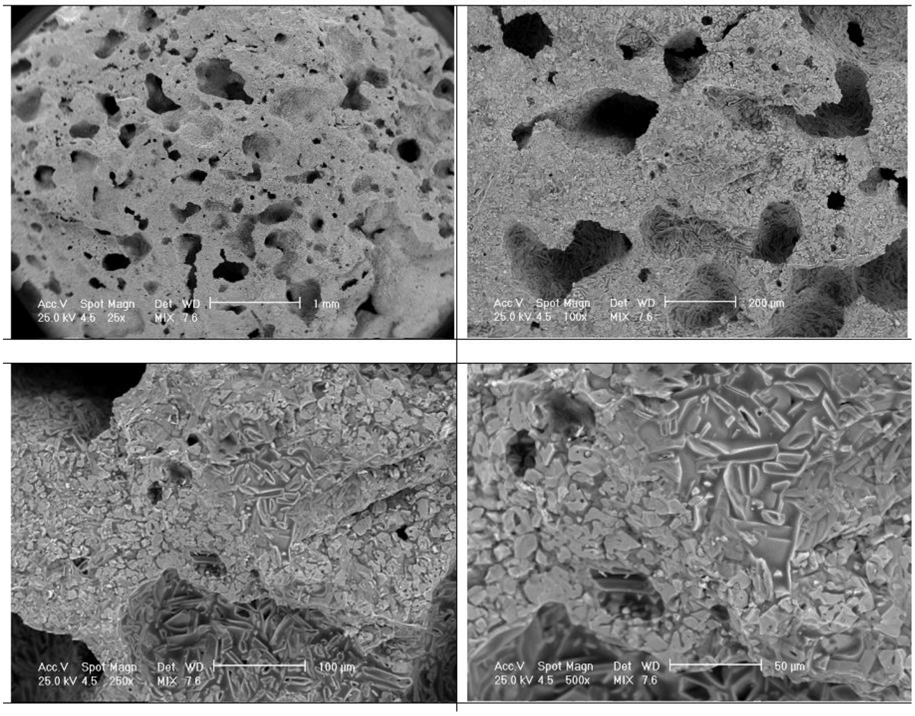

Fig.5 SEM images for R2 sample pellets at different magnification orders [1]

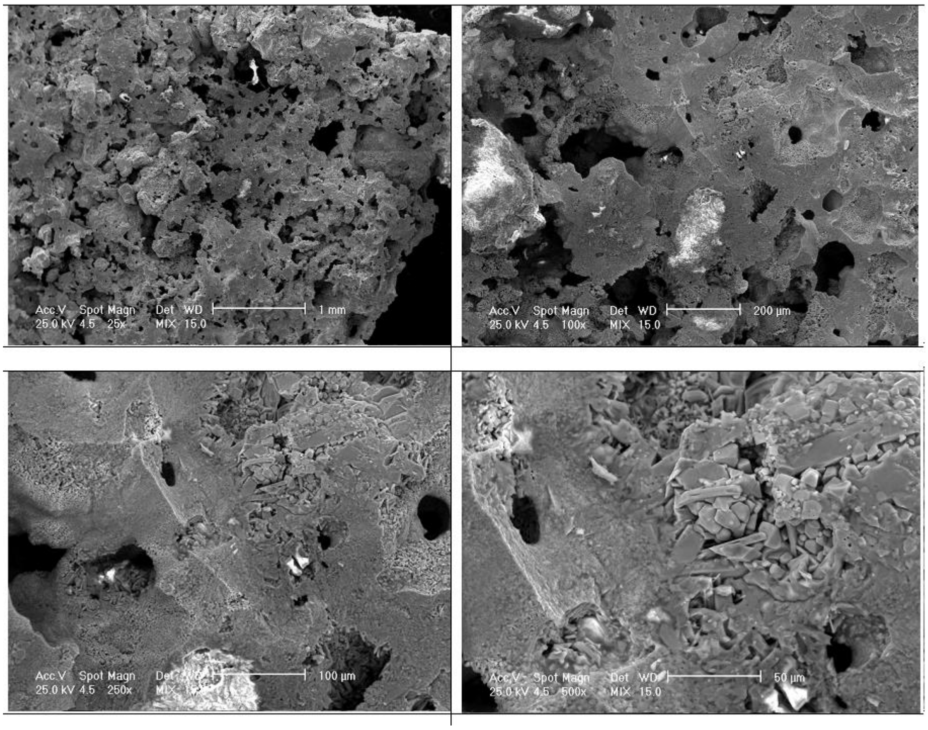

Fig.6 SEM images for R3 sample pellets at different magnification orders [1]

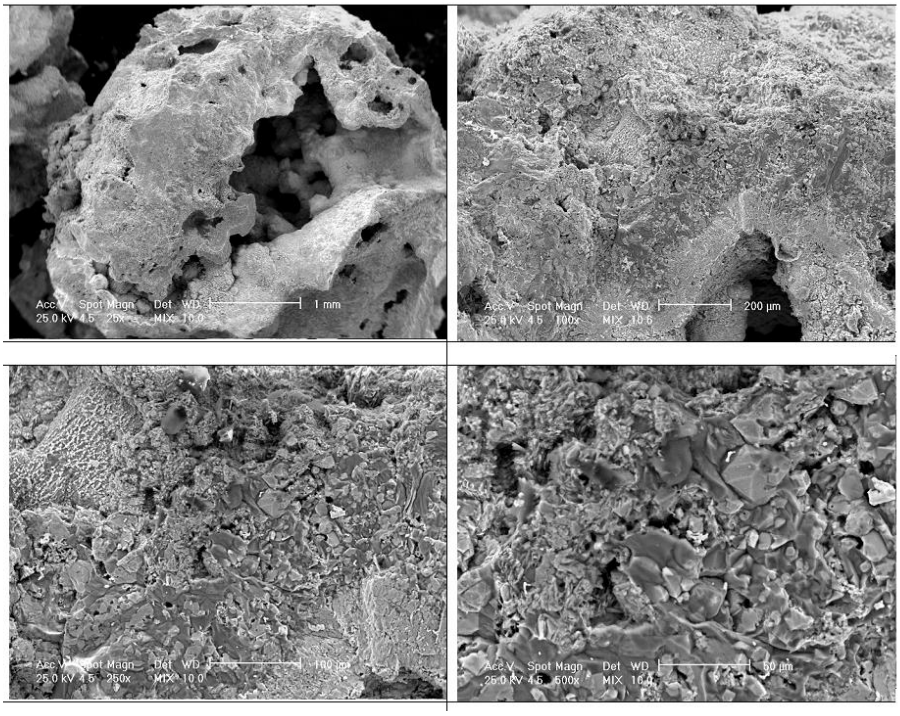

Fig.7 SEM images for R4 sample pellets at different magnification orders [1]

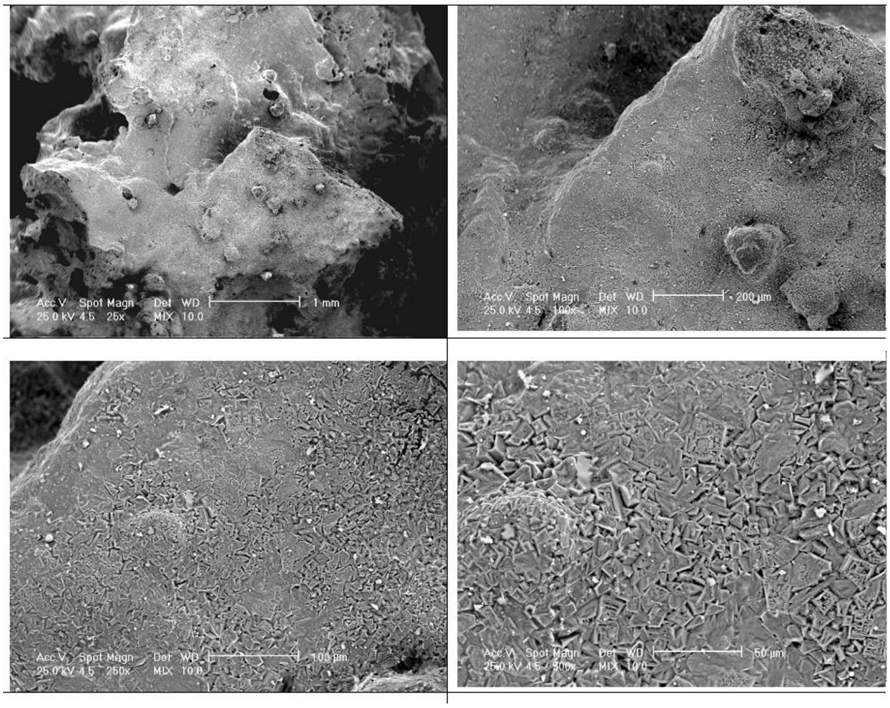

Fig.8 SEM images for R5 sample pellets at different magnification orders [1]

3. Results and discussions

The results of the research are represented by obtaining reduced pellets containing at least 85% metallic iron, their capitalization in the blast furnace and steel sectors, but at the same time an important contribution to improving the environmental conditions in the areas where they are currently stored.

These wastes from which the pellets were made to capitalize on the real potential of these surfaces. It can be observed that the pellets from sample R1 have the highest degree of metallization, in which steel dust predominates 82%, but in which graphite with about 5% is present in the recipe. The weakest degree of metallization has the pellets made in the recipe with the most sludge from the blast furnace 40% but also with the lowest percentage of graphite 3%. A slight disintegration was observed in all samples due to the surface friction forces between the pellets and between them and the walls of the thermal chamber of the furnace. Investigations performed by electron microscopy on pre-reduced pellet samples reveal the appearance of the new phase of freshly reduced iron (areas of maximum brightness), with polyhedral or slightly irregular shapes, dispersed in a mass of unreduced oxides, among which iron oxides predominate. The areas of hematite or wustit, appear in these images in gray with different shades.

In all samples, an increased internal porosity of the pellet is observed, represented by the very dark areas, a porosity that appeared because of a slight disintegration of the pellets during the reduction due to the release of CO following the reduction reaction of iron oxides with carbon. The porosity is more advanced, presenting even macropores and cracks, if the pellets have suffered phenomena of mechanical disintegration because of a low resistance to friction and their physical corrosion. It should be noted that all the pellet samples passed to a mixed structure of metallic iron, unreduced and sterile iron oxides, proven by both chemical analysis and electron microscopy images.

4. Conclusions

The experimental research carried out validates the technology of making pre-reduced pellets of carbofer type, obtained from fine-grained ferrous waste and fine-grained carbonaceous waste or energetic coal dust.

The subject is of great interest starting from the fact that in the current stage the main problems of the steel industry refer to: reduction of manufacturing costs, increase of productivity, improvement of product quality and improvement of the impact on the environment in the conditions of increasing constraints.

The economic impact of the research works consists in the reintroduction in the economic circuit of some industrial wastes (steel dust, tundra, agglomeration-furnace dust, ferrous slag, lime dust, power plant ash, tailings, etc.)

thus making possible the replacement in steel processes of some raw and auxiliary materials extracted from the deposit or quarries. The social impact and implicitly the impact on the environment are direct positive consequences of the implementation of the proposed technology of waste recycling, respectively of prevention and fight against pollution. It should be mentioned that in Romania this technology has a 100% originality character.

R E F E R E N C E S

[1] *Alina Cristina Mihaiu*, Studii şi cercetări privind eficientizarea elaborării aliajelor feroase prin valorificarea avansată in tehnologii alternative a deşeurilor si subproduselor. Teza de doctorat, Bucuresti, 2012

[2].*Nicolae Constantin* ,Procedee neconvenţionale de obţinere a materialelor feroase, Editura Printech Bucureşti 2002, 161 pagini,ISBN-973-652-682-8

[3]. *Heput T., Socalici A., Ardelean E., Ardelean M., Constantin N., Buzduga R*., Valorificarea deşeurilor feroase mărunte şi pulverulente, Editura Politehnica Timişoara,2011, pag.327.

[4]. *Vilcea,E.D., Hritac,M., Constantin, N ; Butu, M ; Rucai, V ; Dobrescu, C* , Experimental Research at the Industrial Level for the Production of Ferrous Agglomerates from Iron Ores and Ferrous Waste , Revista de Chimie (70), nr.12, 2019, p.4275-4282, ISSN 0034-7752

[5]. *Tudor, M D; Hritac, M; Constantin, N; Butu, M ; Rucai, V ; Dobrescu, C* , Experimental Research on the Qualitative Characteristics of Iron Ores and Ferrous Waste That Can Be Used in Blast Furnace Mixt Injection Technology , Revista de Chimie (70), nr.11, 2019, p.3835-3842,

[6]. *A. NicolaE, C. Dragan, C. Stefan Gradinaru, V. Rucai, M. Nicolae*, Ecotechnologies - a major route for durable-sustainable development in the metal materials industry “, Annals of the University Dunarea de Jos of Galati: Fascicle IX, Metallurgy & Materials Science. 2016, Vol. 34 Issue 1, p27-34.

[7]. *Socalici Ana, Ardelean Eerika, Strugariu Maria Laura*, Research on sustainable use of powdery waste, Environmental engineering and management journal, Volume:15, Issue: 1, p. 207-212, Published: JAN 2016

[8]. *Socalici, A.V., Heputţ, T., Ardelean, E., Ardelean, M*., Ferrous waste processing by pelletizing, briquetting and mechanically mixed, International Journal of Energy and Environment, Volume 5, 2011, Issue 4

[9]. *Socalici, A.V., Ardelean, E., Crişan, E*., Research on increasing the reaction surface of self-reducing briquettes, Environmental engineering and management journal, Volume 15, Issue 2, February 2016, pages: 443-451

[10].*Socalici A., Ardelean E., Heput T., Ardelean M.*, "Research regarding pulverous ferrous waste processing by pelletizing", *International Journal of Energy and Environmen*t, 3 (6), pp.334-341,2012.

[11]. *Brandusa Ghiban, V. Rucai, N. Năvodariu, V. Săceleanu, D.-T. Bran*, The influence of the heat treatment over the mechanical behavior of steels used for alternator shafts, U.P.B. Sci. Bull., Series B, Vol. 81, Iss. 3, 2019.