PROCESSING OF FERROUS OXIDE WASTE BY REDUCING MELTING IN CUPOLA FURNACE

Cosmin Petre MITITELU[1], Mircea HRITAC[2], Valeriu RUCAI[3]

The current legislation and the necessity of waste recycling after joining the European Union call for solutions for the processing of a wide variety of waste, especially those from the historical waste dumps left from the industrial activity [1] as well as those that are produced in the capacities of current production in operation. The purpose of the paper is to provide a series of clarifications and contributions on the use of the cupola furnaces' potential in the processing and recovery of waste from various sources, mainly ferrous waste from different industrial sectors and for which there are no other recycling solutions efficient than processing in vertical reduction furnaces in the cupolas or low capacity furnaces category. In this paper is presented a project of specific technology and equipment, adapted to this technology, which produces foundry cast iron, from ferrous bark, coke and self-reducing oxidic briquettes made from iron powders industrial wastes.

Keywords: pulverulent ferrous waste, cupola furnace, cast iron.

1. Introduction

Compared to other cast iron casting processes, cast iron production in cupola furnace aggregate has the benefits of high productivity and relatively low energy consumption (Table 1). The cast iron production technology of the second fusion is characterized by the rewrapping of a metallic charge made of solid fusion first iron, scrap iron in various proportions, ferroalloy additions (mainly ferro-silicon for the required silicon input) and limestone. The second fusion cast iron is used for casting into parts, which is why it is also called foundry casting. [3]

Table 1

Compares the energy consumption and productivity data for different aggregates in which foundry cast iron can be obtained

Aggregate type	Productivity[t/m^2.h]	Heat consumption for 1 t cast iron at 1450^{o}C, [Kj/t]
Cupola furnace with cold air	1,5-1,7	1,21-1,47
Cupola furnace with warm air	1,8-2,1	1,36-1,83
Induction electric furnace 1,5-20 t	0,9-1,3	1,29-2,20
Induction electric furnace - 15 t	1,7-15 *	0,585

*[t/h]

[1] Ph.D. eng., University POLITEHNICA of Bucharest, Romania, e-mail: cosminmiti@yahoo.com
[2] Eng., S.C. CERMAX 2000, Bucharest,Romania, e-mail: m_hritac_cermax2000@yahoo.com
[3] Ph. D. University POLITEHNICA of Bucharest, Romania, e-mail: vrucai@gmail.com

In Table 2 is presented the classical structure of the load of some melting aggregates for production of cast iron.

Table 2

Classical structure of aggregate loading for foundry casting [2*]*

Component charge	Cupola [%]	Induction furnace [%]	Flame furnace [%]	Plasma furnace [%]
Cast iron	15-60	20-40	40 - 75	40-60
Scrap	0-60	0-40	10 - 25	0-20
Old cast iron	20-40	0-20	5 - 15	10-20
Own waste	20-40	20-40	5 - 10	20-40
Cast iron span and steel	0-20	0-20	3 - 10	0-20
Ferroalloy	0-10	0-15	0 - 10	0-15
Load, % collectors	3-10	0,5-2	0.5 - 3	0,5-2
Fuel, % collectors	8-18	-	9 - 17	15-20

2. Presentation of the unconventional technology

2.1. Presentation of the technological solution

The design of the melting technology suitable for the use of ferrous oxide waste materials as well as the establishment of the main parameters of the elaboration technology was accomplished only after detailed analysis of the parameters of the melting regime in the usual cupolas as well as the connection between these and the technological parameters. For this purpose, the correlation of the melting area height with the specific air flow and the temperature of the cast iron was compared with the case of the classical (100% metallic) cupolas and for the mixed load with up to 60% oxide briquettes plus 40% metal bark.

The technological solution is designed with 2 cubes with a 5-day operating cycle and 2 days of repair for each cupola.

The most important aspect dealt with in the present paper is the behavior of oxide briquettes that require radical changes in the process. These are based on the consideration of lighters in the process of heating in the form of bodies with endothermic reactions, which delay the actual heating process. On this basis was made the thermal model of the cube for melting the cargoes containing the fuel briquettes from powdered oxide materials.

Liquid cast iron is routed through the trough to the two cupola furnaces to a meltdown storage ladle from which can be casting directed simultaneously with the cast iron charging. The cast iron siphoned evacuation system shall contain an external accumulation chamber – ante-crucible system – firstly, and a cast-iron discharge system on a 3.54 m long cased trough to a 3,000 kg melting-mixer ladle, secondly. Evacuation of the cast iron from the melting-pot is carried out continuously through 20 mm siphon per single carbon block.

The evacuation process takes place continuously with no need to close the slag evacuation orifice which is placed 60^0 away of cast iron evacuation orifice and it is discharged into a metallic steel ladle lined with a stamped mass. The external storage chamber has a volume of 3.5 l and holds 27 to 30 kg of cast iron in order to maintain a controlled level of liquids in the cupola furnace crucible, namely 100 mm of cast iron from the wind and 150 mm of slag at the iron level.

2.2 The raw materials

The raw material used consists of:

- pig iron bark and steel bark resulting from recycling activity - recovery from slag dumps, the bark must have a maximum size of 200 - 220 mm and a minimum of 30 mm with a degree of impurities between 75-85% with oxide materials;

-coke, coke used may be foundry coke or metallurgical coke used in furnaces. For blast furnace coke it is recommended to cut and use in the cupolas the fraction of over 40 mm or inserted into the recipe for the production of briquettes with a clearance <0.8 mm; coke can be imported from Poland or Ukraine and with small differences, depending on the source, has average granulation: 30-90 mm; density in bulk : 550 to 750 kg / m^3; moisture: 8-10%; ash: 10-14%, volatile: 0.7-1.5%.

-briquettes from dusty ferrous oxide waste recovered from waste dumps with a Fe content between 35-65% of maximum grain size 1 mm.

Pulverized ferrous oxides wastes come from historical or current waste dumps [8], [9], [11] are: blast furnace dust and sludge, dust from electro filters, dross, a high metallurgical value can be used alone in the load of the cupola furnace.

-limestone with grain size is 30 mm and maximum 60 mm; which can be purchased from the intern market from traditional producers, example Medgidia.

The quantity of raw materials used in specific and annual values is given in Table 3, calculated at a production of approximate 12,000 t of liquid per year.

Table 3.

Specific material consumption

Details	kg/t cast iron		t/year	
	Without briquettes	With briquettess	Without briquettes	With briquettes
Barks	1180-1200	590-600	14500-15000	7100-7300
Metallurgical coke	160-170	230-250	2000	2800-3000
Chalk	30-37	35-40	360-400	420-470
Oxide waste	-	7000	-	12000-13000
Coke dust	-	200	-	240-280

2.3. Products and by-products obtained

The products and by-products obtained from the manufacturing process are:

- Liquid cast iron - is designed for a production of 12,000 tons per year and is poured into 17-20 kg / piece billets and a small part - commanded - is poured into pieces - 3-5%.

The chemical composition of the cast iron is C_m = 3.8-4.2%; Si = 0.7-1.3%; Mn = 0.8-1%; S 0.03 - 0.05%; P = 0.06-0.1%.

Cast iron castings are for cast iron foundries as raw material [6], [7].

The by-products obtained by this technology are cupola slag, crude cupola furnace dust and scrubbing dust from scrubbing.

- Cupola furnace slag has a chemical composition: SiO_2 = 38-45%, CaO = 35-47%, Al_2O_3 = 5-7%, MgO = 1.7-2.5%, IB = 0.9-1.05, and resulting in an amount of 80-120 kg / t cast iron. It will be shipped to cement plants by contract.

- Cupola furnace dust results from the regular discharge of the scrubber. Granulation and composition make it attractive for its recycling in oxide briquettes where it participates as a reducer and the arrestor-.

It contains coke dust: 70%, slag: 10% and limestone: 20%

- Scrubber dust - is a mixture of coke powder, slag, lime dust, with a finesse of less than 70-80µm. It is stored and reused in the briquettes.

- Brick and carbon blocks resulting from the periodic demolition of the two cupolas, represented by chips or whole chips of brick and carbon blocks, are processed to the highest degree.

Chamotte brick is ground and used for stamping cast iron gutters as a filler material between brick and brick when building the cupola furnace and the crucible. The estimated quantity of by-products that may result annually is shown in Table 4.

Table 4

The estimated quantity of by-products that can be produced annually

Details	kg/t cast iron		t/year		
	Without briquettes	With briquettes	Without briquettes	With l briquettes	Secondary waste regime
Cupola furnace slag	100	150-160	12000	1800-2000	Recirculate
Dust scrubbers	30-35	440-55	360	480-550	Recirculate
Dust and pieces of the arrestor	20-30	30-50	240-300	480-600	Recirculate
Bricks Scraps from demolitions	3,5-4	4,5-5	42-50	54-60	18-20 – recirculate; 35-40 are dumped or recovered at refractory products

The by-products of the manufacturing process do not come in direct contact with the main environmental factors, so their monitoring is reduced to the periodic measurement of the quality of the gases exhausted in the chimney. The trace elements are: NO_x, SO_x CO, H_2S and are performed sequentially with the cubic gas monitoring analyzer. The projected technological flow indirectly uses the process water to cool the cupola furnace body through a closed-circuit system in which water losses are due to evaporation from the forced draft cooler rated at approx. 20-30% of the recirculated amount. There are no losses or water spills from the circuit in the sewer. Waste from the stream is intended to be deposited in metal barrels or under cover for re-use and therefore possible rainwater infestation with by-products or wastes is excluded.

3. The main technological equipment components

The main components of the technological flow are the blast-furnace scrap batch of iron oxides, the two cubes, the gunpowder for cast iron storage and the casting train.

3.1. The briquetting line of wasteful scrap of iron oxides

It consists of: 2 coke dust storage bins and 2 ferrous waste bins built in a complete casing system and pneumatic supply with bag filtering with bags, storage capacity of 50 tons for ore and 18 to 20 tons of dust of coke. A storage hopper will be used for binder - molasses or bentonite.

The homogenizer for dosing and mixing rotary drum materials has a capacity of 3000 kg / h and continuous operation.

The feed is made with a conveyor belt with a rubber mat of l = 500 mm which brings the components of the recipe, ferrous waste, coke and bentonite dust and with continuous feed.

3.2. Cupola furnace

The cupola furnaces have a working diameter Φ 600 mm; 2 rows of 4 wind gouges on a 900-degree inclined 7-100 scale; continuous cast iron sink and sink hole with 25 - 30 liters of liquid cast iron for controlling the level in the crucible; cast iron level in crucible 70-100 mm, slag level 200 - 250 mm;

Fig. 1 shows the construction of a cupola furnace specifically designed for ferrous waste processing.

The total height of the cupola’s workspace = 5900 mm ~ 6000 mm and the diameter of the parachute Φ 1800 mm.

3.3. Iron ladle for cast iron storage

The cast iron storage compartment must allow continuous casting to be cast from the two-cupola furnace and during casting for cast iron; equipped with a CH_4 burner to maintain iron temperature; capacity of the pot - 0,83 m3.

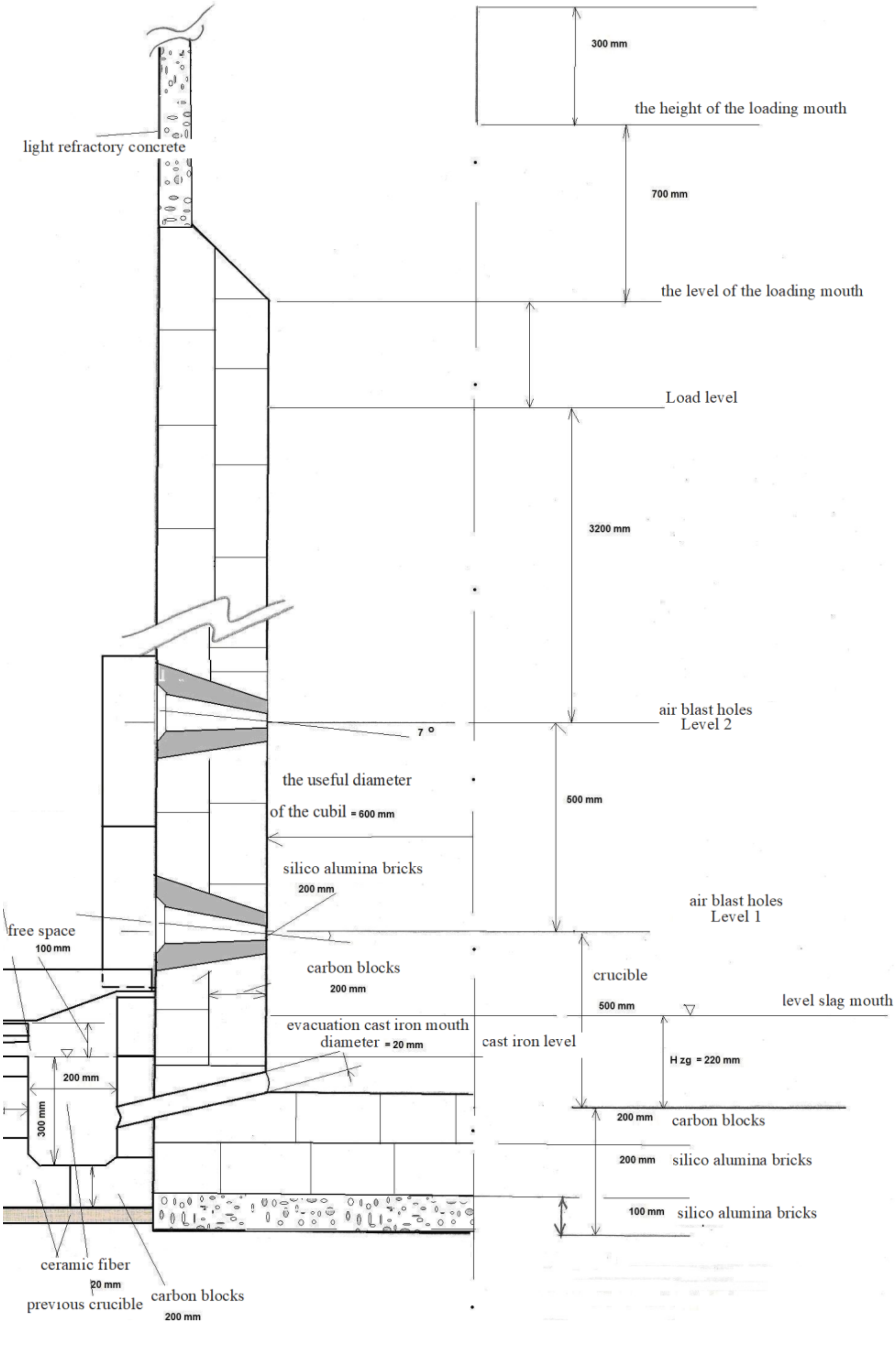

Fig.. 1. Section with unconventional cupola furnace with modified height for working with briquettes from pulverulent ferrous waste and cast iron and steel bark [2]

The construction of the torpedo ladle allows for continuous discharge of the two-cupola furnace. The schematic diagram of the torpedo ladle is presented in Fig. 2.

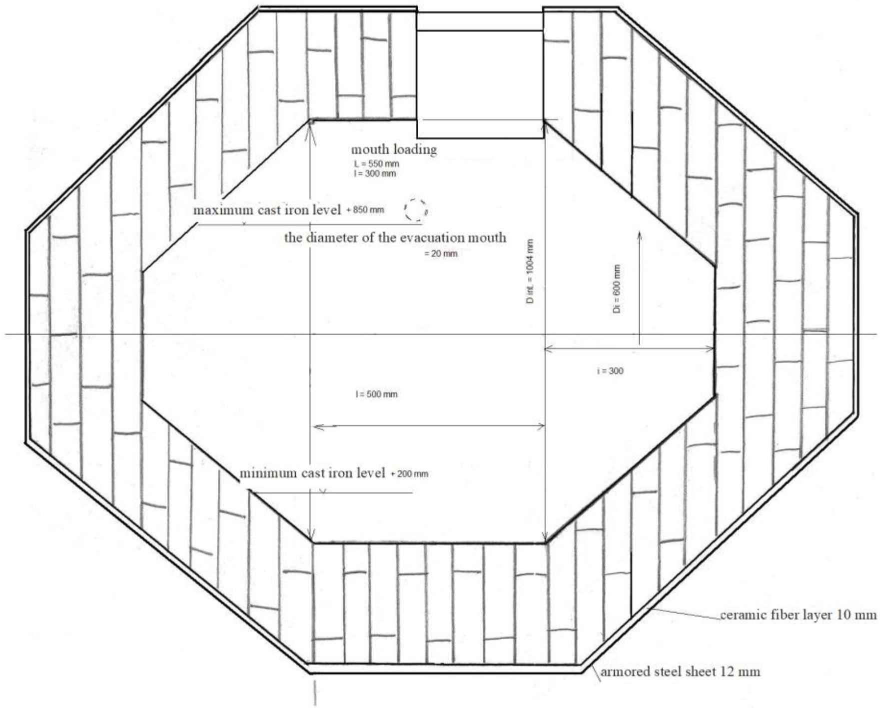

Fig.. 2. Cast iron storage vessel made of cupola furnaces in axial tilt construction [2]

The ladle must store the cast iron produced by the two cupolas furnace during a casting cycle of 90 minutes.

3.4. Casting train

The casting train is shown in Fig. 4 and consists of the rolling path and the mobile train (Fig. 3).

The tread is made of 22 m-long welded reinforced corridor rails;

Moving Rolling Train is a rigid welded profile frame that supports 30 folding cast iron holes that ensure their passage over the filler molding hole, the cooling station to the optimum removal temperature of the ingots and their tilting capability in the debate area. The length of the mobile train is 12 m.

It ensures the casting of 2,2 - 2,8 t / h. The displacement is achieved by cable traction driven by the 12,5-kw driven motorized drum.

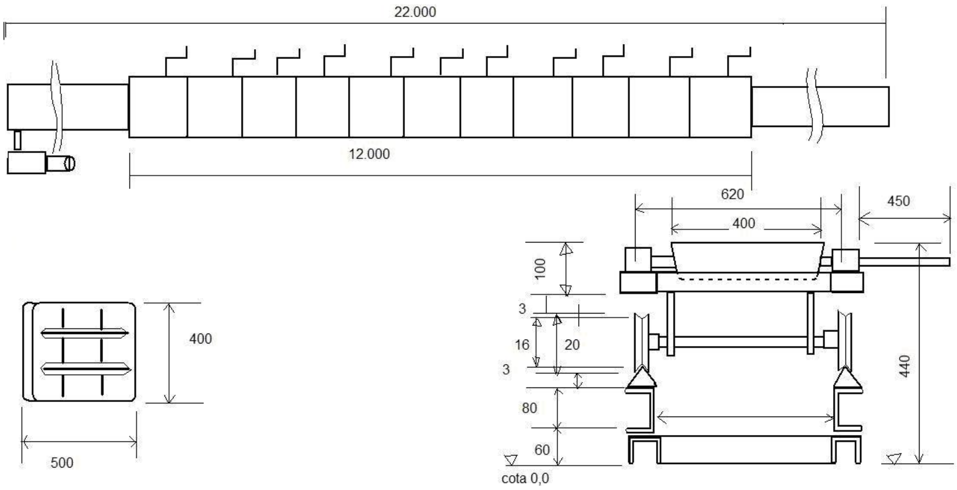

Fig. 3. Casting train with 30 rounds of 90 kg casting capacity [2]

The stripping area - is a work perimeter where the ingots are tipped from the casting train into a perpendicular metal strip downstream of the casting train. The band is 4 m long, l = 500 mm and 20 ° driven with a 5,5-kW reducing-motor.

The billets are stored in metallic bins of 2.0 m^3 and transported in an area to be dispatched. Effects on the environment are controlled and within limits allowed by law and positive. The coke, waste ore, limestone and slag dust from material handling and cupola furnace process estimated at approximately 70-90 kg / t cast iron or 1600-1200 t / year are recycled completely through briquetting and reintroduction into its own production stream. In the first 6 months of commissioning, in Stage I - it will be stored in the perimeter of the production hall in metal containers - and will be recycled at the start of Stage II when it will be used for the manufacture of oxide briquettes from oxide waste ferrous.

4. Conclusions

The most important aspect dealt with in the present paper is the behavior of oxide briquettes that require radical changes in the process. These are based on the consideration of briquettes in the process of heating in the form of bodies with endothermic reactions, which delay the actual heating process. On this basis, the thermal model of the cube for melting the cargoes containing carbonated fuel briquettes from powdered oxide materials was obtained.

With this technology, foundry cast iron is obtained under ecological conditions and at low cost, the raw material being different powdered ferrous scrap, which cannot be efficiently processed by other technology. The effects on the consumption of ferrous oxide waste deposited in tailings dumps can be quantified in annual waste consumption by this technology, which is estimated at approx. 12000 - 13000 t / year. Using this technology highlights the beneficial effect of cupola furnace slag recycling in the cement industry [17], data from the literature showing a decrease of up to 75% in CO_2 emissions when using 70% cubic slag as raw material for cement production.

There is a compromise between the profit level and the metallurgical value of the used waste that is directly the profit decreasing with the decrease in the Fe content of the waste [9], [11], [12]. The extent to which official bodies - the City Hall, the Environment Agency can provide various financial facilities will translate into the larger amount of low-value waste that can be processed annually. In this context, any facility allowed by law and the environmental norms that may be granted by the competent bodies to facilitate the firm's activity must be considered and given because it is for the benefit of the local community. These may be granting the concession of the company's waste dumps under favorable conditions; the allocation of the CO_2 share of the activity in proportion to the quantity of cast iron produced and the amount of waste consumed including the granting of facilities for the acquisition of CO_2 certificates; Providing favorable conditions for achieving the compliance program for the realization of the environmental investment; granting facilities to fund the Environment Fund or European Funding.

The effects on the environment are controlled and within the limits allowed by law and positive [15], [16]. The coke, waste ore, limestone and slag dust from material handling and cupola furnace process estimated at approximately 70-90 kg / t iron cast or 1600-1200 t / year are recycled completely through briquetting and reintroduction into its own production stream. In the first 6 months of commissioning, in stage I - it will be stored in the perimeter of the production hall in metal containers - and will be recycled at the start of stage II when it will be used for the manufacture of oxide briquettes from oxide waste ferrous.

R E F E R E N C E S

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

[2]. *Cosmin Petre Mititelu* -teza de doctorat - Studii şi cercetări experimentale pentru procesarea deşeurilor oxidice feroase prin topire reducătoare în cuptoare de tip cubilou-Universitatea POLITEHNICA Bucuresti, 2014

[3]. *I. Riposan,M. Chisamera.* Tehnologia elaborarii si turnarii fontei. Ed.Didactica si Pedagogica, Bucuresti,1981.

[4]. *I. Riposan, I. Chira, M. Chisamera, L. Sofroni, S. Stan.* FONTE. In: Tratat de Stiinta si Ingineria Materialelor Metalice, Vol. 3, ASTR-Academia de Stiinte Tehnice din Romania, Ed. AGIR, 2009, pp. 463-580.

[5]. *Buzduga Radu; Constantin Nicolae; Ioana Adrian*-Solutions to reduce the environmental pollution by the producers of refractories- Scientific Bulletin Series B Chemistry and Materials Science: Volume: 80 Issue: 1 Pages: 231-244 Published: 2018

[6]. *Nicolae Constantin* “Ingineria producerii fontei în furnal” Editura Printech Bucureşti 2002, 298 pagini,ISBN-973-652-672-0

[7]. *Constantin N., Stanasila O., Stanasila, C., Dobrescu C., Petrache R., Gheorghe N.,* – Alternative iron making technologies, Published: 2009, Metalurgia International Volume 14 Issue 7 Pages: 5-7, ISSN: 1582-2214.

[8]. *Socalici, A., Heput, 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]. *Heput T, Socalici A, Constantin N., ş.a.* " Valorificarea deseurilor feroase marunte si pulverulente", Editura PolitehnicaTimisoara 2011,339pag., ISBN 978-606-554-245-7

[10]. *Carlan Beatrice Adriana, Constantinescu Dan, Constantin Nicolae*- Study regarding the thermal properties of the iron oxides - Scientific Bulletin Series B Chemistry and Materials Science: Volume: 78 Issue: 4 Pages: 169-180 Published: 2016

[11]. *N. Gheorghe, C. Dobrescu* - “Experimental research laboratory for the purpose of their own recovery with maximum economic efficiency of fine ferrous waste” - Revista Metalurgia, Nr 3/2012, pag.5-9, ISSN 0461-9579

[12] *N. Gheorghe, C. Dobrescu* - “Laboratory research onphysico-chemical properties of thermal power station slags “- Revista Metalurgia, Nr 3/2012, pag.10-14, ISSN 0461-9579

[13] *Cosmin Petre Mititelu, Mircea Hritac, Nicolae Constantin*; - Experimental researches on briquetting and melting of fine ferrous waste., Scientific Bulletin Series B: Chemistry and Materials Science. ISSN 1454 – 2331, Vol. 76, Iss. 4, 2014, pag 215-224

[14]. *Cosmin Petre Mititelu, Mircea Hritac, Nicolae Constantin;* - Laboratory experiments for determination of optimal characteristics of ultrafine ferrous waste briquettes to be used in cupola furnace, Scientific Bulletin Series B Chemistry and Materials Science: ISSN 1454 – 2331, Vol. 77, Iss. 1, 2015, pag 157-164

[15]. *C. Stănăşilă, N. Constantin, O. Stănăşilă, R. Petrache*” Some computations regarding directly reduction of the iron ores “Scientific Bulletin Series B Chemistry and Materials Science: Vol. 70, No. 2, 2008, ISSN 1454-2331.

[16]. *Ilie Butnariu, Nicolae Constantin*-Protecţia mediului înconjurător şi microclimat – Editura Universitatea "Politehnica" Bucureşti, 1994, 137 pagini

[17]. *Ilie Butnariu, Nicolae Constantin, Cristian Dobrescu, Teodor Heput* et al.- Research on the recycling of pulverulent waste from the ferrous and non-ferrous industry in order to reduce the pollution, Revista de Chimie, Volume: 69, MAY 2018, Issue: 5 , Pages: 1066-1070.