EXPERIMENTAL RESEARCH REGARDING DECREASING OF FABRICATION COSTS OF METALLURGICAL COKE BY USING NON-COKING COALS AND RECYCLING OF SMALL COAL

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The present article addresses an important subject in the metallurgical industry, the unconventional technological processes of producing metallurgical coke. The fabrication principle presented in the article refers to the utilization of non-coking coals and recycling of small coal. The purpose of the laboratory experiments was to determine the parameters that condition the possibilities of degreasing bituminous coal with certain additions. By adding small coal, an increase in coke quality is obtained. In comparison with the semi-coke, the addition of small coke with the same grain size has a more powerful degreasing effect. The coke's grain size also has an influence on the degreasing capability in the sense that the finer the coke the more degreasing it becomes, more active. Utilizing small coke in the load requires smaller quantities the finer it is grinded.

Keywords: coking, non-coking coals, coke small, economic efficiency

1. Introduction

In Romania, the mining resources of coking coal are small and cannot guarantee the requirements metallurgical industry. Of all the coal mines, only some contain coking coal, these being coal mines from Lupeni, Uricani and Barbateni [2]. Although from a geological point of view these coals are tertiary, from the chemical-technological point of view, they are gas pit coals and under normal conditions, they form swollen and spongy cokes without mechanical resistance. Obtaining metallurgical cokes from the above-mentioned coals requires ameliorating the coking characteristics by degreasing the gas pit coal with different carbon-based materials [3].

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Like [4] “Exploitation of natural resources, energy consumption and wastes resulted from technological processes are the main cause of environmental damage. In this context, the protection of natural environment is a fundamental requirement of the continuity of economic and social life”. Also, in the ecological context, any recycling process, besides the economic advantages, brings ecological advantages subscribing to the Durable Development concept [5,6].

2. Experimental

Research methodology

The purpose of the presented research in this paper is studying the possibilities of utilizing the small coke in the degreasing process, as well as the advantages and disadvantages that could result in the case of performing the process of carbonizing lean material at high temperatures. In this regard, a series of recipes were prepared using Lupeni coal, as degreasing agent fluidization coke and coke small.

For comparison purposes, samples were made using as degreasing agent fluidization semi-coke. The influence of the usable quantity of degreasing agent was tracked, in the case when coke small of different sources was used, on the cokes quality and the results were compared with the ones obtained when using semi-coke as degreasing agent [7].

The test samples were done in Gray-King horizontal furnace, Fig. 1, as well as in the laboratory vertical furnace, Fig. 2. The quality of coke tracked in the first set of samples, was compared to the standards, as well as the mechanical resistance of the obtained coke for the samples in the vertical laboratory furnace.

Through the results obtained, this paper brings a small contribution in clarifying, at experimental level, parameters that condition the degreasing possibilities of the young pit coals with certain additions.

Experimental equipment

The following laboratory equipment was used:

-horizontal laboratory furnaces (Fig. 1);
-grinding and hammer mill, for grinding the coal and coke to the proper grain size (0-1 mm);
-sieve (0.2-0.5; 1 mm), for obtaining the required grain size;
-pestle mill, for coke crushing at different grain sizes accessible to the mill;
-technical scale and weights;
-retorts;
-Nedelmann drum.

Fig. 1. Horizontal furnace for determinations on coke

Where:

1. Electrical horizontal furnace
2. Converter
3. Gas tank
4. Assembly for filtering reaction gas

Raw material used

Studies on the possibilities of utilizing small coke as a degreasing addition to the Lupeni coals have been performed on Lupeni coals, specially washed, from the current production. Chemical and technological characteristics of the utilized materials, according to the above-mentioned methodology are presented in Table 1.

Table 1.

Chemical and technological characteristics of the coals utilized in the laboratory works

Coal Type	Technical Analysis					Expansion index	Dilatometric index	
	Reported to the analysis sample			Reported to the dry sample, 105ºC	Reported to the fuel mass			
	Humidity	Ash	Volatiles	Ash	Volatiles		Contraction	Expansion
	W^a	A	V^a	A^{anh}	V^{mc}		a	b
	%	%	%	%	%		%	%
Specially washed pit coal (0-10 mm)	2.25	8.65	36.2	8.85	40.57	2 ½	20	42
Semi-coke	2.8	11.46	12.34	11.8	14.4	-	-	-
Fluidization coke 900ºC	3.43	18.71	2.64	19.3	3.39	-	-	-
Coke obtained under static coking conditions	1.35	12.85	1.85	13.06	1.93	-	-	-

Conducting the experiments in the laboratory

Tests done on 60 samples, following the methodology descried bellow:

Coal from Lupeni, specially washed, with a grain size of 0-10 mm dried for 2-3 days, after which it was grinded mill.

The coal was put through a sieve of 0.25 mm. After separating the different grain categories, a homogenous mix is made of 20% grain size below 0.25 mm and 80% grain size above 0.25 mm. In addition, coke obtained under static conditions was grinded, and then it was crushed in the pestle mill to the accessible grit to avoid jamming of the mill. Then the mixture is put through sieves 0.2 mm, 0.5 mm, 1 mm.

After everything done, the mixture is introduced into gauge glasses with a plug for each grit. The same process applies to semi-coke and fluidization coke at 900ºC. The quantity of coal prepared for testing must not be more than what can be used in 2-3 days so that it does not degrade by oxidation.

Based on different recipes used in this work experiment a mixture is made in a metallic bowl of 0.5 kg (retort capacity): 90% LUB coal specially washed at 0-1 mm, 2% static coke 0-2 mm, 8% water.

The homogenous mixture is introduced in the retort and then pressed, after which the retort is introduced, using clippers, into the electric furnace heated at 800°C. Here the coking of the load takes place for 3 hours.

The retort is taken out and the coke extinguished by introducing the retort in a bucket of water. The obtained cokes have different quantities of degreasing agent, which differs both through the grain size as well as by its quality. After being dry a granulometric analysis is made, and it’s introduced in paper bags.

Further, the cokes resistance is determined in the Nedelmann drum, by introducing the pieces of coke as it was obtained, for 2 minutes.

Again, a granulometric analysis is performed.

For the degreasing agent’s effect to be recognized outside of the samples taken in the vertical laboratory furnaces, a series of samples were studied in which the mixture of Lupeni coal and degreasing agent was coked under the conditions of Gray-King index. The obtained residue was compared against the standards, thus establishing the degreasing agent’s effect. Results obtained are presented in Table 2. From the data and the results presented in Table 2, the following observations can be made:

-the degreasing effect of the fluidization coke is stronger than the effect of the semi-coke or of the metallurgical coke;

-the degreasing effect of any other addition of this sort is higher as long as the grain size is finer.

Table 2.

Characteristics of the coke obtained in the Gray-King appliance by using Lupeni coal and degreasing agents

Recipe						Gray-King Index	Recipe						Gray-King Index
Coal			Degresing agent				Coal			Degreasing agent			
Type	Grain size, mm	%	Type	Grain size, mm	%		Type	Grain size, mm	%	Type	Grain size mm	%	
Lupeni	0-3	98	Semi-coke	0-0.2	2	G3	Lupeni	0-3	98	Fluidization coke	0-0.2	2	F
Lupeni	0-3	97	Semi-coke	0-0.3	3	G2	Lupeni	0-3	96	Fluidization coke	0-0.2	4	E
Lupeni	0-3	96	Semi-coke	0-0.2	4	G1	Lupeni	0-3	92	Fluidization coke	0-0.2	8	E
Lupeni	0-3	92	Semi-coke	0-0.2	8	G1	Lupeni	0-3	86	Fluidization coke	0-0.2	14	C
Lupeni	0-3	90	Semi-coke	0-0.2	10	G	Lupeni	0-3	84	Fluidization coke	0-0.2	16	B
Lupeni	0-3	86	Semi-coke	0-0.2	14	F	Lupeni	0-3	98	Fluidization coke	0.5-1	2	G2
Lupeni	0-3	84	Semi-coke	0-0.2	16	E	Lupeni	0-3	96	Fluidization coke	0.5-1	4	G1
Lupeni	0-3	98	Semi-coke	0-0.3	2	G3	Lupeni	0-3	92	Fluidization coke	0.5-1	8	G1
Lupeni	0-3	97	Semi-coke	0.2-0.5	3	G3	Lupeni	0-3	86	Fluidization coke	0.5-1	14	G
Lupeni	0-3	96	Semi-coke	0.2-0.5	4	G2	Lupeni	0-3	84	Fluidization coke	0.5-1	16	F
Lupeni	0-3	92	Semi-coke	0.2-0.5	8	G2	Lupeni	0-3	98	Classic coke	0-0.2	2	G
Lupeni	0-3	90	Semi-coke	0.2-0.5	10	G1	Lupeni	0-3	96	Classic coke	0-0.2	4	E
Lupeni	0-3	86	Semi-coke	0.2-0.5	14	G1	Lupeni	0-3	92	Classic coke	0-0.2	8	E
Lupeni	0-3	84	Semi-coke	0.2-0.5	16	G	Lupeni	0-3	90	Classic coke	0-0.2	10	D
Lupeni	0-3	98	Semi-coke	0.5-1	2	G3	Lupeni	0-3	86	Classic coke	0-0.2	14	D
Lupeni	0-3	97	Semi-coke	0.5-1	3	G3	Lupeni	0-3	84	Classic coke	0-0.2	16	C
Lupeni	0-3	96	Semi-coke	0.5-1	4	G3	Lupeni	0-3	98	Classic coke	0.5-1	2	G3
Lupeni	0-3	92	Semi-coke	0.5-1	8	G2	Lupeni	0-3	96	Classic coke	0.5-1	4	G2
Lupeni	0-3	90	Semi-coke	0.5-1	10	G2	Lupeni	0-3	92	Classic coke	0.5-1	8	G1
Lupeni	0-3	86	Semi-coke	0.5-1	14	G2	Lupeni	0-3	86	Classic coke	0.5-1	14	G1
Lupeni	0-3	44	Semi-coke	0.5-1	16	G1	Lupeni	0-3	84	Classic coke	0.5-1	16	G

3. Results and discussions

The purpose of the works performed in the laboratory is the study of the degreasing possibilities using coke small. Standard samples of semi-coke were used, and similar samples were studied by using coke small. The differences in the quality of the obtained cokes under static conditions in classic furnaces, as well as the coke obtained from the pyrogenation installation in fluidized bed.

According to industry specialists, degreasing agents do not form strong chemical bonds during the coking process, they are cemented in plastic [8,9].

In accordance with cementing of grains of the non-agglutinating additions with the plastic mass, the surface characteristics are determined, its size and the property of forming string bonds. It is natural that coke grains, having the same size shall have the exterior surface much bigger than the pit coals and anthracite as a result the formed bond, much bigger for the coal grains, is contributing more in the plastic.

In order to obtain coke grains of the same size and of higher resistance it is required that the particles of the non-agglutinating coals to be grinded at a smaller grit than the coke small.[10]

At an equal grit of the coke in the load with additions of pit coals, finer coke is obtained with a lower resistance than in the load with coke small.

The results of the laboratory experiments mathematically processed are shown in the Figs. 2-9.

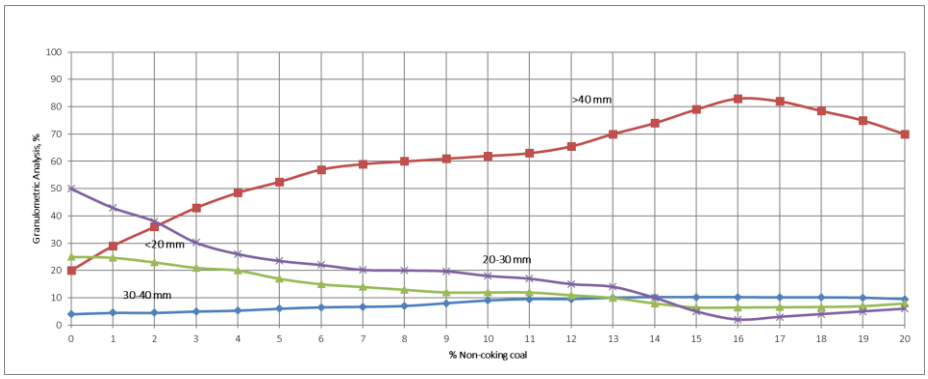

Fig. 2. The influence of non-coking coal (1 mm) on coke granulation obtained from coking pit coal in laboratory conditions [1]

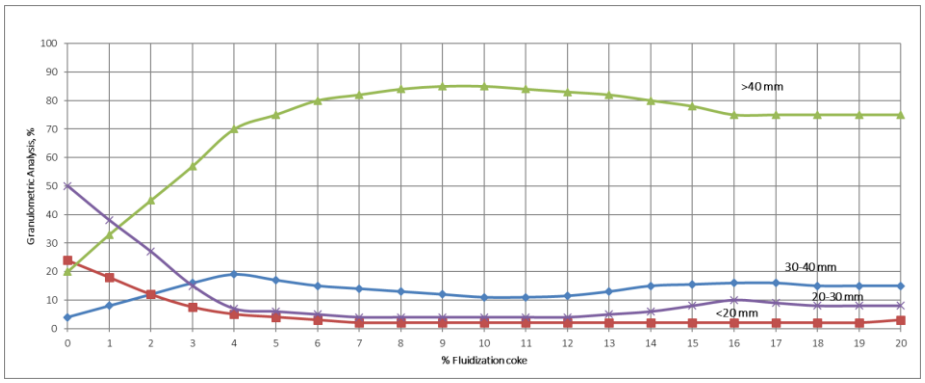

Fig. 3. The influence of the addition of fluidization coke (1 mm) on the granulation of coke obtained from coking pit coal in laboratory conditions [1]

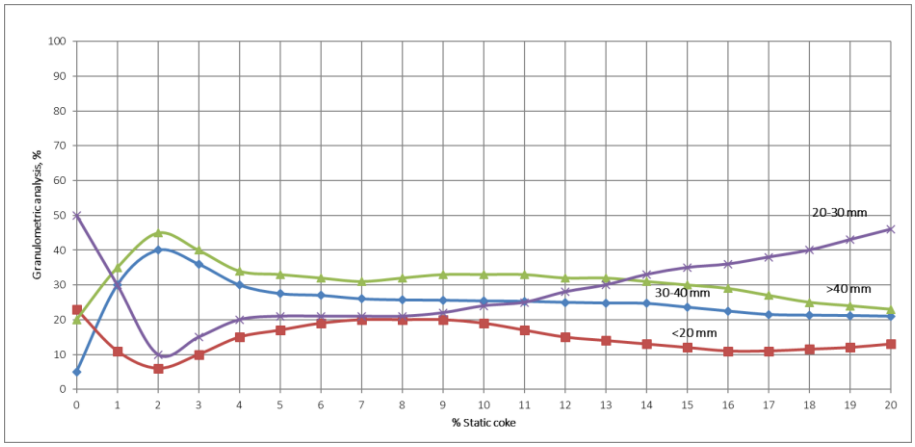

Fig. 4. The influence of the addition of static coke (1 mm) on the granulation of coke obtained from coking coal in laboratory conditions [1]

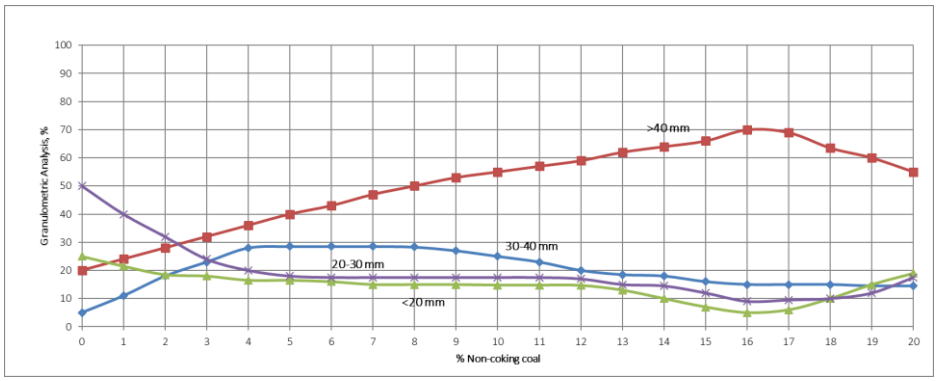

Fig. 5. The influence of the addition of non-coking coal (0.5 mm) on the granulation of coke obtained from coking coal in laboratory conditions [1]

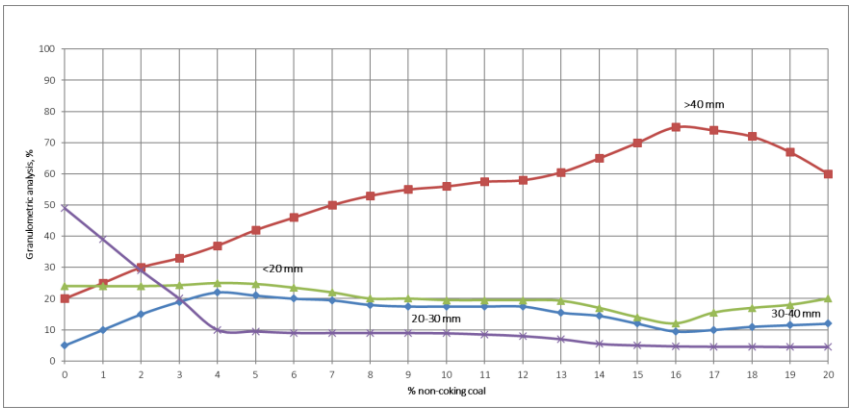

Fig. 6. The influence of the addition of non-coking coal (0-0.2 mm) on the granulation of coke obtained from coking coal in laboratory conditions [1]

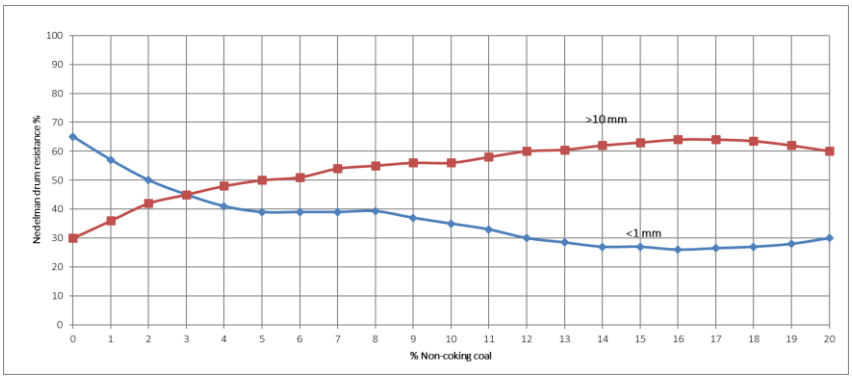

Fig. 7. The influence of non-coking coal (1 mm) on the resistance of coke obtained from coking pit-coal in laboratory conditions [1]

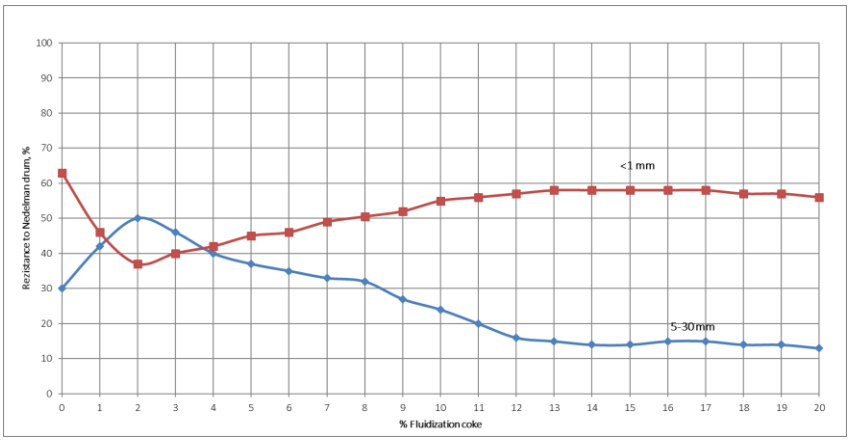

Fig. 8. The influence of the addition of fluidization coke (1 mm) on the resistance of coke obtained from coking pit coal in laboratory conditions [1]

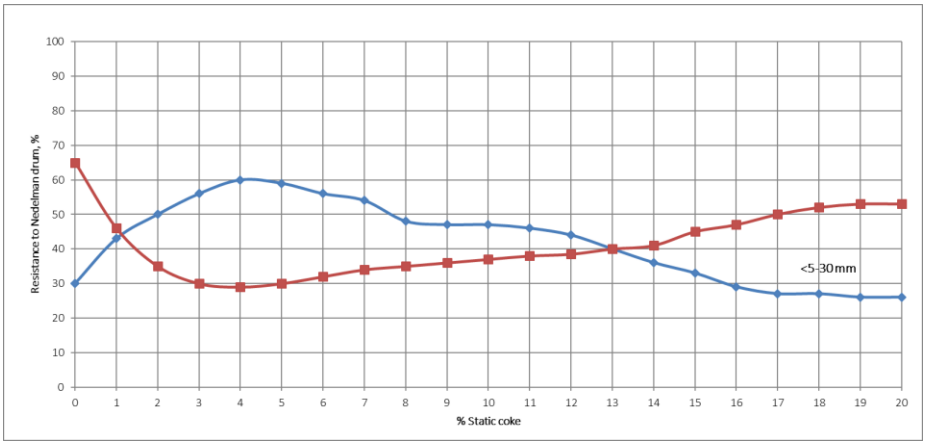

Fig. 9. The influence of the addition of static coke (1 mm) on the resistance of coke obtained from coking pit coal in laboratory conditions [1]

4.Conclusions

By analyzing the charts, resulting from processing the experimental results the following:

- For the additions of degreasing agents, the following materials were used: coke small, semi-coke, calcium oxide, anthracites etc. By adding coke small, a better quality of the coke was obtained;
- Compared to the semi-coke, the coke small at a similar grain size has as stronger degreasing effect;
- The fluidization coke has degreasing capacity higher than the coke obtained in classical furnaces;
- The granulation of the coke used influences the degreasing capacity in the sense that the finer the coke is the more active and degreasing it gets. By using coke small in the batch, it requires smaller quantities the finer it is grinded;
- In the case of coke small produced under similar conditions like the semi-coke, from energetic non-coking pit coals, the quantity of energetic pit coal introduced in the batch by degreasing it with semi-coke is higher than the one introduced by degreasing with coke small. This is natural because the required degreaser, when using coke small, is lower in case of using semi-coke;
- In the case of degreasing with coke small the fact that the grinding of this material is difficult and with a high energy consumption must be considered;
- The coke small at the required grain size is economic to be used for degreasing.

R E F E R E N C E S

[1]. *V. Andrei***,** „Eficientizarea procesului de elaborare a fontei în furnal prin micşorarea consumului specific de cocs metalurgic şi a costurilor de fabricaţie al acestuia”, teza de doctorat, UPB, October 2018

[2]. *V. Andrei***,** „Comparative analysis of the posibilities of decreasing cokes consumption in furnaces by partially replacing it with auxiliary fuels”, U.P.B. Sci. Bull., Series B, Vol. 81, Iss. 3, 2019, Pag.157-168.

[3]. *V. Andrei, M. Hritac, N. Constantin, C. Dobrescu* „Experimental research on the behavior of the pneumatic transport of fine-grained iron”, IOP Conference Series: Materials Science and Engineering 163 (2017) 012011

[4]. *M. Costoiu, A. Ioana, A. Semenescu, N. Constantin, B. Florea, V. Rucai, C. Dobrescu, M. Polifroni, L. Păunescu,* „Environmental performance indicators for decision making and stakeholder interests” in Environmental Engineering & Management Journal (EEMJ) ,Volume 15 Issue10, Pag. 2279-2284.

[5]. *M. Nicolae, C Dobrescu, V. Rucai, A. Nicolae,* „Use of Ecological Paradigm in Material Degradation Engineering”, Data publicării 2018/3/15,The Annals of “Dunarea de Jos” University of Galati. Fascicle IX, Metallurgy and Materials Science, Volumul 41, Numărul 1, Pagini 10-15

[6]. *A. Nicolae, C. I. Dragan, C. S. 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]. *V. Andrei, N. Constantin, C. Dobrescu*, „Cost efficiency of elaborating iron by using pulverized coala s a replacement for coke in blast furnaces”, Annals of Faculty Engineering Hunedoara, International Journal of Engineering, Tome XIII [2015] – Fascicule 3 [A,ugust]; ISSN: 1584-2673

[8[. *C. Stănăşilă, N. Constantin, O. Stănăşilă,* „Alternative iron making technologies”, U.P.B. Sci. Bull., Series B, Vol. 70, No. 1, pag.55-62

[9]. *C. Stanasila, N. Constantin, O. Stanasila, R. Petrache,* „A new method to dry some granular materials”**,** U.P.B. Sci. Bull., Series B, Vol. 69, No. 4, 2007, pag.71-77

[10]. *D. Vonica, M. Hritac, V. Rucai, N. Constantin*, „Proposal for improvement of current technology of processing oxide ashes”, in: ANNALS of Faculty of Engineering Hunedoara –International Journal of Engineering (online ISSN 1584 – 2673), Tome XVI (year 2018, Fascicule 3/2018 [August],BDI, http://annals.fih.upt.ro/ANNALS-2018-3.html