IDENTIFICATION BY EXPERIMENTAL SIMULATION OF THE PROCESS USING PULVERULENT SECONDARY MATERIALS DURING STEELMAKING

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În lucrare se abordează problema ***identificării procesului*** *de valorificare prin reciclare a materialelor secundare pulverulente la elaborarea oțelului în cuptoare cu arc electric (CAE) pe baza* ***modelării experimentale****. Materialele pulverulente se folosesc sub formă de brichete fabricate pe bază de praf CAE, țunder şi nămol. Pentru definitivarea tehnologiei a fost cercetată calitatea brichetelor prin teste de compresiune, teste de termocompresiune şi teste Shatter. În vederea identificării procesului, folosind modelarea experimentală, rezultatele au fost prelucrate grafic şi analitic.*

În final, sunt prezentate concluziile privind posibilitățile tehnologice de folosire eficientă în CAE a brichetelor cercetate

The paper is an approach to the problem aiming at the ***identification of the capitalization process****, based on experimental simulation, by recycling pulverulent secondary materials used in EAF steelmaking. Pulverulent materials are used as bricketts manufactured from EAF dust, scale and sludge. For the technology definitivation the quality brickets was analyzed by performing compression, thermocompression and Shatter tests. In order to identify the process by* ***experimental simulation****, the results were graphically and analitically processed.*

Finally, conclusions were drawn concerning the technological possibilities to use efficiently the studied bricketts in EAF.

Keywords: recycling, pulverulent secondary materials, steelmaking in EAF.

Introduction

In the last year the metallurgical industry was connected to principles of sustainable development (SD) concept. One of the important difficulties is operationalizing this model for the concrete conditions of a metallurgical plant. In this context one has to consider the following objectives when appliying the concept to steel making in EAF:

- recicling secondary materials, like powdered materials resulted at cleaning gases evacuated from the furnace: recicling them

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became compulsory both from the ecological and economic points of view, because it is well know that they contain metals that could be capitalizated;

- modifing technologies and installations for maintaing constant parameters in the new conditions;
- permanent analysis of the technical and economic parameters to demonstrate the superioriy of the new technologies.

Concrete aspects regarding for introducing at EAF of some requirements like those mentioned above are presented in this paper.

So improving the quality and efficiency of such new technologies depend on the application of optimal process and equipment control methods, based mostly on process identification [1].

The identification experiment consisted in two phases:

- obtaining information on the input and output parameters of the system;
- processing of aquired data.

The obtaining of models afferent to a process aiming its identification, represents in fact, the **experimental simulation**, as described by literature.

Taking into account the above mentioned premises, the paper tries to substantiate in a scientific manner the process of using secondary materials in EAF steel making, based on process identification.

1. Materials and Methods

a. *Concerning the brickets composition.*

The bricketts manufactured on the basis of EAF dust were obtained from the following materials within the weight limits mentioned below:

- EAF dust (D): 70-76%;
- bentonite (B): 6.5-7.0%;
- lime (L): 3.8-4.0%;
- limestone (Lst): 0.5-1.0%;
- coke (C): 12-17%.

The brickets manufactured from scale were of the following composition:

- scale (Sc): 59-64%;
- bentonite (B): 6.5-7.0%;
- lime (L): 0.5-1.0%;
- limestone (Lst): 0.5-1.0%;
- coke (C): 24-28%.

The bricketts manufactured from sludge (Sl) were obtained from the following materials:

- sludge (Sl): 62-66%;

- bentonite (B): 6.5-7.0%;
- lime (L): 4.7-5.7%;
- limestone (Lst): 0.3-0.6%;
- coke (C): 22-26%.

Also investigated were the cases when the brickets manufactured from EAF dust contained lime and bentonite in the following composition range:

- bentonite (B): 5-7.5%;
- lime (L): 2.5-4.5%.

b. *Compression tests*.

The goal of compression tests consisted in establishing the influence of brickets composition on their resistance, which is necessary when performing manipulation-transport-loading operations into the melting furnace.

The compression tests were carried out using a hydraulical universal machine UHP 20/17358 for tensile-compression-axial fatigue tests performed under statical conditions up to 200kN.

The test machine records the compressive force F [kN], it is also possible to record its values increasing function of time and plot the F-τ for each specimen (Fig.1).

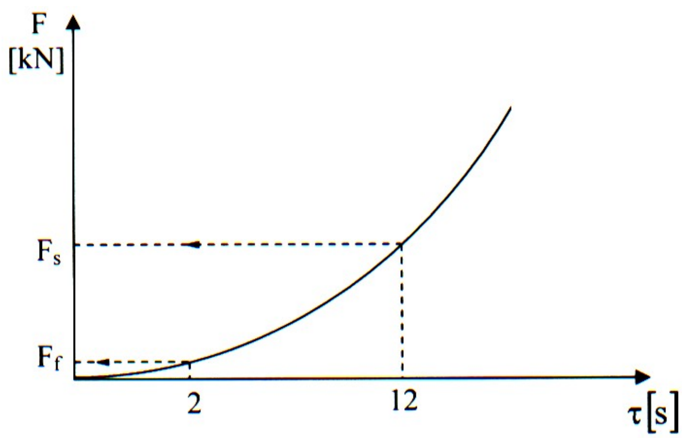

Fig.1 „F - τ ” diagram in the compression test

In order to evaluate the handling and transportation hazards for the bricketts [2], three technological characteristics were determined.

- *Cracking resistance*

$$R_f = \frac{4F_f}{\pi . d_b^2} \qquad [kN/cm^2] \qquad (1)$$

The cracking force F_f is considered as the force determining the first cracks, which can be visually detected. After a sufficient number of preliminary tests, one considers that this is the value recorded at the moment τ=2 seconds.

• *Crushing strength*

$$R_s = \frac{4F_s}{\pi . d_b^2} \qquad [kN/cm^2] \qquad (2)$$

Based on preliminary observations, one proposes the proper pellet crushing moment at τ=12 seconds;

• *Crushing range*

$$\Delta R_{fs} = R_s - R_f \qquad [kN/cm^2] \qquad (3)$$

c. *Thermocompression tests*

These tests were performed in order to determine the influence of temperature on the cracking resistance. The testing stages consist in:

• heating the dry kiln (V_u= 25x25x25 cm) at a testing temperature of (200, 400^0C) + 20^0C;

• feeding the heated furnace with bricketts, which are held for 5 minutes in order to obtain a thermal uniformization;

• extracting the brickett from the furnace, which is then placed on the testing stand;

• starting the compression under conditions similar to the cold compression ones: 20^0C.

d. *Shatter tests*

The generalized Shatter test, which is usually applied for physically damaged materials due to their handling (of ferrous agglomeration type), was adjusted in the case of bricketts manufactured from EAF dust, for a more accurate description of physical damage processes. This test aimed, also, to determine the grain distribution of crushed bricketts, under conditions, which are similar to those of the electric furnace (as concerns the fall height and temperature).

The testing stages consisted in:

- selecting a lot weighing 1kg, without cracks;
- natural fall from 1m height onto a metallic plate of the lot weighing 1kg;
- the weight determination for grain-size fractions of the damaged lot by impact due to natural fall, by emphasizing the fraction + 15 mm, which must be >85%;

In the case of the Shatter test performed under heat conditions, the lot of bricketts was charged into a dry kiln (Vu= 25x25x25 cm) at the testing temperature (200, 400^0C) + 20^0C, then maintained approximately 15 minutes for obtaining the thermal homogeneity and finally, was extracted for the proper testing of the impact with the metallic plate.

2. The experimental simulation of results

The experimental simulation performed in view to identify the process was based on graphical and analytical processing [3], aiming to obtain the following quality indicators:

- the handling and transportation capacity (Fig.2-5);
- the importance of lime and bentonite additions for the analysis of the brickets behavior during transportation (Fig.6-9);
- the performances of thermocompression (Fig.10);
- the behavior of brickets at heating and fall (Fig.11-12).

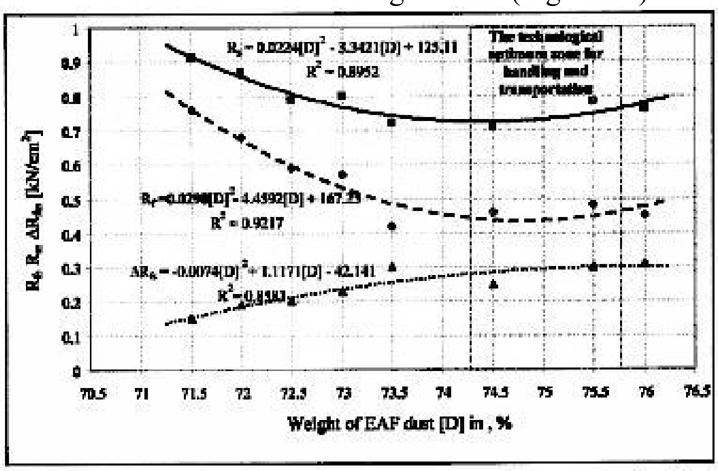

Fig.2 Behavior of bricketts during handling and transportation function of EAF dust weight

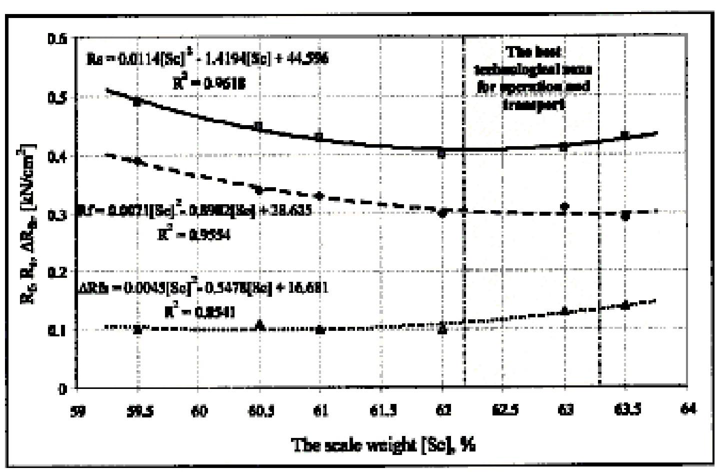

Fig.3 Influence of scale weight on the compression resistance

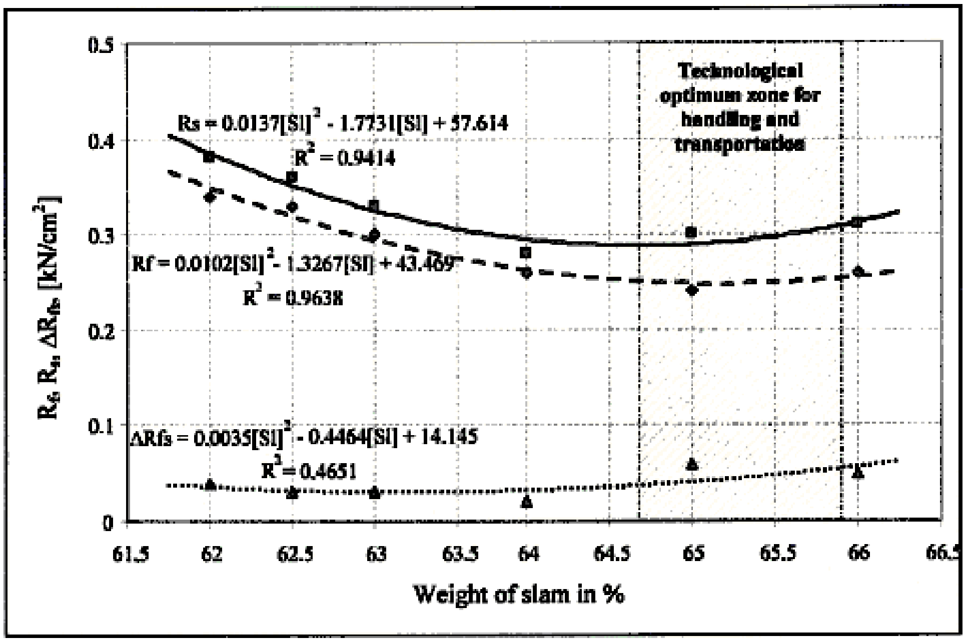

Fig.4 Compression resistance variation function of sludge weight

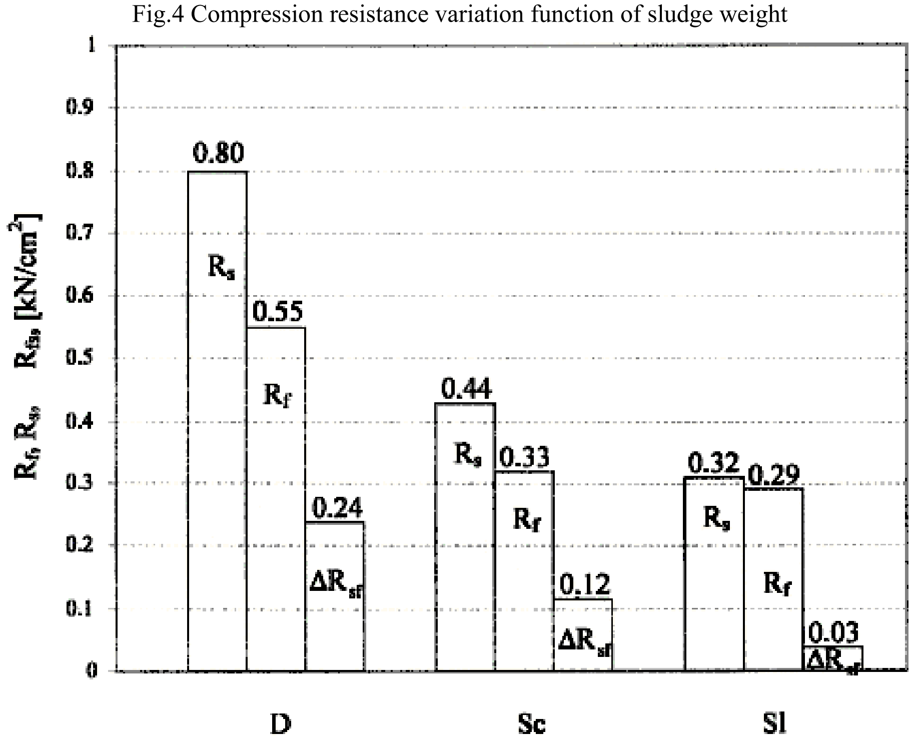

Fig.5 The comparative histogram for the three technological situation using mean values

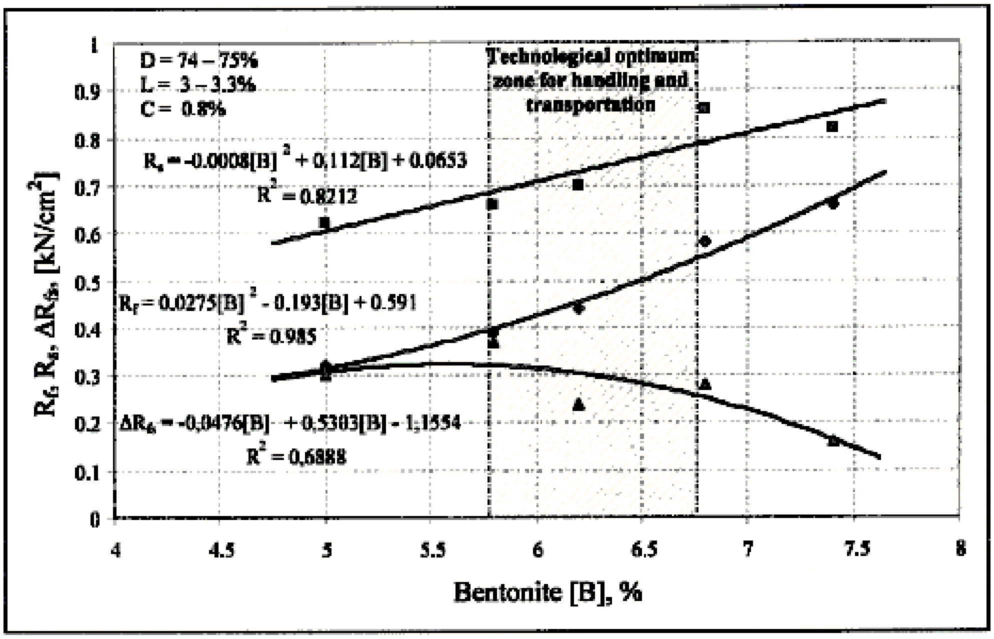

Fig.6 The influence of bentonite content on the behavior during handling and transportation

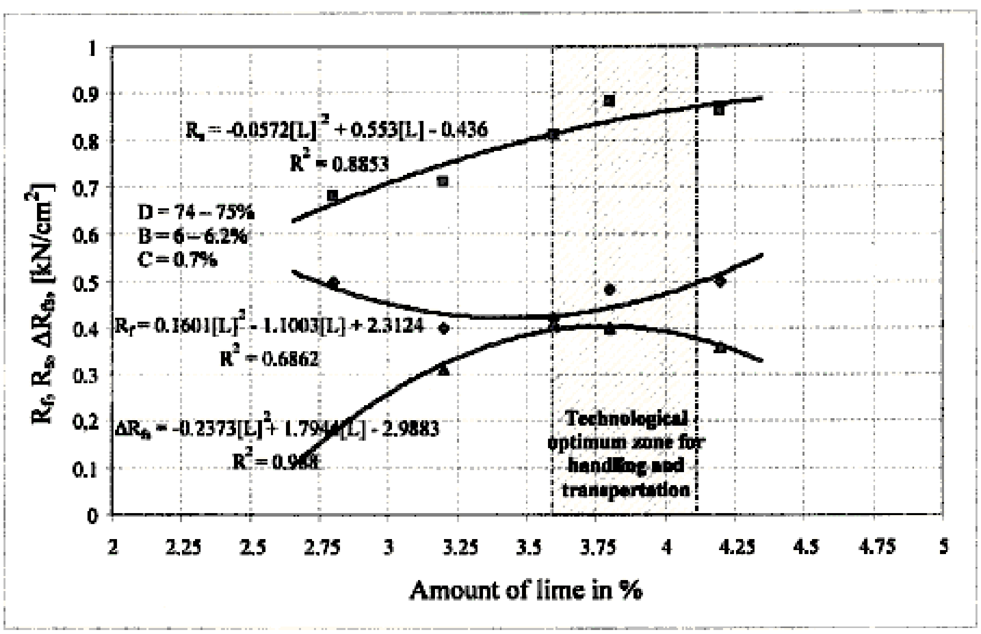

Fig.7 The role of lime amount in brickets manufacturing

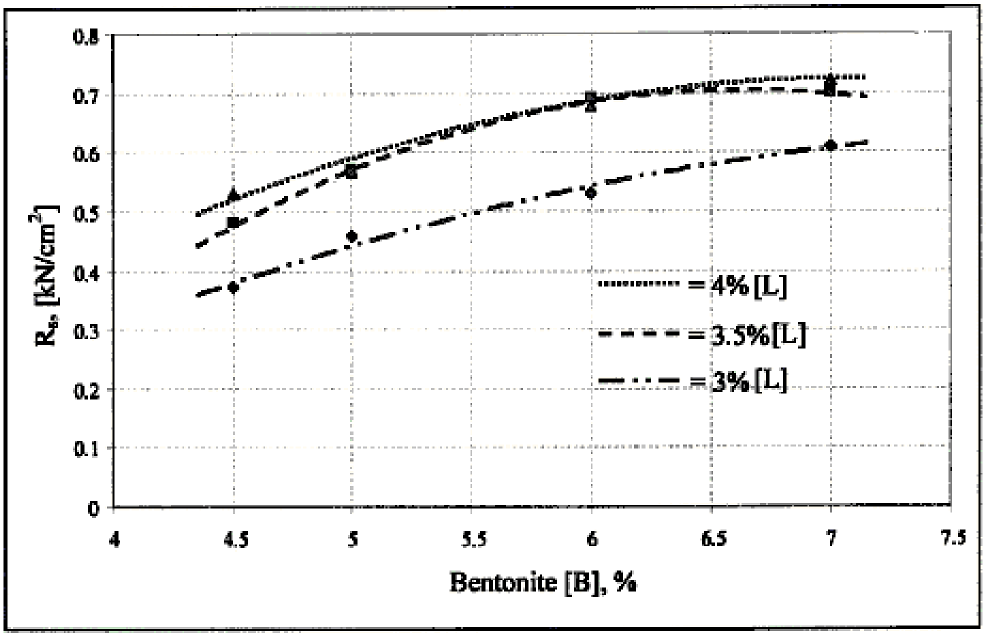

Fig.8 The modification of bricketts behavior to simultaneous variations of bentonite and lime

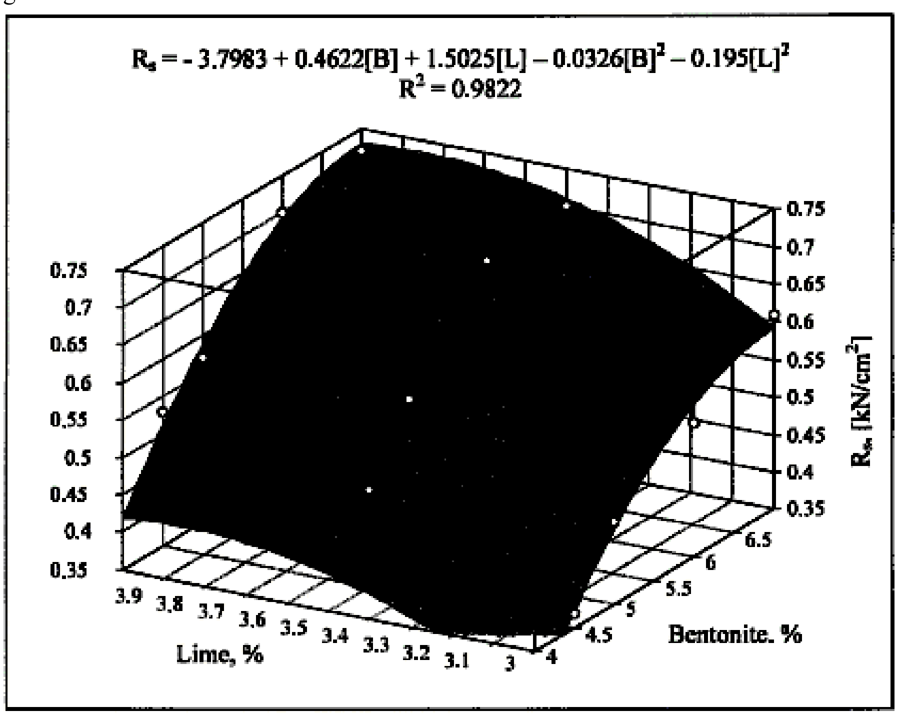

Fig.9 Spatial variation of crushing strength versus bentonite and lime content

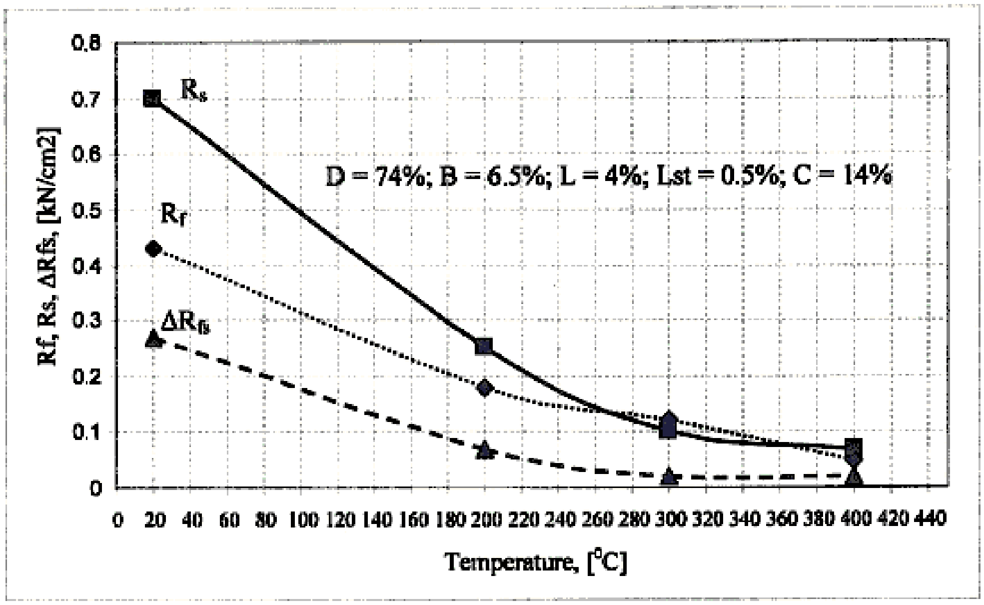

Fig.10 Brickets behavior in thermocompresion

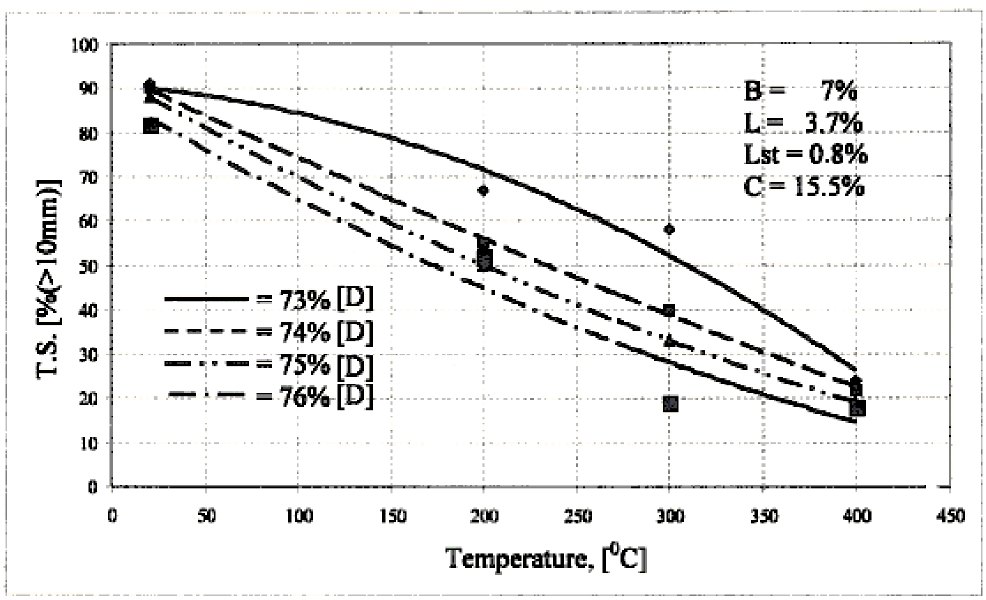

Fig.11 Variation of Shatter coefficient

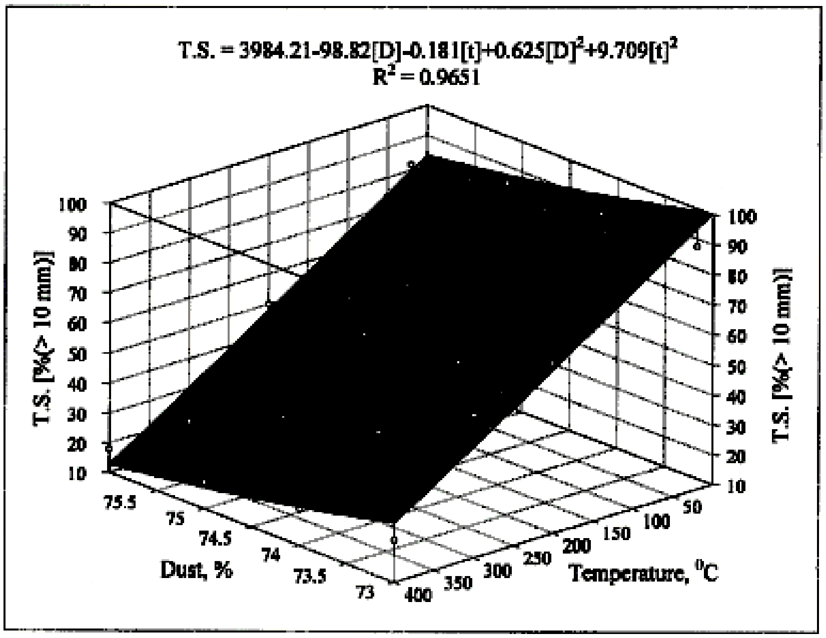

Fig. 12 Spatial variation of Shatter coefficient versus dust content and temperature

Conclusions and technological recommandations

The interpretation of the results (namely the aspect of graphical curves, the regression coefficients, the comparisons of values for various experimental cases, etc.) was made, first of all, function of the hypothesis launched as concerns the mechanism of brickets behavior to the above analyzed stress types.

Thus, the aspect of the curve showing the crushing strength variation, R_s, represents the tendency of decrease in the first zone due to the following processes:

- the amount of ultrapulverous additives decreases (bentonite, coke, lime) when the weight of dust, scale or sludge increases, thus, having a negative influence on the binding capacity, on the possibility of filling out the space between grains and on the blocking of cracks propagation;
- the second zone of the curve reveals the increase of resistance values, thus, meaning from the viewpoint of the author, a positive effect exerted on the intrinsic resistance of the basic material particles and on the phenomenon named within this paper "selfcompression".

One can observe, also, the increase of the damage range, ΔR_{fs}, on behalf of the fact that the cracking resistance decreases more pronouncedly than the crushing strength. This empirical observation allows us to emphasize the important role during the cracking and crushing process of cracks propagation, which is provided by their blocking due to ultrapulverous materials and by the binding capacity conferred by lime and bentonite. The research was finalized by the experimental simulation of instruments (minimathematical models), which have to be used for the control of the pulverous materials capitalization during the EAF steelmaking process.

Also, it is possible to forecast the conditions and technological prescriptions for the proper evolution of the process. This aspect will be further discussed.

The quantitative analysis of the correlation diagrams, obtained by simple regression, emphasize the following aspects:

- the cracking resistance of brickets decreases, if the EAF dust weight is increasing (Fig.2); it increases, if the amount of bentonite is increasing (Fig.6) and increases slightly if the lime content increases (Fig.7); bentonite is, thus, a better binder than lime, which provides the main contribution to basicity;
- the cracking - crushing range increases if the EAF dust content (Fig.2) increases and it decreases with the increasing of bentonite and lime content (Fig.6 and Fig.7).

The quantitative analysis of the correlation diagrams obtained by simple regression shows the following:

- the EAF dust concentration must be 74% in order to provide a cracking resistance of at least 0.48% [kN/cm^2];
- the 7% high bentonite content can be considered as providing a cracking resistance of minimum 0.52% and a crushing strength of over 0.6 [kN/cm^2];
- the lime exerts little influence on the cracking process, but has a fundamental influence on the crushing process; the weight of lime must be limited to 3%.

After analyzing the compression tests for brickets made from EAF dust, one can draw up following conclusions:

a. the brickets are physically damaged during transportation and handling; the compression resistance is influenced as well by the EAF dust content, binder (bentonite) content as by the lime content;

b. during the physical damage process, there are two stages:

I. the stage of crack initiation (generation of first cracks) and

II. the stage of crushing (destruction of the bricket structure).

The crushing strength is essential for the second stage; this kind of resistance, in the case of an optimized EAF dust content, depends on the lime and bentonite weights, as it is emphasized by Fig.6.8;

c. after charging the brickets into the electric furnace, their structure continues to be speedly disintegrated, still from 200^0C.

The Shatter tests show that the particle with equivalent diameter of 10 mm and even smaller, is that one which is representative for the melting processes under reducing conditions in the furnace.

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