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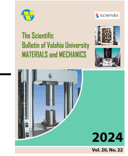

ANALYSIS OF OXIDIC MATERIALS IN THE CONTINUOUS MOLDING OF ALLOYS

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Abstract: *The aim of the work was to obtain advanced oxide materials, obtained through technologies compatible with sustainable development materials. These materials are used in special operating conditions, such as in the case of continuous steel casting, where there is a temperature difference of over* 1000^0C *between the mold wall and the steel crust. These are the lubricating powders for the crystallizer.*

Keywords: *lubricating powders, mold (crystallizer), and shell (crust)*

1. INTRODUCTION

At the Liberty Steel Plant Galati (Romania), the large semi-finished products, blooms and billets are obtained by continuous steels casting with medium carbon content. In order to put these technologies into practice, it is necessary to use in the mold some lubricating powders with high carbon content, powders which, in addition, have a very good flow and spreading capacity and a low volumetric mass, also. This paper presents our preoccupations regarding the production of mineral powders that meet this role.

2. BASIC THEORY

Mold lubricating powders are mixtures of oxide compounds or combinations thereof, calcium and magnesium silicates and aluminous silicates, to which fluxes, fluidizers and melting rate regulators are added for directing of physical and chemical properties in a specific desired field.

These types of products are powdery materials framed in multioxidic systems of type $CaO–SiO_2 – Al_2O_3 – MgO - Fe_2O_3 - Na_2O – CaF_2$ or $CaO – SiO_2 – Al_2O_3 – MgO – Li_2O – B_2O_3$ and consisting of at least 5% carbon in various forms (metallurgical coke, oil, carbon black, graphite, etc).

The carbon-bearing material regulates the melting rate of the main refractory oxides in the powder composition, and it is a fuel whose thermal contribution compensates for part of the heat loss from the steel surface, also.

The main functions of the powdery material are: optimal lubrication of the steel wire and ensuring a homogeneous heat transfer through the slag film, thermal insulation and prevention of oxidation of the liquid steel bath surface, capture and dissolution of decanted steel inclusions, also.

But if these inclusions were captured by the crust of the meniscus, its radius will be greatly reduced, and the shell will be soaked with oxidic inclusions, leading to an increased heat flow.
This phenomenon causes surface defects such as cracks, slag inclusions, blows or even crevices.

The appearance of these defects requires the subsequent reconditioning of the surfaces, an activity that is accompanied by material losses [1-3]. The optimal behavior of a powder results for the casting in good technological conditions of the steel and the reduction, even until the elimination, of the defects on the surface of the semi-finished product.

At the same time, the quality of the powder influences the internal purity of the steel, through the absorption and dissolution of non-metallic inclusions in the liquid slag layer.

When continuous casting, the non-metals on the steel surface are metal oxides, small amounts of sulphides and possibly inclusions of refractory materials captured on the processing transport- treatment-casting route. The composition and properties of the liquid slag must be

chosen taking into account, inter alia, the composition of the liquid steel, the flow rate of the wire
in the crystallizer, its extraction speed and the oscillations of the mold.

After the addition of the casting powder, a layer of liquid slag must form on the steel surface of the mold, which captures and dissolves the impurities. This layer of liquid slag must uniformly moisten the space between the crystallizer's walls and the steel shell, by forming an insulating and lubricating film, acting as a thermal barrier for the thermal flow from the crust to the walls of the mold. At the same time, a powdery layer (powder as such) must be maintained on the surface of the liquid steel (Fig. 1), with the role of integral coating of the liquid surface, which melts over time, helping to maintain the thickness of the liquid slag layer, so that its melting speed to be low. [3-5]

3. RAW MATERIALS AND WORKING METHODS

For the investigation of raw materials and finished products, the techniques of classical qualitative and quantitative chemical analysis were used, investigations of X-ray fluorescence spectrometry and X-ray diffraction analysis, too. The technological framework for making lubricating powders for crystallizer included the following technological operations: crushing, grinding, drying, dosing, mixing-homogenization and packaging.

On the new powders obtained, the sintering, melting and flow temperatures were determined by high temperature microscopy, and density, granulometry, spreading surface also. To obtain the powders the raw materials were used, some with advanced fineness, others with granulation imposed by the developed technology.

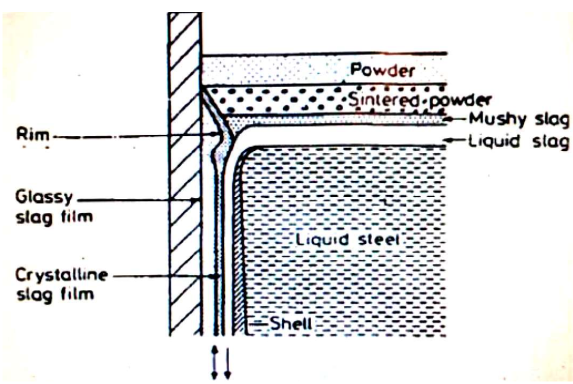

Figure 1. Representation of the continuous steel casting mold (the copper mold)

Blast furnace slag

Blast furnace slag is a by-product of the cast iron obtaining process. It is a mixture of silicates, silica-aluminates and iron oxides with other materials added as fluxes in the production of cast iron. The slag grinding is achieved by its sudden cooling in water, obtaining a material with fine granulation. The admissibility conditions are as follows: max. 39% SiO_2, max. 50% CaO, max. 7.0% MgO, 14% Al_2O_3, max. 3.0% MnO. [4,5]

According to the data of the X-ray diffraction analysis, the blast furnace slag consists of mineralogical components, such as: β or γ calcium orthosilicate, $2CaO{\cdot}SiO_2$; calcium metasilicate, $CaO{\cdot}SiO_2$; solid solutions of the melilite type consisting of gehlenite - $2CaO{\cdot}SiO_2{\cdot}Al_2O_3$ and akermanite - $2CaO{\cdot}MgO{\cdot}2SiO_2$; calcium and magnesium orthosilicates (monticellite) - $CaO{\cdot}MgO{\cdot}SiO_2$; various sulfides (CaS, MnS, FeS); next to some of the amorphous material.

The quality characteristics of the other components used as raw materials are presented. below [5-7]

Perlite

Natural perlite is a volcanic tuff. It contains water, which, by heating, is eliminated, a process accompanied by an expansion with a sudden increase in volume 7 - 16 times compared to the initial volume. The main oxide constituents are SiO2 (70 – 75%), Al_2O_3 (12 –15%), Na_2O (3– 4%). The expanded perlite has a volumetric mass of 30 – 150 kg/m³.

Calcium fluoride (CaF_2)

It is a fluorescent, colorless or yellow-green mineral and has a glassy luster. The density of natural calcium fluoride is 3.1 - 3.2 [g/cm^3] and contains 51.15% calcium and 48.85% fluorine. It is often contaminated with SiO_2, $CaCO_3$ and CaO.

Metallurgical coke

The metallurgical coke is obtained by coking the coal at temperatures of 900 – 1100ºC. The characteristics that coke must meet in order to be used in the manufacture of powders for continuous steel casting are the following: max. 12% ash; max. 1.5% sulfur; max. 4% humidity; max. 1.5% volatile matter.

Sodium carbonate

Sodium carbonate - Na_2CO_3, also known as calcined soda, is widely obtained by the Solvay process. Calcined soda is soluble in water. It melts at 851^{0}C and has a density of 2.5 [g/cm³]. Sodium carbonate is used as a flux in the composition of lubricating powders.

By its decomposition, Na2O is released at 700-800^{0}C, an oxide with a strong basic character and with a strong melting effect on the silicate network.

4. RESULTS AND DISCUSSIONS

After laborious experimental work performed in this context, three compositional masses resulted: the Powder 1, Powder 2 and Powder 3 (Table 1). The defining characteristics for these powders were highlighted (Table 2). The comparative analysis of these data (Table 2) shows some similarity of the new experimental powders with the recognized Stollberg powder named Accutherm type ST-SP/521, currently used for the continuous casting of low and medium carbon steels, at speeds of 0.6 - 3.0 [m/minute] [8,9]

Table 1. Experimental compositions

Experimental powders	Blast furnal slag ,%	Perlite %	CaF2%	Coke ,%	Na2CO3,%
Powder1	53	16	6	19	6
Powder2	61	10	5	24	-
Powder3	52	12	6	18	12

Table 2. Powders for the mold of the continuous steel casting installation

Sample Properties	Symbol Sample			
	Powder1	Powder2	Powder3	Accutherm ST-SP/521
SiO_2, [%]	33.30	32.0	33,02	26.84
CaO, [%]	23.03	27.72	26,50	22.92
Basicity Index, CaO/SiO_2	0.7	0,86	0.80	0.85
MgO, [%]	5.86	2.33	3.42	0.80
Al_2O_3, [%]	8.35	8.94	7.59	10.38
TiO_2, [%]	0.28	0.47	0.27	0.48
Fe_2O_3, [%]	2.88	2.10	2.12	4,00
MnO, [%]	0.31	0.40	0.32	0,10
$Na_2O + K_2O$, [%]	6.19	1.29	10.0	3.41
F, [%]	3	3	3	7,10
Granulometry, mm	< 3	< 3	< 3	-
C_{total}, [%]	22.00	21,77	15,67	21,17
Sintering/melting/flow temperature, [^{0}C]	1060/1090/ 1105	1120/1140/ 1145	1050/1075/ 1085	1110/1120/1150
Bulk density, [Kg/dm^3]	0.71	0,67	0,66	0,68

Investigations of X-ray fluorescence spectrometry of the three experimental powders allowed the identification of the main chemical elements present in these powdery materials: F, Al, Mg, Na, Fe, O, Si, Fe, Mn, Ca, K and other elements found as impurities. An example is gives for the highlighting of magnesium, iron, sodium and oxygen (Fig. 2).

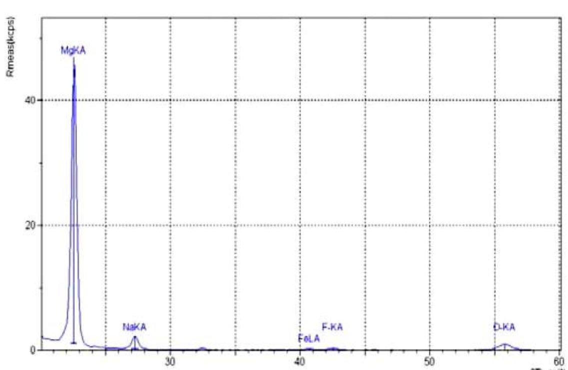

Figure 2. The presence of Mg, Na, Fe, and O is highlighted for the Powder 1

With the Powder 1 and Powder 3, preliminary application of continuous steel casting was made at the Mini-steelworks. The good results obtained from these experiments [9,10,11] determined that in the next stage the Powder 1 and Powder 3 to be tested on the industrial line at the mold of the continuous steel casting installation from the Liberty Plant in Galati.

5. CONCLUSIONS

In the present study, the compositional masses of lubricating powders from the continuous steel casting plant were established. In the composition of these experimental powders the blast furnace slag holds an important place, its compositional weight exceeding 50%. This is because its mineralogical composition ensures the formation of a fluid slag, with a good basicity index and a melting temperature corresponding to the intended purpose.

Last but not least, the environmental protection effect must be mentioned by introducing in the material production circuit a by-product resulting from the metallurgical industrial process. Thus, the blast furnace slag will no longer be a polluting agent of the soil and air (as would be the case if it was stored in the tailings dump), because it will be reintroduced, as a raw material, into the circuit of useful materials production.

Qualitative investigations into the new powders have shown that these could be used as powders for the mold at the steel continuous casting plant. The preliminary experimental tests on the continuous steel casting installations confirmed this desideratum. In the next stage, the experiments will be applied on industrial installations.

REFERENCES

[1] Assar M. B., Dauby P.H., Lawson G.D. 2001. Voyage dans une lingotière de coulée continue, Revue de Métallurgie - CIT, (April, 2001): 353-366.

[2] Stoian E. V., Bratu V. 2018. Analysis of internal defects appeared in the continuous casting, Scient Bull Valahia Univ Mater & Mechan, 16 (14), DOI 10.1515/bsmm-2018-0005, 2018.

[3] Carlos-Pinheiro A. M. 1997. Mould thermal response, billet surface quality and mould-flux behaviour in the continuous casting of steel billets with powder lubrications. Doctorate Thesis, The University of British Columbia, (December, 1997).

[4] Tripşa I., Pumnea C. 1984. Retopirea şi rafinarea oţelurilor, Editura tehnică, Bucureşti, 1984.

[5] Toma F. M. 2019. Work of dissertation, Valahia University from Târgoviște, 2019.

[6] Arianit Reka A., et al. 2019. Chemical, mineralogical and structural features of native and expanded perlite from Macedonia. Geologia Croatica, 72 (3), 2019.

[7] Baia Mare Museum of Mineralogy. 2019. Catalog, (November, 2019).

[8] www.tufgroup.com. 2020.Casting Fluxes And Covering Compounds - TUF Metallurgical . xxx. 2019. Stollberg Lists, 2019.

[9] Bratu V., et al. 2014. Mathematical model of solidification process in steel continuous casting taking into account the convective heat transfer at liquid–solid interface, Computational materials science, Vol.94, p.2-7, 2014, Elsevier.

[10] Toma F. M. 2019. Doctorate Progress Report I, Valahia University from Târgoviște, 2019.

[11] Toma F. M. 2020. Doctorate Progress Report II, Valahia University from Târgoviște, 2020.