EXPERIMENTAL RESEARCH TO CHARACTERIZE POWDERS FROM REFRACTORY MATERIALS USED IN CASTING STEEL

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In this paper, the authors present the properties and technology of obtaining some powdery refractory materials used in the steel casting process. The researches carried out to determine the most important physical and chemical properties of the refractory materials used as coating powders for steel casting are presented, namely viscosity and fusibility. The temperatures at which the eutectic occurs in the ternary systems SiO2-Al2O3-CaO were determined. The influence of the Al2O3 content in the raw materials on the viscosity of the casting powders at different temperatures was determined.

Keywords: refractory materials, fusibility, slag viscosity, continuous casting, casting powders

1. Introduction

The use of ointments and heat-insulating materials has become a common practice in steelworks, their application leading to particularly important metal savings. The products included under this generic name represent lubricating powders, anti-retraction powders, masselot plates and powders for continuous casting.

Auxiliary materials used worldwide for steel casting are in a very diverse range both in the form of chemical compositions and in the form of raw materials used in their manufacture.

In current practice, lubrication and anti-seize materials are applied in the form of powders after packaging in polyethylene bags or in the form of shaped plates made of powders with a binder. [1-4]

From the documentation carried out, the imported casting powders are manufactured in several varieties depending on the place, the size of the ingot, the casting temperature, and the quality of the steel. [5-7].

Satisfaction of the casting powder functions is ensured by the chemical composition of the powder, which, by the proportion of oxides as well as by its other components, determines both the temperature and the melting-solidification

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range, falling within the ternary system CaO-Al2O3-SiO2 as well as in the CaO-Al2O3-CaF2-Na2O, CaO-Al2O3-SiO2-CaF2-Na2O-C systems.

2. Experimental

2.1.Chemical and mineralogical composition of casting powders

In this work was studied the possibility of producing a pilot batch of casting powders using the raw materials and the equipment of the research laboratory within the Center for Research, Design and Production - CCPPR SA Alba Iulia.

From a chemical point of view, casting powders are part of the metallurgical slag field, meaning the SiO_2-CaO-Al_2O_3 system [1,2].

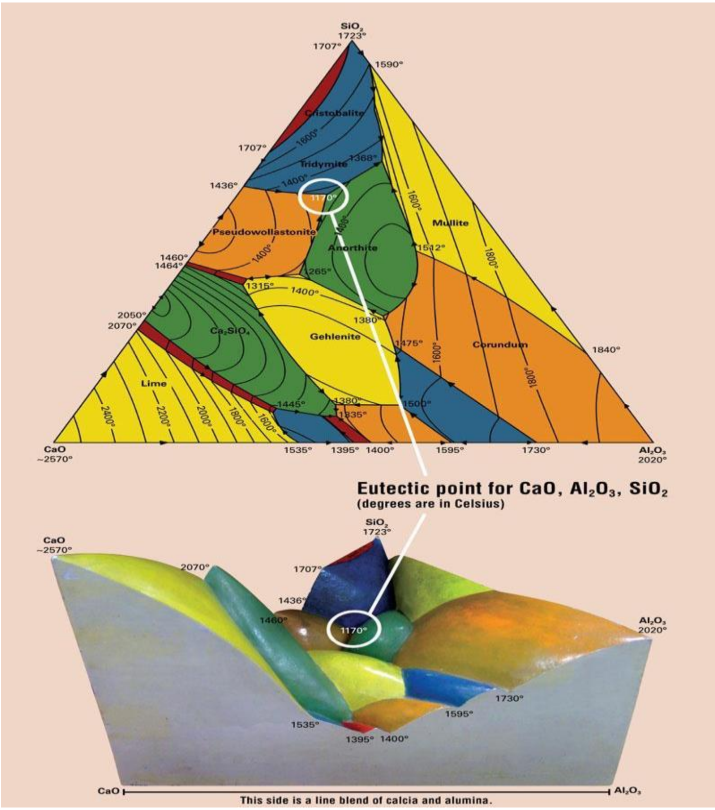

Fig. 1. Thermal balance diagram SiO_2-CaO-Al_2O_3 [1]

The SiO_2-CaO-Al_2O_3 system consists of:

-ANORTIT (Ca felspat), $CaO \cdot Al_2O_3 \cdot 2SiO_2$: is congruent with melting point at 1550 °C; crystallizes into tricline blades; is a compound found in eruptive rocks and in technical silicates such as acid metallurgical slags.

-GHELENIT, $2CaO \cdot Al_2O_3 \cdot SiO_2$: is congruent with melting point 1590 °C; crystallizes into quartz crystalline forms.

-GRANAT, $3CaO \cdot Al_2O_3 \cdot 3SiO_2$; is incongruent in the solid phase, therefore under normal pressure it does not appear in the presence of the liquid phase and does not appear in the equilibrium diagram of the system.

It does not appear in technical silicas but only in minerals that have formed at high pressures

-ALUMINOSILICATE TRICALCIUM $3CaO \cdot Al_2O_3 \cdot SiO_2$: is incongruent in solid form; crystallizes the rhombic and decomposes into the liquid phase, to balance.

$$3CaO \cdot Al_2O_3 \cdot SiO_2 \xrightarrow{1335°C} 2CaO \cdot SiO_2 + CaO \cdot Al_2O_3 \quad (1)$$

2.2. Fusibility

Fusibility is the property that allows a casting powder to melt at a particular temperature or temperature range such that a liquid slag layer is formed on the free surface of the cast steel to provide a certain fluidity.

However, it is not enough to find an optimal melting temperature, but an optimal melting-solidification interval should also be achieved, which is based on the size of the surface of the steel bath.

Optimal melting range of the casting powders has been found to be within the range of 1150-1300°C.

In the SiO_2-Al_2O_3-CaO system there are three eutectics having melting temperatures in this range.

Table 1.

Eutectic melting temperatures in the SiO_2-Al_2O_3-CaO system [1]

Eutectic	SiO_2 %	CaO %	Al_2O_3 %	Temperature ° C
E_{11}	62	23,25	14,75	1165
E_{12}	42	38	20	1265
E_{13}	40	49	11	1310

It can be noticed, however, from the position of the points in the system that:

- E11 can not be taken into study, being outside the optimal range,
- E12 is at the limit of the range, with the Al2O3 content being high,
- E13 is at the upper limit of the temperature range.

For this reason, various fondants such as magnesium oxide, sodium oxide, fluorine, boron trioxide had to be tried.

2.3. Viscosity of casting powders.

According to the definition, viscosity is the force acting on the surface unit so as to maintain a velocity gradient Δv/dt between two layers inside the slag, and after Arhenius the viscosity is a function of temperature:

$$\log \eta = \frac{E}{KT} + B$$

Where K=1 when the tetrahedric structural groups are free.

In silicate melts the viscosity will decrease as the anions (structural groups) are less complex, so the more mobile they are.

For this reason a highly acidic slag with a structure $(SiO_4)^-$ can not be used for steel casting. [6,7]

Several authors have found that the most suitable steel casting would be neutral or almost neutral, giving different values for the CaO / SiO_2 ratio, most grouping in the range [2]:

$$\frac{CaO}{SiO2} = 0,7 - 1,1$$

Practically, a direct relationship between viscosity and temperature could not be established.

Mixtures with higher melting temperatures and lower viscosity are known than other mixtures with lower melting temperatures.

Thus, it can be shown that in the SiO2-CaO-Al_2O_3 system, the more basic E13 mixtures have a lower viscosity than those in zone E11, more acidic, although the latter have lower melting temperatures of about 100 ° C. [8-11]

But as a general rule, raising the temperature leads to a decrease in viscosity.

2.4. Experimental research to determine the influence of aluminum oxide content on casting powders and casting slag viscosity.

It has been noted that the introduction of Al_2O_3 into slags produces an increase in viscosity, being a "network trainer".

Not only the total amount of oxide influences the viscosity but also its ratio to the other oxides, such as Al_2O_3/SiO_2.

In order to establish a more precise correlation between temperature and Al2O3 content in slags, we have worked out in the EXCEL and MATLAB calculation programs, the known data of casting powder compositions, especially the content of Al_2O_3 of pubes and their properties.

These data processing allowed to establish dependencies between puberty Al2O3 content and their properties, correlations represented both graphically and analytically in Figs. 2 - 13.

The multiple correlation allows the choice of optimal temperature and Al_2O_3 values to determine viscosity in a certain range, Fig. 2.

Horizontally, subdomains of viscosity variation are shown.

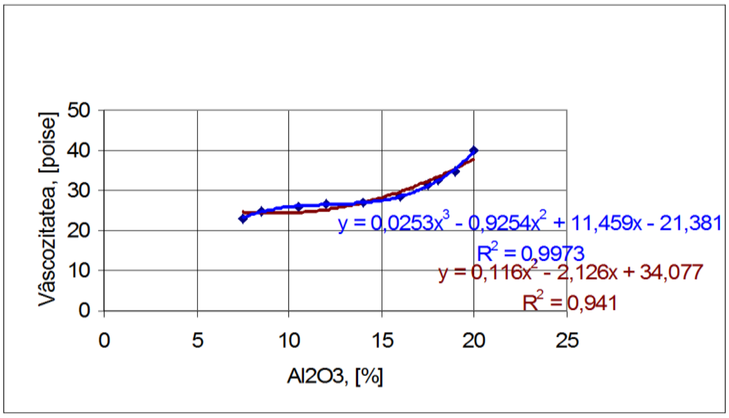

Fig. 2. The viscosity of the slag for continuous casting according to the content of Al_2O_3 at a temperature of 1300° C [1]

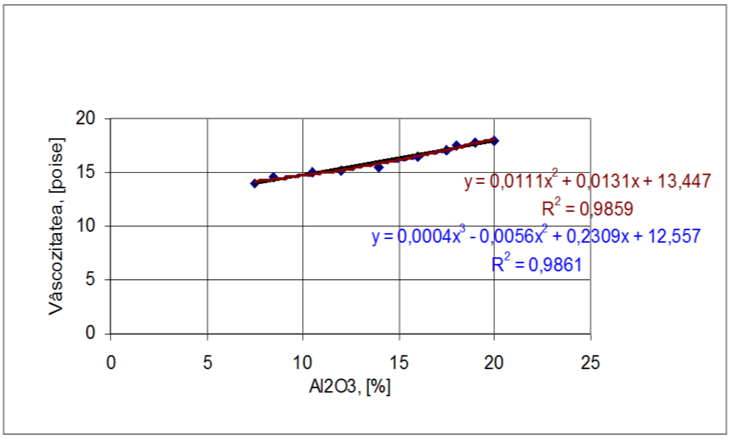

Fig. 3. The viscosity of the slag for continuous casting according to the content of Al_2O_3 at a temperature of 1350° C [1]

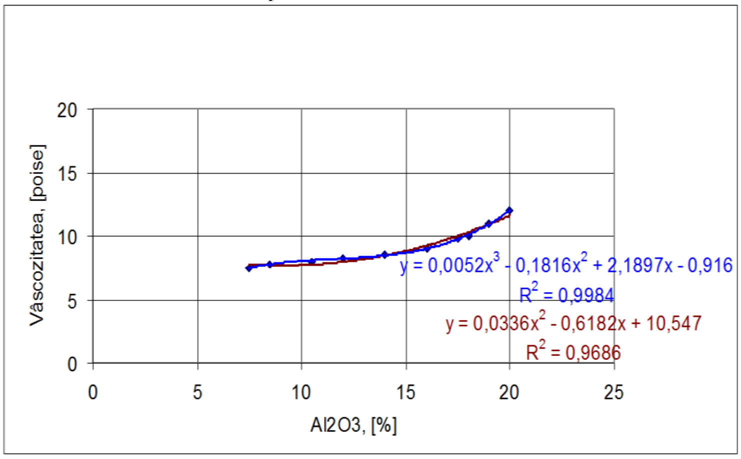

Fig. 4. The viscosity of the slag for continuous casting according to the content of Al_2O_3 at a temperature of 1400° C [1]

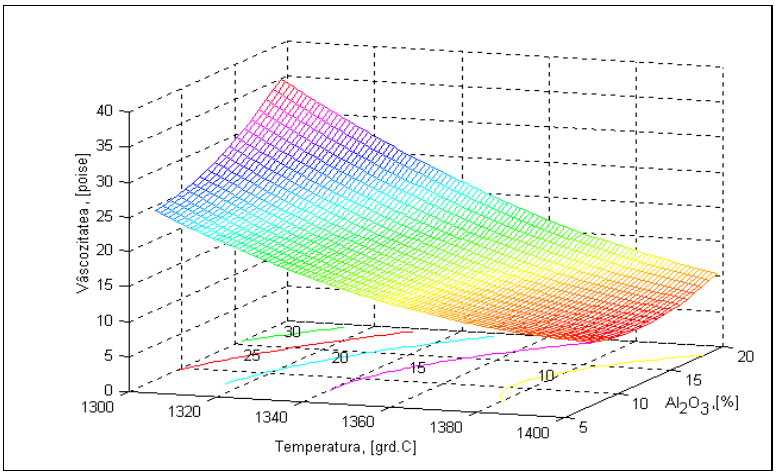

Fig. 5. The viscosity of the slag for continuous casting according to the temperature and the content of Al_2O_3 [1]

From the practical data it was found that the viscosity is influenced not only by the total amount of Al_2O_3 introduced but also by its ratio to the other oxides, the most representative being the ratio of Al_2O_3 / SiO_2.

These dependencies are obtained by processing the data in the MATLAB program.

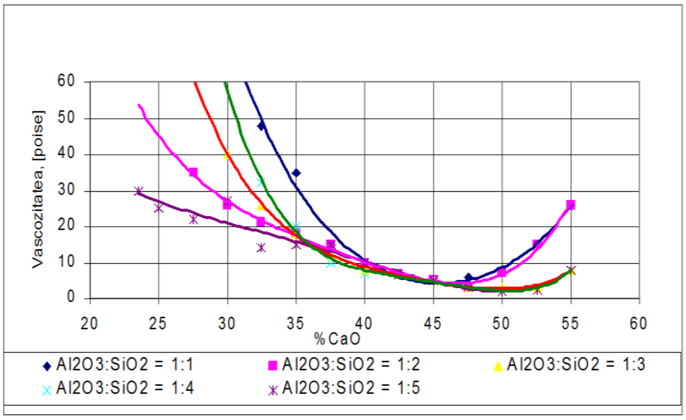

Fig. 6. Influence of Al_2O_3 / SiO_2 ratio on viscosity for 0% MgO [1]

In order to obtain an expressed and analytical dependence between viscosity and the CaO content of slag, 0% MgO and different values of the Al_2O_3 / SiO_2 ratio, we present the results obtained in the Figs.. 13 also present the same variation but at different MgO contents, as follows: for 5% MgO, 10% MgO and 15% MgO.

It can be noticed that with the increase of the percentage of MgO in the slag composition, there is a decrease of the viscosity values, falling within increasingly narrow limits.

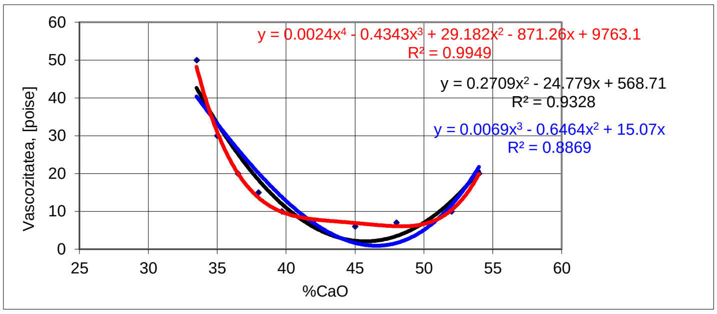

Fig. 7. Influence of Al_2O_3/ SiO2 ratio=1/1 on viscosity for 0% MgO [1]

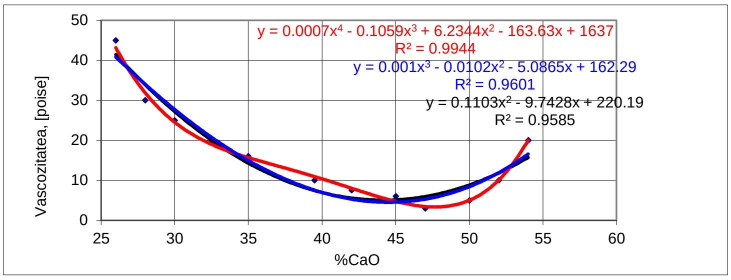

Fig. 8. Influence of Al2O3 / SiO2 ratio=1/2 on viscosity for 0% MgO [1]

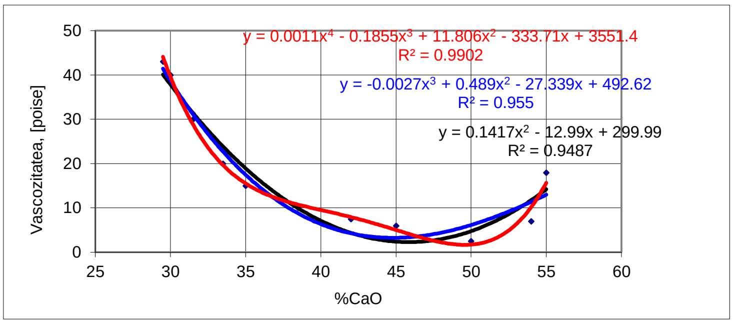

Fig. 9. Influence of Al_2O_3/ SiO2 ratio=1/3 on viscosity for 0% MgO [1]

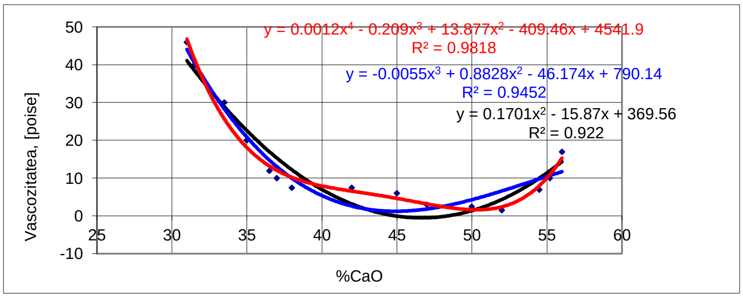

Fig. 10. Influence of Al_2O_3/ SiO2 ratio=1/4 on viscosity for 0% MgO [1]

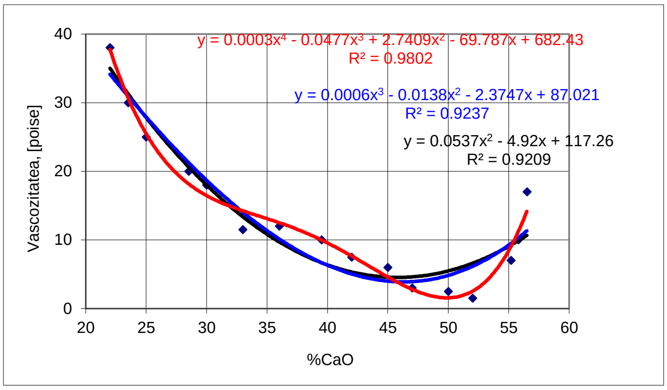

Fig. 11. Influence of Al_2O_3/ SiO2 ratio=1/5 on viscosity for 0% MgO [1]

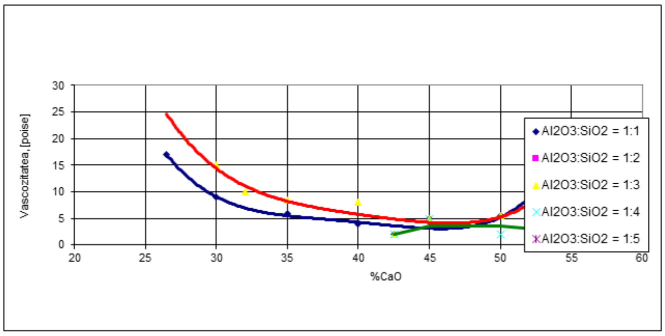

Fig. 12. Influence of the Al_2O_3/ SiO2 ratio on viscosity at 5% MgO [1]

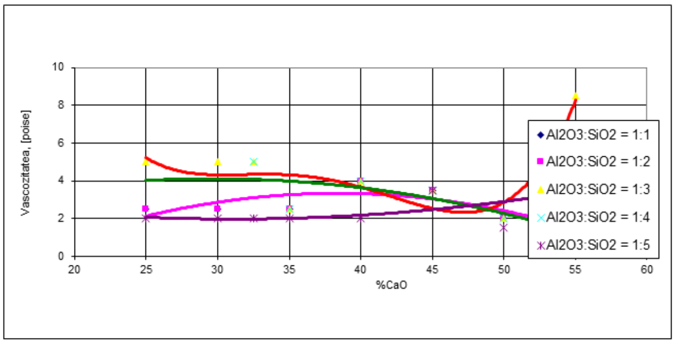

Fig. 13. Influence of Al_2O_3/ SiO2 ratio on viscosity at 15% MgO [1]

3.Results and discussions

From the qualitative characteristics determined in the laboratory conditions, the data presented in Table 1 and Figs. 2-13 reveals the following aspects:

-In Figs. 2, 3 and 4 show that the viscosity increases with the increase in Al_2O_3 content, the best statistical correlation being the 3rd degree polynomial equation, with R=0.9984.

-In Fig. 6 shows that viscosity decreases with increasing temperature but increases with increasing Al_2O_3 content

-In Figs. 7 and 8, it can be seen that the viscosity decreases with the increase in the percentage of CaO, the minimum viscosity value being recorded at approximately 45% CaO, after which it slightly increases.

The best correlation between viscosity and Cao content is represented by the 4th degree polynomial, where the correlation coefficient is 0.9944.

-In Figs. 9, 10 and 11 it can be seen that the decrease in the viscosity value with the CaO content is more pronounced with the decrease in the ratio between SiO2 and Al_2O_3.

-In Figs. 12 and 13 show the influence of magnesium oxide content, which lowers viscosity values depending on CaO.

4.Conclusions

Casting powders, in their various forms of lubrication, coating and continuous casting, are of particular importance in the steel casting process.

The research carried out in the present work showed that the quality and possibilities of use of a refractory product cannot be determined by knowing only one or two of its properties, but all of its chemical and physicochemical properties, which are closely dependent, must be taken into account.

The initial content of Al_2O_3 in slag is not decisive for casting slag, it becomes saturated around 30% Al_2O_3 ,but the continuous flow of the slag powder as usual does not reach this value.

The increase in viscosity at the introduction of Al_2O_3 is due to the fact that this oxide forms octahedral $(A10_6)9^-$ instead of tetrahedra (AlO_4) 5^-, bonding the free ends of the silicate chains or those having the last $Ca2^+$ bonded oxygen.

For the most rational choice of the casting powder, the specific operating conditions must be known, as well as its most important properties.

The satisfaction of the functions of the casting powders is ensured by the chemical composition of the powder, which, through the proportion of oxides, as well as through its other components, determines both the temperature and the melting-solidification interval, falling within the $CaO\text{-}Al_2O_3\text{-}SiO_2$ ternary system .

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