MARATHEMATICAL MODEL OF CHARTS MELT VISCOSITY OF THE
CaO - SiO₂ - Al₂O₃ – MgO

INTRODUCTION

In the research and production activities is common for evaluation of the properties of slag and metal from the diagrams. They are visible and give the opportunity to choose among the many specific compositions presented. However, there are difficulties in their use. This inability to image plane multicomponent (more than four) systems, insufficient accuracy of removing the charts data by geometric constructions, the impossibility of their use in automatic process control in real time. It seems appropriate to create a mathematical model diagrams when the above-mentioned difficulty is largely removed. Sharing graphic diagrams and mathematical models should help improve the effectiveness of research in this area. This article presents the results of the work in this direction.

RESEARCH METHODOLOGY

The decision of the goal to create a mathematical model requires the use of a common reference data of high accuracy. Analysis of the available data[1 - 8] showed significant differences in viscosity of the same slag at the same temperature due to methodological errors[9 - 11], therefore, it was decided to independently carry out experimental investigations, taking measures to reduce instrument and computational errors. For the above reason, it was decided to independently perform experimental studies viscosity, taking measures to reduce the instrumental and computational errors. To determine the viscosity was chosen amplitude resonant version of the method vibration viscometry. It has high sensitivity and allows to determine the viscosity of the slag in a wide range of values [12].

RESULTS OF RESEARCHING

For research in the system CaO - SiO₂ - Al₂O₃ - MgO was selected portion encompassing the most common oxide melts domain, cupola, ferroalloy, ceramic and other industries. It was a tetrahedron whose vertices are located in the following areas: the first - on the side of the binary CaO – Al₂O₃ at crystallization at twelve-calcium seven aluminate (12CaO·7Al₂O₃) with coordinates 48,48 % CaO and 51,52 % Al₂O₃, the second one on the side of the binary CaO – SiO₂ between rankinite (3CaO·2SiO₂) and pseudowollastonite (aCaO·SiO₂) with coordinates / %: 52 CaO and 48 SiO₂, in a third one of the ternary eutectic crystallization point with coordinates / %: 9,8 CaO, 19,8 Al₂O₃ and 70,4 SiO₂, and the fourth was in the volume of the tetrahedron and contained / %:12CaO, 19SiO₂, 9Al₂O₃ и 40MgO.

Used on the simplex method of planning, allowing a mathematical model and build diagrams «structure-property» [13, 14]. In this method, the form approximating polynomial is given in advance, and the degree of the polynomial is determined depending on the expected complexity of the response surface. To study four-component system CaO - SiO₂ - Al₂O₃ - MgO was selected fourth degree polynomial.

The total form of the equation for calculating the viscosity versus composition at a fixed temperature as follows.

\[
\eta = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_1 x_2 + \beta_6 x_1 x_3 + \beta_7 x_1 x_4 + \beta_8 x_2 x_3 + \beta_9 x_2 x_4 + \gamma_1 x_1 x_2 (x_1 - x_2) + \gamma_2 x_1 x_3 (x_1 - x_3) + \gamma_3 x_1 x_4 (x_1 - x_4) + \gamma_4 x_2 x_3 (x_2 - x_3) + \gamma_5 x_2 x_4 (x_2 - x_4) + \gamma_6 x_3 x_4 (x_3 - x_4) + \gamma_7 x_1 x_2 x_3 (x_1 - x_2) (x_1 - x_3) + \gamma_8 x_1 x_2 x_4 (x_1 - x_2) (x_1 - x_4) + \gamma_9 x_1 x_3 x_4 (x_1 - x_3) (x_1 - x_4) + \gamma_{10} x_2 x_3 x_4 (x_2 - x_3) (x_2 - x_4) + \gamma_{11} x_1 x_2 x_3 x_4 (x_1 - x_2) (x_1 - x_3) (x_1 - x_4)
\]

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where $\eta$ – viscosity / Pa·s, 
$\beta_1$, $\beta_2$, $\beta_3$ and so on - the coefficients of which are calculated from the experimentally found values of viscosity, and are shown in Table 5.

$x_1$, $x_2$, $x_3$, and $x_4$ – content, respectively pescu-components CaO, SiO$_2$, Al$_2$O$_3$ and MgO in the vertices of the simplex, of a unit.

In planning matrix Central slag composition of the coordinates of pseudo-weight percentage is produced by the formulas:

- $\text{CaO} = 4.8,48x + 52x_1 + 9,8x_2 + 12x_4$, \hspace{1cm} (Eq 2)
- $\text{SiO}_2 = 4x_1 + 70,4x_2 + 39x_4$, \hspace{1cm} (Eq 3)
- $\text{Al}_2\text{O}_3 = 51,52x_1 + 19,8x_2 + 9x_4$, \hspace{1cm} (Eq 4)
- $\text{MgO} = 40x_4$, \hspace{1cm} (Eq 5)

When the method machine for finding the viscosity of the expression (1) the system of equations (2) - (5) are solved in a general way with respect to $x_1$, $x_2$, $x_3$, and $x_4$:

- $x_1 = 4.28 \times 10^{-6} \text{MgO} + 1.516 \times 10^{-2} \text{Al}_2\text{O}_3 - 4.892\times 10^{-2} \SiO_2 + 4.516 \times 10^{-1} \CaO$, \hspace{1cm} (Eq 6)
- $x_2 = 3.629 \times 10^{-1} \text{MgO} - 1.622 \times 10^{-2} \text{Al}_2\text{O}_3 + 2.162 \times 10^{-2} \SiO_2 + 1.723 \times 10^{-1} \CaO$, \hspace{1cm} (Eq 7)
- $x_3 = 1.137 \times 10^{-2} \text{MgO} + 106 \times 10^{-2} \text{Al}_2\text{O}_3 + 1.273 \times 10^{-2} \SiO_2 - 1.175 \times 10^{-2} \CaO$, \hspace{1cm} (Eq 8)
- $x_4 = 2.5 \times 10^{-2} \text{MgO}$, \hspace{1cm} (Eq 9)

According to the developed method, a known part of slag CaO, SiO$_2$, Al$_2$O$_3$, and MgO by using Equations (6 - 9) are initially values $x_1$, $x_2$, $x_3$, and $x_4$ that substituting into equation 1, one can determine the viscosity. The crystallization temperature of slag of the logarithm of viscosity versus inverse absolute temperature and applied the same processing techniques to create a mathematical model.

### DISCUSSION RESULTS OF RESEARCHING.

Experimental values of viscosity ($\eta$) and the crystallization temperature ($T_c$) served as a basis for calculating said equation (1) the polynomial coefficients. For example, $\beta_1 = \eta_1$; $\beta_2 = \eta_2$; $\beta_3 = \eta_3$; $\beta_4 = \eta_4$; $\beta_5 = 9.4(\eta_{12} + \eta_{13} - \eta_{14})$ and so on [15]. The thus obtained all 35 coefficients for the polynomial viscosity and crystallization temperature are given in Table 5. In accordance therewith, the equation for calculating the viscosity to temperature, such as 1773K as follows:

$$\sigma_1x_1x_2(x_1 - x_2)^2 + \sigma_2x_2x_3(x_2 - x_3)^2 + \sigma_3x_3x_4(x_3 - x_4)^2 +$$

$$\beta_1x_1x_3 + \beta_2x_1x_4 + \beta_3x_2x_3 + \beta_4x_2x_4 + \beta_5x_3x_4 +$$

$$+ \beta_{23}x_1x_2x_3 + \beta_{24}x_1x_2x_4 + \beta_{34}x_1x_3x_4 + \beta_{24}x_2x_3x_4$$


### REFERENCES

Figure 1: Diagrams the melt viscosity of the system CaO - SiO$_2$ - Al$_2$O$_3$ - MgO with 2 (a), 4 (b), 6 (c) and 8 % MgO (d) at 1723K.

Figure 2: Diagrams the melt crystallization temperature systems CaO - SiO$_2$ - Al$_2$O$_3$ - MgO with 6 % (a), 8 % (b) and 10 % MgO (c).

Note: The responsible for English language is lector from University.