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The Application of Numerical Methods to Evaluate the Viscosity of the Coating Using the Model Extraction Iida

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Abstract

The article presents a reflection on the viscosity of the coating extraction using numerical methods. The viscosity of the coating slag is a factor affecting a high degree on the quality of the ongoing process of refining. Too high a viscosity will restrict the diffusion of impurities from the metal to the slag, in turn, too low a viscosity will cause spreading of slag in the vicinity of the furnace wall, and thus exposing the mirror of the liquid metal which may result in adverse effects of an oxidizing atmosphere. You should also remember that too low a viscosity can increase the loss of metal in the slag as well as hinder its recovery during casting. Using the materials database and numerical methods it is possible to determine the level of selected blends of slag viscosity. Additionally, in order to determine their usefulness in refining the values obtained can be confronted with laboratory tests using derivatograph. On the basis of the designated energy index Ew and mass index r can determine the suitability of a mixture of slag and its impact oxidizing or reducing agents..

Keywords: Computer aided manufacturing casting, Numerical methods, Viscosity, Iida model, The program SLAG - PROP, Refining capacity

1. Introduction

Viscosity is one of the very important properties of the slag. It is important both in metallurgical processes, metallurgical - processing and casting. It exerts an important influence on the phenomenon of refining, as well as through the work of the furnace, through the impact of corrosion on the lining of its adverse impact on the material of the crucible, it can also hinder the recovery of the slag shell before spilling into the vat. In addition, also affects the size of the resulting melting loss. Thing is, therefore, reasonable to use numerical methods to evaluate the viscosity of coatings extraction in order to select the most favorable value.

2. Current state of knowledge

It is important that the viscosity of the slag used was relatively low [1,2,3]. It was also found that the diffusion of impurities from the metal to the slag can be represented Stockes formula (Einstein - Smoluchowski) [4÷9]:

$$D = \frac{R_g \cdot T}{6 \cdot \pi \cdot r_D \cdot N_a} \cdot \frac{1}{\eta} \quad (1)$$

where:
D – diffusion coefficient
R_g – gas constant (8,31 J/(mol*K))
T – temperature
r_D – a moving radius of the particle
N_a – Avogadro's number ($6{,}022 \cdot 10^{23}$ mol^{-1})
η - the viscosity of the slag

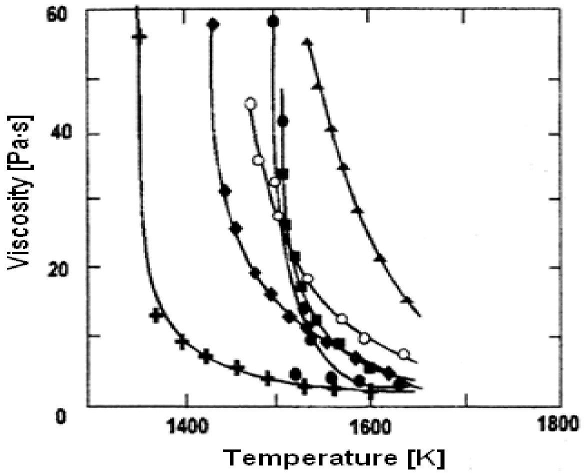
As is clear from the formula (1) and research [15,16,8,10 ÷ 14], the viscosity depends on the temperature of the slag, the composition of gases in the atmosphere and the effects of the refined alloy. There are various methods for determining the viscosity of the liquid. These include the method of Stokes flow through a tube (Engler), vibration, using a rotameter, and finally the method of concentric cylinders appropriately modified and patented by AGH in Krakow [17]. Not all of the classic methods of measurement is, however, possible to use in the metallurgical industry, due to the nature of high-temperature measurement, and thus appropriate selection of materials for certain parts of the measuring apparatus.

The variety of research methods and the nature of the refining process result in discrepancies in determining the value of slag viscosity. The viscosity of the slag can vary considerably, not only with the temperature (Fig. 1a) [16], but also their composition [18,19] (Fig. 1b).

As can be seen in Figure 1a, the slag having the composition 55% SiO_2, 13% Al_2O_3, 14% CaO, 7% MgO and 3% other compounds difference in viscosity in the temperature range from about 1525 K to about 1625 K was more than 30 poise. In turn, sub-paragraph b) for the selected instance (marked white point) of the following composition 37,6 SiO_2; 16,5% CaO; and 9,41% Fe; 3,03% Pb; 4,36% Cu, and the symbol of the black point of the composition 33,1% SiO_2; 15,0% CaO; and 9,21% Fe; 5,80% Pb; 6,72% Cu) difference in viscosity was approximately 20 - 30 poise, with a small percentage change in the system under study.

Interestingly presents a semi-empirical model proposed by Iida viscosity [20,21] for the liquid slag, that contains in its composition CaF2. It is based on the assumption that the viscosity of the slag viscosity is the sum of its individual components, and the ratio of the slag basicity. It includes 2 additional parameters that are a function of temperature and are properly aligned for the class of slags.

a)



b)

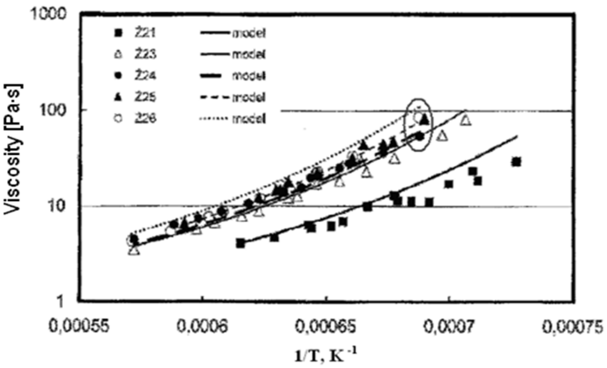


Fig. 1. a) Slag viscosity changes with temperature b) slag viscosity change at a given temperature at the various configurations [16, 18]

3. The concept of the method

The overriding aim is to use an application that uses numerical methods based on semi-empirical model Iida, allowing the selection of optimal physical and chemical properties of coatings for the extraction of these processes. On the basis of studies conducted and appropriate material basis can create original tool by which to gain the ability to precisely determine the melt viscosity of the system also those areas that have not been unequivocally confirmed experimentally.

Obtaining such a tool will result in the selection of the optimal values of the viscosity of coatings extraction. As a result, it will no longer need to perform laborious and costly tests to determine the level of refining slag viscosity. By entering the appropriate data into the database management system you can get information in just a few seconds. This will greatly restrict your search for optimal configurations possible mixtures of slag, as well as modify the most appropriate line-ups for new ingredients and chemicals.

As an indicator of optimal viscosity values provided by the program can use the concept of refining capacity assessment coatings extraction using derivatograph developed by A.W. Bydałek [22 ÷ 30].

4. Results

After starting the program, the user should first indicate the direction of the analysis of the properties of slag. Because the search criterion will be in the areas of viscosity coatings extraction should choose an area served criteria. Then the user must select the type of slag, which will be analyzed. The proposed composition of the refiner will be described as a system of base containing essential components of slag matrix oxide Al_2O_3 – CaO – SiO_2. Another important choice is to indicate the type of alloy, which will be refined - copper, and select the type of atmosphere in which treatments will be carried out. The adopted set the example that it would be inert atmosphere. The final step is to choose your search criteria, or selection "viscosity" as the search area. In the next window, you can enter the minimum and maximum viscosity indicated a mixture of slag. In the present system in order to select the widest possible group of compounds introduced minimum value at 3 P, and the maximum value of 50 P. Thanks so posed boundary conditions program sought out 82 areas meeting the criteria specified by the user. The results are presented in tabular form (Fig. 2). At the same time it can be seen that they relate to a specific area of 3 - component adhesives chart Gibbs, which for better illustrate the example shown in the figure below and highlighted in light – gray.

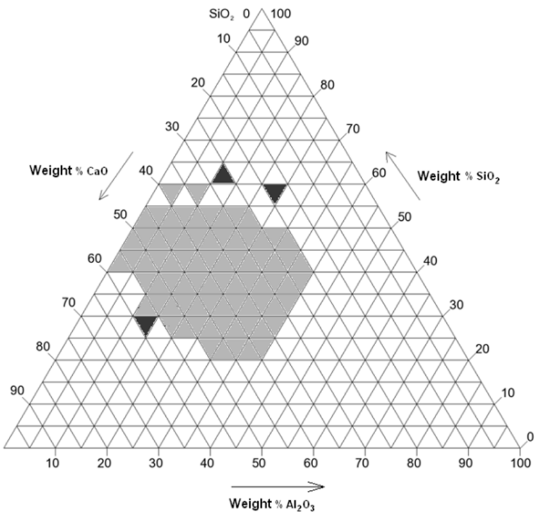


Fig. 2. Areas designated by the program (light - gray - the designated viscosity, dark - gray - testing the ability of refineries)

Thanks to this performance, you can browse the various formations of mixtures of slag in terms of physicochemical properties and refineries. When analyzing the data collected in the table shown in Figure 2, it can be seen that the viscosity of the mixture components increases with decreasing amounts of CaO. For example, the sequence number indicated by a mixture of 116, of the composition of 15 - 20% Al_2O_3, 50 - 55% CaO, 30 - 35% SiO_2 has a viscosity of 3 - 20 poise at 1500^{0}C. Meanwhile blend numbered 371, having a composition of 5 - 10% Al_2O_3, 30 - 35% CaO, 55 - 60% SiO_2 has a viscosity of 30 - 50 P at 1500^{0}C.

It can therefore raise the question, which of the presented compound slag will be exhibited the best ability of refiners. For this purpose have been tested three compounds, the compositions of which are located on the outskirts of the study area. Location of test samples is shown in dark - gray in the above figure 3.

Table 1.
The experimental results

Symbol of slag	Other	Inc.	EW [kJ/mol]	r [%]	T [K]
307	10% NaCl, 5% C	Cu_2O	-120	-76	1300
180	40%CaC_2	Cu_2O	-140	-15	1250
368	20%Al	Cu_2O	+1	+1	>1273

Symbol of slag	Composition of basic slag [%]					
	Al_2O_3	CaO	SiO_2	Na_2O	MgO	B_2O_3
307	15	10	35	20	-	5
180	9	22	57	8	4	-
368	13	52	23	-	4	8

The first area designated by order number 307, was characterized by unfavorable refining abilities. In this case the region of interest obtained energy index EW 1 kJ/mol and mass index r = 1%. This means that the compound has the impact oxidizing slag. It should be noted that this area is located in the immediate vicinity of the slag mixtures of lower viscosity values.

The next two mixtures were analyzed at opposite ends of the analyzed area. One of them is designated order number 180, which corresponds to that of 10 - 15% Al_2O_3, 25 - 30% CaO, 60 - 65% SiO_2. This mix of slag

Areas that meet your criteria:

Type of slag: Al_2O_3 - CaO - SiO_2

Found areas that meet your criteria: 82

Features found areas:

Temp. min.	Temp. max.	Viscosity min.	Viscosity max.	Wettability min.	Wettability max.	Surface tension min.	Surface tension max.	Conductivity min.	Conductivity max	Mass of Al2O3 min.	Mass of Al2O3 max.	Mass CaO min.	Mass CaO max.	Mass SiO2 min.	Mass SiO2 max.	id
°C	°C	P	P	°	°	N/m	N/m	$Ohm^{-1}cm^{-1}$	$Ohm^{-1}cm^{-1}$	%	%	%	%	%	%	-
1266	1500	7	15	*	**	0.53	0.55	0.4	0.5	20	25	35	40	35	40	330
1266	1500	15	25	*	**	0.459	4.657	0.1	0.4	25	30	30	35	35	40	329
1266*	1317*	7	20	*	**	0.46	4.535	0.4	0.5	15	20	35	40	40	45	342
1266*	1400	7	20	*	**	0.443	4.535	0.1	0.4	20	25	35	40	40	45	140
1300	1400*	5	10	*	**	0.433	0.5	0.4	0.6	10	15	35	40	45	50	153

Fig. 3. The results sought out areas that meet the criteria specified by the user specified by the program

achieved high refining capacities. The energy index of this area was -140 kJ/mol, and the mass index r = 15%. This blend is on the border of the area is characterized by a higher viscosity value of up to 50P. To check the dependence analyzed another mix indicated sequence number 368, whose composition was as follows: 20 - 25% Al_2O_3, 15 - 20% CaO, 55 - 60% SiO_2. Also, this blend achieves good refining capacities. The energy index was, in this case -120 kJ/mol, while the mass index r = -76%. This means that a mixture of the following composition has a high reducing ability.

The results of verification areas are summarized in Table 1. It is worth noting that these mixtures. Speedway has been enhanced with additional components, which improve their properties and act as promoters or catalysts.

5. Summary

Summarizing the above considerations it can be concluded that the optimum extraction physicochemical properties of coatings, including their level of viscosity is a very important factor in the economics of the enterprise. Too high viscosity will hinder the diffusion of pollutants into the shell slag and thus hamper will carry out the process of refining. On the other hand, too low a viscosity will cause not only the slag melting behavior of the coating in the vicinity of the oven walls, which will cause the liquid metal mirror discovery that at this point would be exposed to harmful effects of the external atmosphere, but also will lead to weight of transition metal into the slag, causing his loss.

The Polish copper smelters of produced annually is over 400,000 Mg post - process slags. Assuming the possibility of increasing the "yield" of copper only at the level of 0.1% represents a 400 Mg metallic copper allocated directly to the refining fire. Put it in the lowest price of scrap copper allows it to estimate the expected profits from the project to develop the technology, only costs directly resulting from the increase in copper recovery from slag, at about 2 million zł per year. In addition, gains will be achieved by shortening the process and to reduce the weight of slag processed again in shaft furnaces, which ultimately will reduce energy consumption.

Due to the use of new technological solutions leading to the reduction of the amount of copper in the slag excludes the need to post-process the further processing in metallurgical conditions (a process called. "Recycle") will also considerably reduced consumption of materials previously used, including the weight of the dolomite. This will affect the possibility of limiting the extraction of these minerals which will also bring tangible benefits to both environmental and economic - reducing the amount of material transported to the smelter batch.

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