ISSN 0543-5846
METABK 62(1) 25-28 (2023)
UDC – UDK 669.18:669.184:513.13:541.481=111

VISCOSITY AND PHASE TRANSLATED ANALYSIS OF CONVERTER MOLTEN SLAG

Received – Primljeno: 2022 - 03 - 08
Accepted – Prihvaćeno: 2022-07-10
Original Scientific Paper – Izvorni znanstveni rad

Slag viscosity effect the physical and chemical process of the converter.In the paper, thermodynamic calculations and interruption experiments are carried out to explore the slag viscosity and phase translated. With the increase of new components Al_2O_3 and TiO_2, the viscosity is decreased. According to experiment result, the low-basicity slag is in molten state except for a small amount of SiO_2,and the SiO_2, Al_2O_3 and Fe_2O_3 are not melted in the high-basicity slag. Thus the reasonable basicity should be controlled at 2,4 ~ 3,2 at 1 500°C.

Keyword: steel, converter slag, viscosity, basicity, interrupt experiment

INTRODUCTION

The slag-metal reaction is effected by slag viscosity directly in converter molten pool, it also influences the smelting reaction rate, inclusion removal, slag-metal separation and furnace lining life, etc. [1 - 2].There are many studies on the converter molten slag viscosity in the steel process and mature theories have been obtained. Jiao Z.Y et al. did some research on the viscosity of CaF_2-SiO_2-Al_2O_3-CaO-MgO slag system and found that the viscosity is reduced by controlling mass fraction of CaF_2, the viscosity is increased by adding SiO_2, Al_2O_3 and MgO, it is decreased with adding CaO [3]. Huang B et al. did research on CaO-SiO_2-FeO-Cr_2O_3-MgO-MnO slag in the aspects of component activity, phase composition, viscosity model and slag structure, in this way, then the relationship between them can be gained [4]. Jia J.Y et al. established the slag viscosity calculation model of ternary containing TiO_2 and obtained that when there are more TiO_2 in the slag, the viscosity of slag system is decreases [5]. Li J.X et al. did some research on the slag viscosity of the CaO-MgO-MnO-FeO-CaF_2-Al_2O_3-SiO_2 slag system, and found that the concentration calculation model can reflect the actual structure, viscosity model can reflect the correct relationship between the viscosity and temperature with the other structural units concentration [6]. Weymann H D et al. studied the dependence of viscosity on temperature, pressure and specific volume. The conclusion is that the pores volume and the energy needed to generate pores are determined by the pressure and some liquids viscosity [7]. The slag viscosity is important for furnace lining and technological process. Selecting proper basicity is to select proper slag composition which would keep the slag in a good liquid phase region and form reasonable slag fluidity. Increase of basicity not only increase the alkaline oxides which are beneficial to the depolymerization of the network structure, but also reduce the network structure formed by acidic oxides, in this way, the converter slag viscosity can be controlled properly [8].

This paper study viscosity changes from the different factors, by analyzing the converter CaO-SiO_2-MgO-FeO slag system at first, then there are CaO-SiO_2-MgO-Al_2O_3-FeO slag system and CaO-SiO_2-MgO-Al_2O_3-FeO-TiO_2 slag system step by step, it will determine the effects of different components on slag viscosity, the combination of calculation and interruption experiments and provide a theoretical basis for obtaining reasonable fluidity of converter slag.

RESERACH SCHEMES

Based on production slag composition characteristics, FactSage software is used to calculated with the components in Table 1~Table 3. The viscosity changes of CaO-SiO_2-MgO-FeO quaternary slag system under

Table 1 **CaO-SiO_2-Al_2O_3-FeO slag composition / %**

Num	R	CaO	SiO_2	MgO	FeO
1	2	50	25	9	16
2	2.2	51,6	23	9	16
3	2,4	52,9	22,1	9	16
4	2,6	54,2	20,8	9	16
5	2,8	55,3	19,7	9	16
6	3,0	56,3	18,8	9	16
7	3,2	57,1	17,9	9	16
8	3,4	50	25	9	16

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Table 2 **$CaO-SiO_2-MgO-Al_2O_3-FeO$ slag system composition / %**

Num	R	CaO	SiO_2	MgO	Al_2O_3	FeO
9	2	48,7	24,3	9	2	16
10	2,2	50,2	22,8	9	2	16
11	2,4	51,5	21,5	9	2	16
12	2,6	52,7	20,3	9	2	16
13	2,8	53,8	19,2	9	2	16
14	3,0	54,8	18,2	9	2	16
15	3,2	55,6	17,4	9	2	16
16	3,4	56,4	16,6	9	2	16

Table 3 **$CaO-SiO_2-MgO-Al_2O_3-FeO-TiO_2$ slag system composition / %**

Num	R	CaO	SiO_2	MgO	Al_2O_3	FeO	TiO_2
17	2	48,7	24,3	9	2	16	0,4
18	2,2	50,2	22,8	9	2	16	0,4
19	2,4	50,2	21,5	9	2	16	0,4
20	2,6	51,5	20,3	9	2	16	0,4
21	2,8	52,7	19,2	9	2	16	0,4
22	3,0	53,8	18,3	9	2	16	0,4
23	3,2	54,8	17,4	9	2	16	0,4
24	3,4	55,6	16,6	9	2	16	0,4

Table 4 **Chemical composition of converter phase analysis / %**

Num	R	CaO	SiO_2	MgO	Al_2O_3	FeO	MnO_2	P_2O_5	TiO_2
25	2	46,4	23,2	9	2	16	2	1	0,4
26	2,2	47,9	21,7	9	2	16	2	1	0,4
27	2,4	49	20,5	9	2	16	2	1	0,4
28	2,6	50,3	19,3	9	2	16	2	1	0,4
29	2,8	51,3	18,3	9	2	16	2	1	0,4
30	3,0	52,2	17,4	9	2	16	2	1	0,4
31	3,2	53	16,6	9	2	16	2	1	0,4
32	3,4	53,7	15,8	9	2	16	2	1	0,4

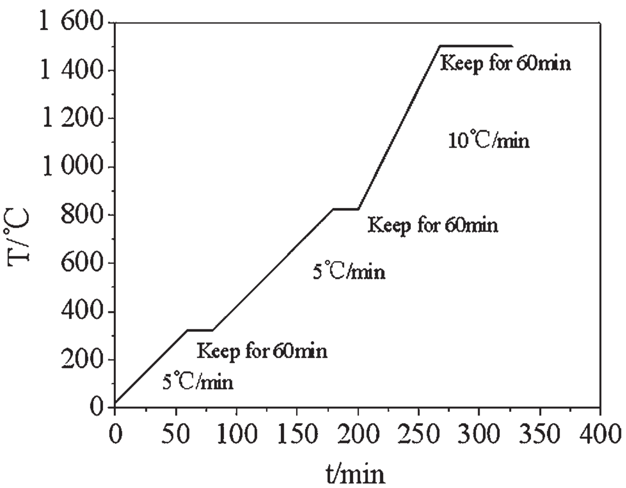

Figure 1 experimental temperature rise curve

different basicity and temperature are analyzed, then the FeO and TiO_2 are added.The basicity R is $w(CaO)/w(SiO_2)$. then we prepare the sample using chemical analysis. In order to ensure the accurate content and proportion of each slag sample, slag sample is weighed for three times with 50 g slag, and it is mixed in agate mortar, and put it into a graphite crucible, the composition are in Table 4.

The interrupting water quenching experiment is adopts, and the samples is took out from the furnace quickly at 1 500 °C, the temperature rise procedure is shown in Figure 1.Then the cooled sample is grind to 200 mesh sieve, and 300 mg sample for X-Ray Diffraction (XRD) detection and analysis.

RESULTS AND DISCUSSION

Calculation results and analysis

According to the component composition in Table 1, the $CaO-SiO_2-MgO-FeO$ viscosity changes with temperature is shown in Figure 2, It can be seen that the viscosity tends to decrease with the increase of basicity. The slag shows an excessive trend when R is 2, but the viscosity curve coincides when the R reaches 2,4. Through calculation, it can be seen that the temperature is an important factor affecting the viscosity.With the increase of temperature, the slag viscosity is not decreases rapidly after the 1 600 °C. The $CaO-SiO_2-MgO-Al_2O_3-FeO$ viscosity is shown in Figure 3, when Al_2O_3 is added to the system, the viscosity of the five element slag system decreases obviously at the same temperature. When R is 2 to R is 2,2, the viscosity of slag shows an excessive trend compared with that of other basicity, but when the basicity reaches 2,4, the trend is slightly more high, when R is 2,6 ~ 3,4, the viscosity curve coincides. It can be seen that the increase of new components will play the role of doping, the formation liquid phase temperature and overall melting temperature of the system are reduced, so that the viscosity of the system shows a downward trend. According to the composition in Table 3, the viscosity of $CaO-SiO_2-MgO-Al_2O_3-FeO-TiO_2$ slag system changes with temperature, as shown in Figure 4, it can be seen that when TiO_2 is added to the system, when R is 2, the slag viscosity shows an excessive trend compared with that of other basicity, and the viscosity value is also large at 1 400°C,when the basicity reaches 2,2, the basically trend of comparing other viscosity values is the same,when R is 2,4 ~ 3,4, the viscosity curve coincides. The bigger the basicity, the better the coincidence, and the smaller the viscosity value. It can be seen that CaO can separate into the free ions at high temperature, which can play the role of depolymerization and simplify the original complex network structure of the slag system. Thus, the mobility of slag is increased and the fluidity is improved. It can be seen that TiO_2 has a great impact on the low-temperature slag with low basicity. Therefore, the

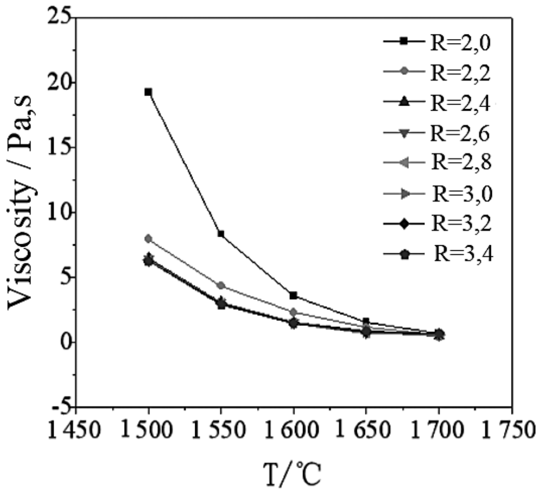

Figure 2 CaO-SiO_2-MgO-FeO slag viscosity with different basicity

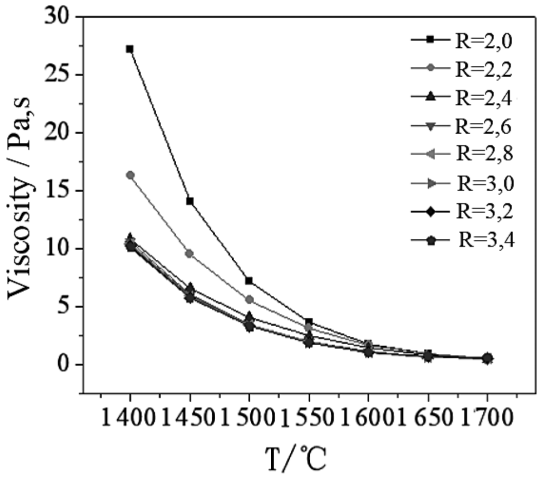

Figure 3 CaO-SiO_2-MgO-Al_2O_3-FeO slag viscosity with different basicity

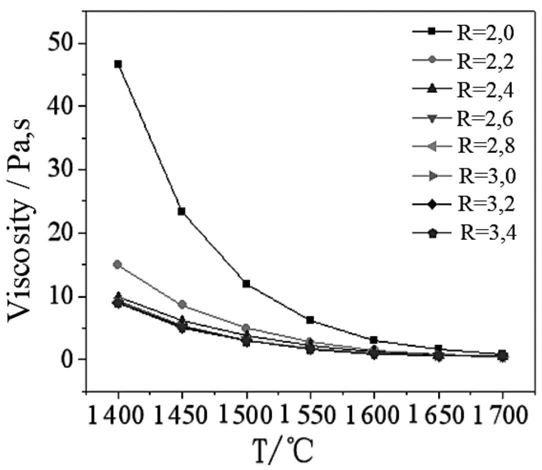

Figure 4 CaO-SiO_2-MgO-Al_2O_3-FeO-TiO_2 slag viscosity with different basicity

slag system with simpler components has higher liquid phase generation temperature and worse low-temperature fluidity, and the slag system with more complex components has lower melting point and lower viscosity with the increase of temperature.

Experimental results and analysis

The XRD test results are shown in Figure 5. It can be seen that only a small amount of SiO_2 is in crystal state when the basicity is between 2,0 and 3,2, it shows that there is still the possibility of reaction under this temperature condition. With the increase of temperature, SiO_2 may continue to dissolve and promote the further development of the reaction. And the whole formed an obvious large envelope peak, with different basicity. It can be seen that amorphous form has been formed when heated to 1 500 °C, and the dissolution of each phase in the slag is basically good, at this time, the slag has gone through a large number of chemical reaction stages and formed a liquid state composed of a large number of low melting point substances, so the viscosity of the slag begins to decrease. It can be seen from the figure of R is 3,4 that SiO_2, Al_2O_3 and Fe_2O_3 will precipitate in the slag phase, indicating that when the basicity increases to a certain value, the phase will not reach a good reaction state due to excess. Therefore, the converter slag R can be controlled within 2,2 when the temperature is 1 500°C.

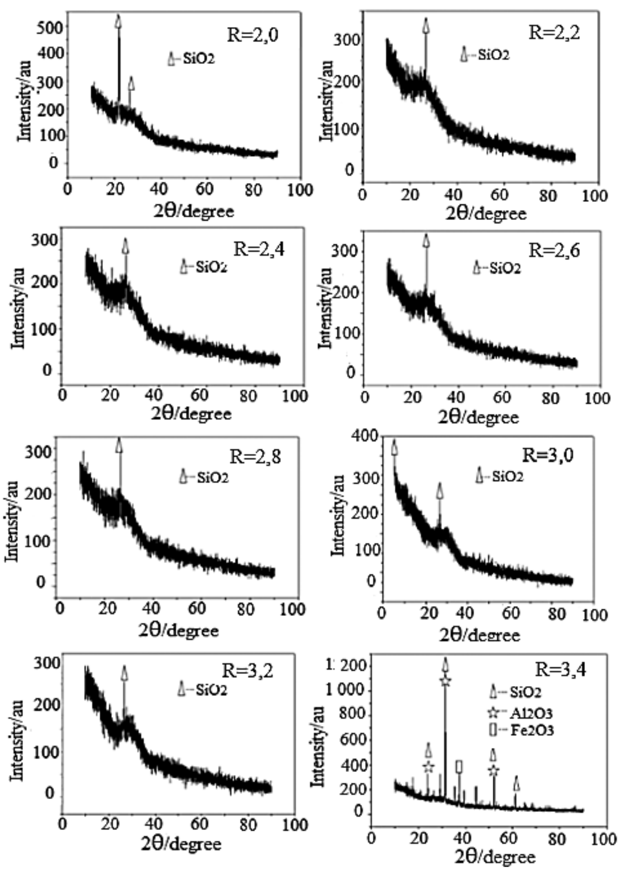

Figure 5 XRD analysis with different basicity

CONCLUSIONS

At the same temperature, the viscosity of slag decreases with the increase of basicity.The increase of new components Al_2O_3 and TiO_2 makes the viscosity decrease, especially for the slag with low temperature and low basicity.

The slag viscosity changes with the temperature, the higher the temperature, the more obvious the decrease of viscosity.When the temperature is above 1 600°C, with increase of superheat, the viscosity slag systems tends to be stable, and viscosity decreases with the increase of basicity.

According to the high temperature phase detected by XRD, it shows that the glass state is basically formed when heated to 1 500°C. At the same time, although the increase of basicity has the ability to depolymerize the complex network structure, there will be SiO_2, Al_2O_3 and Fe_2O_3 unmelted in the slag at high basicity.Combined with the viscosity calculation results, it is determined that the reasonable binary basicity at this temperature should be controlled within 2,4 ~ 3,2.

Acknowledgements

This work is financially Supported by the National Science and Foundation of China. (No.51774032& 51874171)

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Note: The responsible translator for language English is associate Professor S.Zhang -- University of Science and Technology Liaoning,