ISSN 0543-5846
METABK 62(2) 194-196 (2023)
UDC – UDK 669.781/66.06:669.782.26.002.2:66.014:536.45=111

FEATURES OF THE SLAG REGIME OF SMELTING BORON CONTAINING SILICOCHROME

Received – Primljeno: 2022-10-20
Accepted – Prihvaćeno: 2022-12-25
Original Scientific Paper – Izvorni znanstveni rad

The article presents the results of a study of the slag mode of melting boron-containing silicochrome. It is shown that the addition of boron-containing fluxes to the silicochromium charge made it possible to reduce the thermal level of the melting process by reducing the melting temperature and viscosity of the final slags.

Keywords: boron-containing fluxes, production of silicochrome, chemical composition, temperature, properties of slag.

INTRODUCTION

The process of melting silicochrome is considered to be slag-free, although during the melting process 3–5 % of slag is formed per 1 ton of metal [1-2]. At the same time, despite the relatively small amount of slag, it has a significant effect on melting performance. Slags have a high melting point and viscosity and therefore require a high thermal level of the process and, as a result, frequent emergency shutdowns due to the increased amount of sublimates, increased power consumption. We propose a technology for smelting silicochrome with a given amount of boron (0,3-0,5 %), which will be used as a complex reducing agent in the smelting of low-carbon ferrochrome grades.

The use of boron-containing silicochrome will ensure the stabilization of highly basic slags with high technical and economic melting performance.

This article presents the results of a study of the effect of boron-containing fluxes on the viscosity and crystallization temperature of the final slags from the smelting of silicochrome.

WAYS OF RESEARCH

Calculation and theoretical analysis established that in order to provide 0,3-0,5 % B_2O_3 in low-carbon ferrochrome slag, which ensures the stabilization of the latter in the silicothermic method, ferrosilicochrome must contain 0,3-0,5 % boron. Estimated composition of the charge per 1 ton of silicochrome grade FeSiCr-48/kg:

- quartzite – 1 254;
- coke – 585;
- metal shavings - 103;
- conversion ferrochrome - 493.

The chemical composition of the initial components of the charge is presented in Table 1.

Table 1 **Chemical composition of the initial components of the charge**

Material	Content / %					
	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	B_2O_3
Quartzite	0,3	97,0	0,7	0,6	–	–
coke ash (A = 12,5 %, C_{nonmet}. – 86,0 %)	4,368	49,104	30,184	11,504	–	–
colemanite	27,6	5,5	0,4	0,09	3,0	42,0
	Cr	C	Fe	Si	Mn	
Carbon Ferrochrome	68,0	9,0	19,0	4,0	–	
Shavings	–	0,3	99,0	0,14	0,47	

For the smelting of silicochrome with a content of 0,3 % and 0,5 % boron, 23 kg and 38 kg of colemanite, respectively, were added to the charge.

Taking into account the distribution coefficients of the main components (Fe, Cr, Si, Ca, Al, B), which are shown in Table 2, the amount and composition of the slag are calculated.

Table 2 **The distribution of elements between the products of smelting silicochrome**

Smelting products	Elements							
	Fe	Si	Al	Ca	Mg	B	P	S
Alloy	100	92	48	15	–	90	55	1
Slag	–	2	42	80	80	2	3	5
Fly elements	–	6	10	5	20	8	15	94

An analysis of the results of the melting material balance showed that the introduction of the calculated amount of colemanite (23 kg, 28 kg) into the charge significantly affected the amount and composition of the slag. The yield of slag in experimental heats per ton of metal increased from 4,33 % to 4,87-5,24 %. With a total electricity consumption during the melting of 1 ton

A.S.Kim, A.A. Akberdin, A.S. Orlov Chemical-Metallurgical Institute, R.B. Sultangaziyev, G.H. Adamova «Abylkas Saginov Karaganda Technical University», Karaganda, Kazakhstan, e-mail: sulrus83@mail.ru

of FeSiCr – 48,5 500 kWh [3-4], the electricity consumption due to the increase in the amount of slag will increase by an average of 0,14 %. These costs will be covered by improving the physical properties of slags, which contribute to a decrease in the thermal level of the process and, thereby, a decrease in the amount of sublimates, a decrease in emergency shutdowns of the furnace.

The calculated chemical composition of the experimental slags is presented in Table 3.

Table 3 **Calculated chemical composition of experimental slags**

Slag numbers	content/ %				
	CaO	SiO_2	Al_2O_3	MgO	B_2O_3
1(Basic charge)	12,47	56,12	29,05	2,36	–
2(Experimental charge No. 1)	21,07	49,63	25,74	3,18	0,38
3(Experimental charge No. 2)	25,68	46,15	23,95	3,63	0,59
4(Experimental charge No. 3)	29,68	43,13	22,44	3,99	0,76

For research, experimental slags were synthesized from pure oxides by fusing them in predetermined ratios.

Experiments to determine the viscosity and crystallization temperature were carried out on an electrovibrational viscometer in the Tamman furnace using molybdenum equipment. The temperature in the working space of the furnace was fixed with a TR-5/20 tungsten-rhenium thermocouple, the viscosity was determined with continuous cooling at a rate of 1-3 degrees per minute.

The results of the viscosity study are shown in Figure 1.

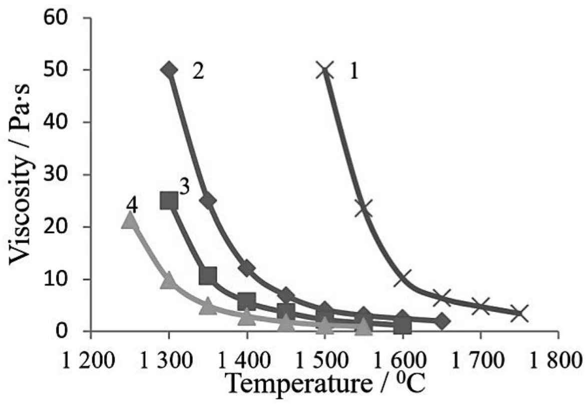

Figure 1 Results of the study of viscosity

Figure 2 shows the dependence of the logarithm of viscosity on the reciprocal temperature – Table 4.

To analyze the results of the study, the experimental slags were recalculated for the CaO - Al_2O_3 - SiO_2 three-component system, the sum of which is 95 % (Table 5) and plotted on the CaO - SiO_2 - Al_2O_3 three-component state diagram.

Table 6 shows the chemical and phase compositions of experimental slags of the CaO – SiO_2 - Al_2O_3 system. With the addition of colemanite in the experimental

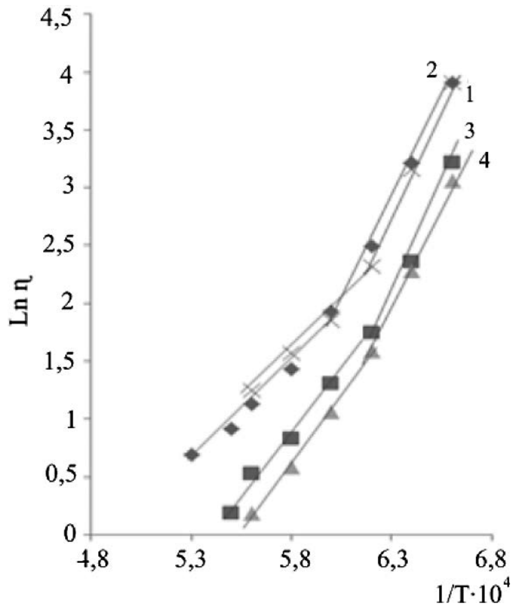

Figure 2 Dependence of the logarithm of viscosity on the reciprocal temperature

Table 4 **Crystallization temperature and activation energy of viscous flow**

Slag	Equations	$t°_{cr}$ / °C	E / kJ/mol
1(Basic charge)	$ln\eta_a$=75 502/T-38,369 $ln\eta_b$=24 269/T-10,627	1 580	627 201
2(Experimental charge No. 1)	$ln\eta_a$=42 901/T-24,238 $ln\eta_b$=22 819/T-11,951	1 450	356 189
3(Experimental charge No. 2)	$ln\eta_a$=39 050/T-22,71 $ln\eta_b$=21 701/T-13,13	1 420	324 180
4(Experimental charge No. 3)	$ln\eta_a$=35 470/T-18,784 $ln\eta_b$=19 908/T-9,6883	1 380	294 165

Table 5 **Chemical composition of slags in terms of the CaO - SiO_2 - Al_2O_3 system**

Slag numbers	Content / %			
	CaO	SiO_2	Al_2O_3	CaO/SiO_2
1 (Basic charge)	12,77	57,48	29,75	0,22
2 (Experimental charge No. 1)	21,85	51,46	26,69	0,42
3 (Experimental charge No. 2)	26,81	48,18	25,01	0,56
4 (Experimental charge No. 3)	31,16	45,28	23,56	0,67

slags, the content of CaO increased from 12,77 % to 31,16 %, which led to the displacement of the compositions into the wollastanite region SiO_2-CaO·Al_2O_3·2SiO_2-CaO·SiO_2. This circumstance, with the presence of 0,38-0,76 % B_2O_3 in slags, ensured a decrease in the melting temperature of final slags from 1 580 °C to 1 380 °C, the temperature range of fluid slags (viscosity less than 3,0 Pa·s) from 1 650 °C and higher up to 1 400-1 500 °C.

Changes in the physical properties of slags (viscosity, melting point) are consistent with their phase composition. Slags with elevated melting temperatures are characterized by an increase in the content of high-temperature phases [5 - 6]. The melting temperature of the base slag is determined by the high-temperature phases of mullite 3Al_2O_3·2SiO_2 (melting point 1 850°C) and silica (melting point 1 723°C).

Table 6 **Chemical and phase compositions of experimental slags of the $CaO - SiO_2 - Al_2O_3$ system**

Slag numbers	Chemical composition / %			
	CaO	SiO_2	Al_2O_3	S
1	12,77	57,48	29,75	27,573
2	21,85	51,46	26,69	12,336
3	26,81	48,18	25,01	4,738
4	31,16	45,28	23,56	0
Slag numbers	Phase composition / %			
	CAS_2	CS	A_3S_2	C_2AS
1	63,218	0	9,20	0
2	72,923	14,740	0	0
3	68,333	26,929	0	0
4	59,816	35,702	0	4,482

Table 7 shows the chemical and phase compositions of experimental slags of the $CaO - SiO_2 - Al_2O_3 - B_2O_3$ system. The decrease in the melting temperature of experimental slags can be timed to the appearance of low-temperature phases of wollastanite $CaO·SiO_2$ (melting point 1 464 °C) and calcium borate $CaO·B_2O_3$ (melting point 1 160 °C).

Table 7 **Chemical and phase compositions of experimental slags of the $CaO - SiO_2 - Al_2O_3 - B_2O_3$ system**

Slag numbers	Chemical composition / %				
	CaO	SiO_2	Al_2O_3	B_2O_3	
2	21,76	51,27	26,59	0,38	
3	26,65	47,9	24,86	0,59	
4	30,92	44,94	23,38	0,76	
Slag numbers	Phase composition / %				
	S	CAS_2	CS	C_2AS	CB
2	12,627	72,650	14,040	0	0,683
3	5,222	67,923	25,794	0	1,061
4	0	60,885	34,802	2,947	1,367

CONCLUSION

Thus, the laboratory studies of the physical properties of the final slags showed that the introduction of colemanite eliminates the problems of mining the final slags, and the limiting process is the reduction of silicon and the formation of a metal phase with the formation of iron and chromium silicides. These processes are completed at temperatures of 1 650-1 700 °C and there is no need to keep increased heating (more than 1 700 °C) in the furnace bath, at least there is a reserve of work at a reduced thermal level of the process. This factor will remove all the negative phenomena of the process of smelting silicochromium: carburization of the furnace bath, clogging of gas ducts, the roof of the furnace. Maintaining a lower thermal level of the process, reducing the melting time by increasing the rate of silicon reduction will provide significant energy savings.

On the whole, it has been shown that the technology of melting boron-containing silicochrome is feasible with high technical and economic indicators. In this case, it is necessary to comply with the basic requirements for melting silicochrome: deep seating of the electrodes and the presence of charge cones around the electrodes.

ACKNOWLEDGEMENT

This research is funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP09259038).

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Note: he responsible translator for English language is Nataliya Drag, Karaganda, Kazakhstan