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**Kinetics of Bauxite Sinter Reduction****A.N. Ovcharuk, A.J. Taran, V.K. Rudenko**National Metallurgical Academy of Ukraine  
4 Gagarin Ave., Dnipropetrovsk 49600, Ukraine**Abstract**

*The kinetics of bauxite sinter reduction under different content of reducing agent in the charge is studied. The microstructure and distribution of elements in phases of sinter are analyzed. It is shown that as carbon content in test charge increases, the temperature of charge softening rises and phase composition of finished product changes, quantity of corundum grains and metallic beads increases. The importance of preparation of charge components for smelting is explained.*

**Keywords:** *bauxite sinter, kinetics of reduction processes, carbonaceous reducing agent, softening temperature*

**The task of research. Methodology.**

Substantial separation of charge materials in the reaction volume of furnace takes place in the industrial ore-smelting electric furnaces under smelting of sintered bauxite with the use of anthracite as a reducing agent [1]. This extremely undesirable phenomenon is caused by a major difference in specific mass of charge components (sinter and reducing agent), their large size, etc. This leads to formation of macrovolumes in reaction volume of furnace where an oxide part of charge does not contain a solid reducing agent, or contains it less than necessary in accordance with stoichiometry or its content is surplus.

The behavior of pure sinter and charge containing from 20 up to 120 % of carbon from theoretically necessary amount at heating was studied in order to find out the possible mechanism of processes progress in a furnace in these

macrovolumes. The charge investigated was heated up from a room temperature at the rate of 10 °C/minute in argon atmosphere. The temperature and charge softening pattern under loading, qualitative, quantitative and phase composition of smelted products were observed during the tests. The research was carried out on the plant allowing us to determine the pattern and initial temperature of charge softening under loading with simultaneous control of reduction processes rate at the temperature mode set by the program in advance [2].

The sintered bauxite of Vysokopolskiy deposit with 2-3 mm fractions and anthracite with 0.25-0.5 mm fractions were used in the experiments.

The chemical composition of raw materials is presented in Table 1. Charge composition for each experiment is given in Table 2.

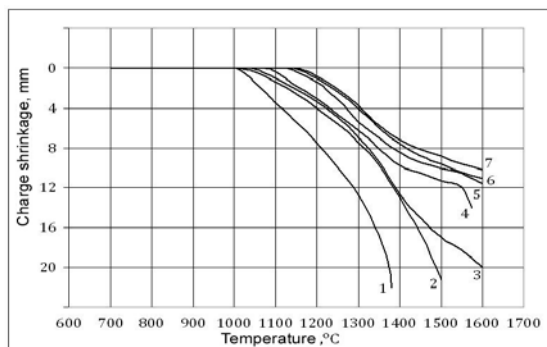
**Table 1. Chemical composition of raw materials**

Material	Content of components, %								
	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	CaO	Fe	C
Sinter coke	48.06	8.85	3.16	21.00	15.56	0.27	0.2	0.72	1.05
Anthracite	0.88	1.52	0.15	4.04	–	0.28	0.2	–	89.9

**Table 2. Charge composition for thermokinetic studies**

Material	Experiment number						
	1	2	3	4	5	6	7
Sinter, g	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Anthracite, g	0	0.1336	0.386	0.638	0.890	1.142	1.395
% C in charge from theoretical amount	9.5	20	40	60	80	100	120

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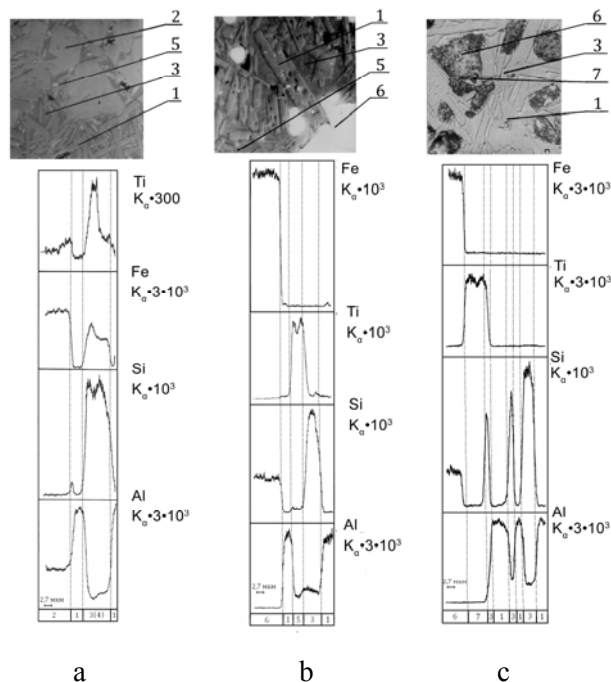
**Figure 1. Change of charge shrinkage depending on temperature:** 1 – raw sintered bauxite of Vysokopolskiy deposit and sintered charges with various content of carbon from stoichiometrically necessary amount, %: 2 – 20; 3 – 40; 4 – 60; 5 – 80; 6 – 100; 7 – 120.

The lowest initial temperature of charge softening 1010 °C and the narrowest temperature interval are observed at heating of pure sinter (Figure 1). At further heating up to 1200 °C, the sinter is characterized by significant viscosity and it becomes plastic only after reaching 1380 °C. After cooling, the sinter was in the form of melted material.

The qualitative and semi-qualitative estimation of phase composition of sinter was carried out on X-ray micrographic analyzer and proved the existence of corundum  $\alpha$ -Al<sub>2</sub>O<sub>3</sub>, hercynite FeO·Al<sub>2</sub>O<sub>3</sub> and glass with inclusions of FeO·TiO<sub>2</sub> (Figure 2a).

The softening interval increases noticeably, as amount of reducing agent grows up to 20 % (see Figure 1). The charge has become plastic enough at 1500 °C (Figure 1). The quantity of corundum grains increased a little and content of hercynite decreased. Metallic beads appeared on hercynite grain boundaries, in which silicon is absent. All the other phases are similar to those in pure melted sinter.

The increase of carbon content in charge up to 40%, 60%, 80 % from stoichiometric necessary amount leads, first of all, to raise of initial temperature of charge softening. So, at 40 % of carbon the initial temperature of softening was 1050 °C, 60 % – 1075 °C, and at 80 % of carbon – 1130 °C. The pattern of softening changes as well: at 40 % of carbon a stock pressing on the charge plunged into it by 20 mm at 1600 °C, and at 80 % of carbon – only by 12 mm. Phase composition of



**Figure 2. Microstructure and concentration curves of elements distribution:** a – in phases of sinter at 1380 °C; b – in products of charge interaction with stoichiometric quantity of carbon at 1600 °C; c – in products of charge interaction with surplus carbon 20 % at 1600 °C: 1 – corundum; 2 – hercynite; 3 – glass; 4 – FeO·TiO<sub>2</sub>; 5 – TiO<sub>2</sub>; 6 – metal; 7 – TiC

finished product changes as well – beads coarsen, quantity of corundum grains increases, hercynite partially reduced is completely absent as a separate phase and partially forms a phase with fayalitic glass.

This phase is close to ferriferous cordierite 2FeO·2Al<sub>2</sub>O<sub>3</sub>·5SiO<sub>2</sub> but with less quantity of glass. The observable raise of initial temperature of charge softening (1050 °C, 1075 °C, 1130 °C) occurs, basically, due to increase of share of reduction processes from solid phases that finally leads to increased refractory quality of charge.

At stoichiometric ratio of carbon in the charge, the initial temperature of softening was higher than in the charge with lack of carbon - 1145 °C (Figure 1). Corundum is main phase in the product obtained at 1600 °C. Corundum is observed as light grey colored plates with high relief in polished microsection. The space between corundum is filled by glass, which is close to mullite 3Al<sub>2</sub>O<sub>3</sub>·2SiO<sub>2</sub> by its material composition. The iron oxides are almost completely reduced,

which is proved by the curve of iron radiation intensity in the product investigated (Figure 2b). The metallic beads contain 8–9 % silicon, up to 1 % aluminum, 0.5–1.5 % titanium and up to 2 % residual carbon. There is also a low amount of titanium oxide inclusions with high reflective ability.

The charge containing surplus carbon (120 % from theoretically necessary amount) is characterized by the highest softening temperature – 1155 °C (Figure 1) and variable speed of stock submersion. From the moment of onset of softening up to 1450 °C, the speed of stock submersion into the charge was of the order of 0.26 mm/minute, and in the interval of temperatures 1450–1600 °C it did not exceed 0.15 mm/minute and tended to further reduction. The deepest stock submersion made 10 mm. After experiment, the charge was a loose slightly sintered mixture with a lot of metallic beads (Figure 2c). The charge had a little difference by its mineralogical makeup from the charge with stoichiometric quantity of carbon. This difference consists only in size of zones, small amount of graphitized debris of anthracite and fine inclusions of titanium carbides.

### **Summary**

Thus, the lack of carbon as well as its surplus in the charge result in either early slag formation in the furnace bath or its carbonization so that a normal course of technological process is disturbed. To avoid this it is necessary to pay a close attention to mixing of charge components and not to allow their separation. It is difficult to achieve with the use of sintered bauxite in the charge. Dehydration of bauxite without its smelting, subsequent crushing coupled with the quantity of reducing agent required and briquetting seem to be more

reasonable. Such a scheme of charge preparation will enable to eliminate the formation of fayalite, hercynite, ferriferous cordierite, formation of early slag in charge and will also create more favorable conditions for reduction of oxides of iron, silicon and aluminum.

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### **Кинетические особенности восстановления бокситового агломерата**

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Исследована кинетика восстановления бокситового агломерата при различном содержании восстановителя в шихте. Проанализирована микроструктура и распределение элементов в фазах агломерата. Показано, что с повышением содержания углерода в навеске повышается температура размягчения шихты и меняется фазовый состав конечного продукта, увеличивается количество зерен корунда и корольков металлической фазы. Сделаны выводы о важности качества подготовки компонентов шихты к плавке.