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RESEARCH OF IRON EXTRACTION FROM PRIMARY STEELMAKING SLAG

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The article examines the issue of involving primary steelmaking slag in the processing with the extraction of iron and the production of slag, which can be used in the manufacture of construction products. Currently, primary steel slag is not used for the production of construction products due to the large amount of iron, and its use is limited to road construction and in most cases, primary slag is sent to landfills. In the Pavlodar region of the Republic of Kazakhstan, during steel production at electric steelmaking enterprises, the resulting electric furnace slag and dust are stored in slag dumps. They are practically not used, despite their high content of iron oxides and metallic iron particles (up to 40% by weight in some types of slag). The work experimentally determined the chemical and mineralogical composition of primary electric furnace slag with a total iron content of more than 20%. The slag contains the following minerals: wüstite (FeO), magnetite (Fe_3O_4), gehlenite ($Ca_2Al(Al,Si)_2O_7$), merwinite ($Ca_3Mg(SiO_4)_2$). In the course of experimental studies on the recycling of primary electric furnace smelting slags by reduction induction melting of slag-lime-coke pellets, the possibility of extracting iron in the form of iron-carbon alloys and using the slags for the production of concrete was established.

Keywords: metallurgy, steel, slag, recycling, X-ray spectral analysis

1 INTRODUCTION

One of the significant wastes of the metallurgical industry is steel slag, which is divided into primary and secondary. Currently, primary steel slag is not used for the production of construction products due to the large amount of iron, and its use is limited to road construction, and in most cases, primary slag is sent to dumps [1].

Primary steelmaking slag is a multicomponent system in which the oxides that determine the composition are CaO, SiO_2, Al_2O_3, MgO, FeO. In addition, they contain oxides of Mn, P, Cr, Ba, S, Fe, V, Ti and others. In terms of chemical composition, up to 85% of primary steelmaking slag is CaO, SiO_2 and iron oxides. In addition, they contain metal. Metal enters the steel-smelting slag mainly because of its transfer by bubbles during boiling of the bath or its purging with inert gases.

Pavlodar region, which is essentially a diversified industrial complex where electricity, aluminum is produced, oil refining, mechanical engineering, ferrous metallurgy, production of building materials is developed, is one of the most industrialized regions of Kazakhstan. The presence of a large number of industrial enterprises also implies a great burden on the local ecology. The real environmental situation requires an increase in the efficiency of the use of secondary production products. In this regard, it becomes necessary to use man-made waste as an ore base for industry [2,3].

It should be noted that the production of electric steel and rolled products of various grades is one of the main drivers of growth in the ferrous metallurgy of the Republic of Kazakhstan [4,5]. However, modern electric steelmaking is characterized by the production of a by-products significant number. Among them, it is possible to distinguish primary steelmaking slag (10-12% of the melting mass); secondary slag from the bucket–furnace unit (up to 2.5% of the melting mass); dust (up to 1.5% of the melting mass) [6, 7].

In the Pavlodar region of the Republic of Kazakhstan, in the production of steel at the electric steelmaking enterprises of Casting LLP and KSP Steel LLP, the resulting electric steelmaking slags and dust are stored in slag heaps and are practically not used. They have a high content of iron oxides and metallic iron particles in them (up to 40% of the mass in certain types of slags) [8, 9, 10].

Innovative projects are already being implemented in Kazakhstan to involve secondary steelmaking slags and other metallurgical waste in the processing [11 - 20]. However, primary steelmaking slags formed in arc furnaces are not involved in processing. In this paper, the possibility of processing primary steelmaking slags with additional extraction of iron and slag for the construction products production is investigated.

This work explores the possibility of involving primary steelmaking slag in the processing with the extraction of iron by re-melting the slag in an induction furnace and low-iron slag, which can be used to produce concrete.

2 MATERIALS AND RESEARCH METHODS

The object of the study is the primary electric steelmaking slag formed in arc furnaces. As materials for the manufacture of fluted pellets were used: primary steelmaking slag, metallurgical coke, freshly burnt lime, bentonite. To determine steelmaking slag chemical composition, samples of a fraction with a diameter of 10 to 50 mm were selected. The samples were crushed to a fraction of 3 – 5 mm on a jaw crusher DSCH 80-150, crushed to a fraction of 0.01 mm on a Herzog vibration separator and the samples were pressed on a Herzog laboratory press (Fig. 1).

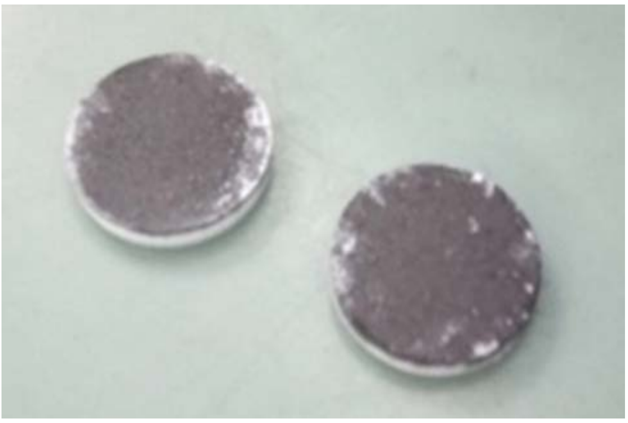

Fig. 1. Finished slag samples

Slag samples were examined by X-ray spectral analysis on a CPM-35 spectrometer. Steelmaking slag chemical composition of is presented in Table 1.

Table 1. Primary steelmaking slag chemical composition, %.

Fe_{total}	SiO_2	Al_2O_3	CaO	MgO	MnO	S	P_2O_5
23,4445	15,4259	3,8932	27,7137	4,9844	5,8785	0,0340	0,3972

Slag mineralogical composition was determined using an Empyrean diffractometer. The results of the analysis are shown in Table 2 and Fig. 2.

Table 2. Primary steelmaking slag mineralogical composition, %.

Compound name	Vustit	Magnetite	Gelenite	Mervinite	Magnesium and manganese oxide in contact with iron
Chemical formula	FeO	Fe_3O_4	$Ca_2Al(Al,Si)_2O_7$	$Ca_3Mg(SiO_4)_2$	$(MgO)_{0.43}$ $(MnO)_{0.57}$
Quantity	29	3	29	19	20

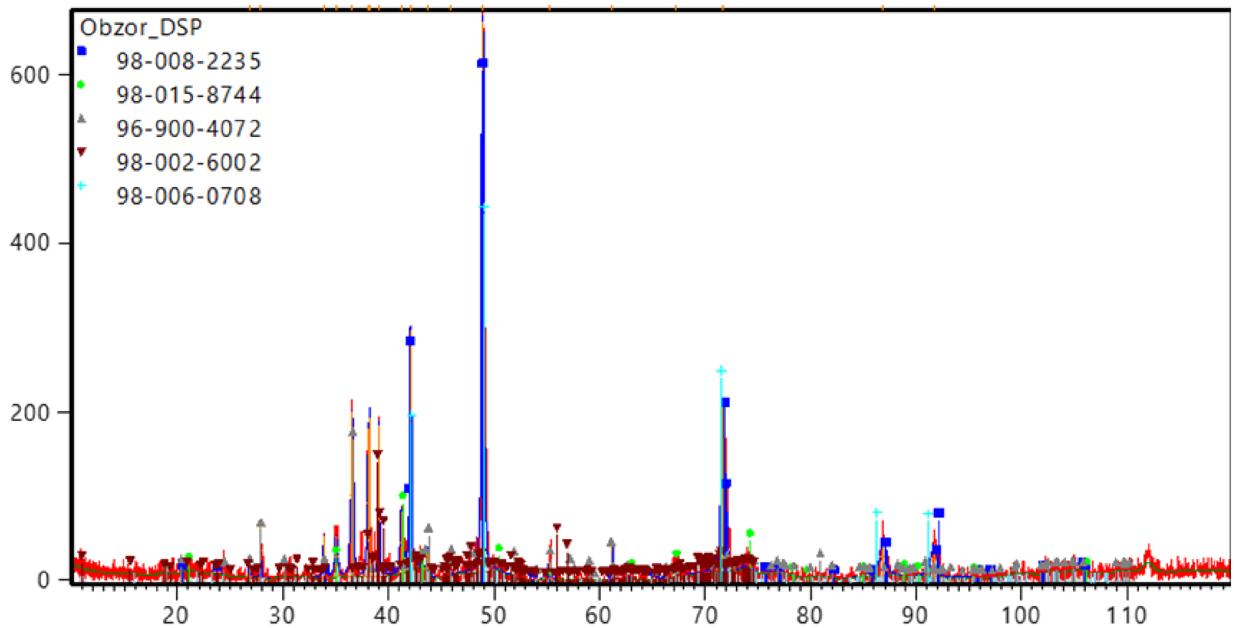

Fig. 2. Steelmaking slag diffractogram

3 RESULTS AND DISCUSSION

Pellets were prepared from primary steelmaking slag, metallurgical coke, freshly burnt lime and bentonite. Each series of experiments was carried out from pellets with a different ratio of components. Components compositions for various series of experiments are shown in Table 3.

Table 3. Components compositions according to various series of experiments, %.

Name of component	Series 1	Series 2	Series 3
Primary slag	60	65	70

Name of component	Series 1	Series 2	Series 3
Metallurgical coke	20	15	10
Lime	10	10	10
Bentonite	10	10	10
Water (over 100%)	15	15	15

Pellets of experiments each series were restored in an induction furnace at a temperature of 1500^{0}C.
The total weight of the filling was 5.5 kg. During the melting process, steel chips (0.25 kg) and fluorspar (0.3 kg) were additionally introduced into the furnace to improve metallurgical processes. Resulting slag was examined for mineralogical composition. (Table 4).

Table 4. Mineralogical composition of induction melting slag, %

Compound name	Chemical formula	Weight fraction
White	$2CaO*SiO_2$	44
Calcium and manganese oxides	$CaO*MnO_2$	10
Magnetite	$FeO*Fe_2O_3$	14
Mullite	$2Al_2O_3*SiO_2$	32

Iron-carbon materials (pellets) production in the experimental work is caused by a higher degree components dispersion, the contact surface area of iron oxides with carbon and gas. In this case, the reduction proceeds more intensively and is compatible with the high oxidative potential of the gas in the interstitial cavities.
After the melting, the resulting metal and slag were examined on a Niton X-ray fluorescence spectrometer (Table 5).

Table 5. Components compositions according to various series of experiments, %

Metal part		Slag	
Iron	82,080	Iron oxide+oxide (Fe_3O_4)	30,100
Manganese	4,070	Calcium Oxide (CaO)	27,300
Silicon	2,790	Silicon dioxide (SiO_2)	26,200
Carbon	2,560	Aluminum Trioxide (Al_2O_3)	5,310
Chromium	0,700	Magnesium Oxide (MgO)	6,200
Phosphorus	0,223	Manganese oxide (MnO)	3,900
Copper	0,050	Sulfur (S)	0,247
Sulfur	0,034	Phosphorus pentoxide (P_2O_5)	0,150
Nickel	0,020		

The results of experimental studies (Table 5) indicate that as a result of induction melting of slag-lime-coke pellets, an iron-carbon alloy was produced with an amount of iron of 82.080% Fe, Si - 2.79%, C - 2.56%, which can be considered good result for its further use in the production of steel products in arc steel-smelting furnaces.
The composition of the slag (Table 5) obtained from induction melting of slag-lime-coke pellets showed a decrease in iron oxides compared to primary steelmaking slag, namely: Fe_3O_4 - 30.1%, CaO - 27.3%, SiO_2 - 26.2 %, Al_2O_3 – 5.31%, MgO – 6.2%. This slag composition is acceptable for further use as a filler in concrete production.

4 CONCLUSIONS

The mineralogical composition of primary electric steelmaking slag with a total iron content of more than 20% has been experimentally determined, which includes the following minerals: wustite (FeO), magnetite (Fe_3O_4), helenite ($Ca_2Al(Al,Si)_2O_7$), mervinite ($Ca_3Mg(SiO_4)_2$).

In the course of the conducted experimental studies on the processing of primary electric steelmaking slags by reducing induction melting of slag-lime-coke pellets, the possibility of extracting iron-carbon alloys and using the final slag for the production of concrete has been established.

Research results the allow us to assert the possibility of practical implementation of the technological scheme for processing primary electric steelmaking slags with the production of additional charge materials in the form of an iron-carbon alloy, as well as induction melting slag suitable as a filler in the production of concrete.

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