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RESEARCH OF ELECTRICAL RESISTANCE AND TEMPERATURE OF THE BEGINNING OF SOFTENING OF CHARGE MIXTURES FOR SMELTING A COMPLEX ALLOY

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Preliminary note – Prethodno priopćenje

The results of the study of the electrical resistance and the temperature of the beginning of softening of high-ash coals of three working seams of the Saryadyr deposit and mixtures of charge materials are presented. The high electrical resistance of the charge in the ore smelting furnace provides a low proportion of charge conductivity and, thereby, contributes to the release of the bulk of the energy in the reaction zone of the furnace, where the metal is formed. The research results showed that the magnitude of the electrical resistance of the charge during non-isothermal heating to high temperatures largely depends on the chemical and mineralogical composition of the charge, as well as on the processes of phase transformations in the sample.

Keywords: electrical resistance, temperature, high-ash coals, charge mixture, complex alloy.

INTRODUCTION

Since one of the most important indicators of the process of smelting ferroalloys is the active useful power of the furnace, which is closely related to the physicochemical properties of the raw materials used, in particular the electrical resistance of the charge, to increase the resistance of the furnace bath, it is necessary to use reducing agents with increased electrical resistance. Considering that when melting complex alloys using a slag-free (little slag) method, the consumption of solid carbon in the charge will be almost twice as high as in the processes of slag smelting, this charge parameter has a prevailing value [1-3].

Therefore, the effective distribution of power and the maximum concentration of heat in the reaction zone are directly related to the electrical conductivity of the charge materials, since in ferroalloy furnaces part of the electric current passes through the charge. The electrical resistance of the charge is determined mainly by the resistance of their ore part and the proportion of carbonaceous reductant in it [4, 5].

From the practice of smelting high-silicon alloys, it is known that the rate of the process of melting or melting of raw materials should not outstrip the rate of reduction reactions. Otherwise, the process of recovery of elements is disturbed with the obvious formation of difficult-to-recover slags, as in the case of melting complex alloys [6-9]. In the electric melting of complex alloys, an important role is played by the selection of a reductant with an increased electrical resistance, as well as the depth of the electrodes in the charge. The latter depends on the melting point and electrical resistance of the charge layer, of which the electrical resistance of the reducing agent is the main one. Since the charge in the melting of a complex alloy by 60 % or more consists of carbonaceous raw materials containing a certain amount of carbon, it is important to know the specific electrical resistance of the charge.

In this regard, it becomes necessary to conduct research to study the electrical resistance of charge materials for smelting a complex alloy with highly active elements Al – Mn – Ca – Si.

When assessing the coal raw materials of the coal basin of Central Kazakhstan, attention was paid to the chemical composition of ash, as well as the thickness of the deposits. Preliminary laboratory studies of high-ash varieties of coal from various coal openings have shown that the coals of the Saryadyr, Borly and Zhamantuz deposits of the Teniz-Korzhunkol and Karaganda coal basins, as well as the Zhamantuz group of deposits, are interesting in terms of their physicochemical properties and industrial capacity.

EXPERIMENTAL PART

In order to simulate a process close to a real process, coals from working seams of the Saryadyr deposit and charge mixtures of the same fraction of 2,5 - 5 mm were subjected to measurements of electrical resistivity in the experiments. The determination of the electrical resistance of various types of carbonaceous raw materials was carried out according to the well-known method of the Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences [10, 11], which makes it

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possible to measure the electrical resistance of materials and charges at temperatures up to 1 800 °C in a bulk layer with simultaneous recording of the degree of their softening (shrinkage).

The pressure on the material was 0,02-0,04 MPa, the heating rate was 20 - 25 °C per minute, the inner diameter of the alundum tube was 0,04 m, the height of the material layer was 0,07 m.

Based on the results obtained in the study of the metallurgical properties of coals of various deposits, for a more complete study of the metallurgical properties, we selected coals from the working seams of the Saryadyr deposit as raw material [12]. The results of technical compositions and chemical analyzes of representative samples of three formations are shown in Table 1.

RESULTS AND DISCUSSION

Figure 1 shows the temperature dependences of the electrical resistivity (RES) of the studied coals of three working seams of the Saryadyr deposit.

It can be seen from this graph that the specific electrical resistivity of the coals of all three layers in the temperature range 200-500 °C is approximately the same and corresponds to the value of the specific electrical resistance 1,4 – 1,7 Ohm·m.

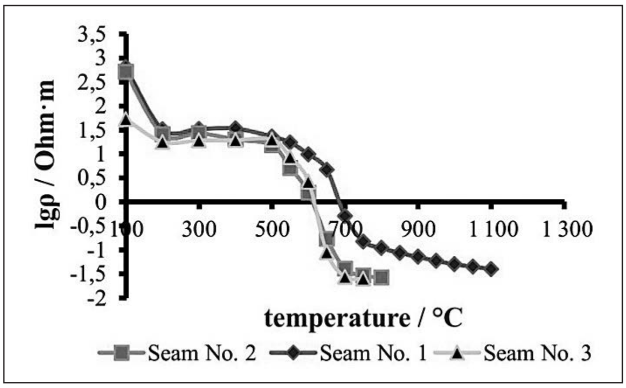

Figure 1 Comparative resistivity of coals of different seams

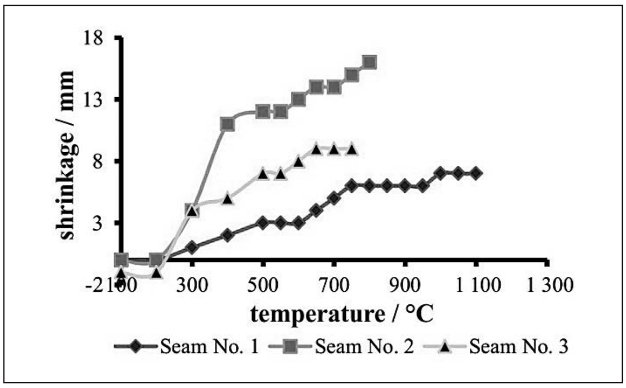

Figure 2 Curves of softening of the studied coals of different layers

In the temperature range of 500 - 600 °C, the electrical resistivity of coal from seam No. 1 is the highest compared to the coals of seams No. 2 and No. 3. At 650 °C, coal from seam No. 1 has a specific electrical resistivity of 0,9 Ohm·m, while the coals of other seams No. 2 and No. 3 showed minus values equal to - 0,7 - 1 Ohm·m. The high electrical resistivity of seam No. 1 coal to a certain extent depends on the amount of volatiles. With an increase in temperature from 600 °C to 700 °C, all coal seams are characterized by a monotonic decrease in electrical resistivity.

For reservoir No. 1, a decrease in specific electrical resistivity is characteristic to a value of 0,7 Ohm·m, and for reservoirs No. 2 and 3, a sharp loss of resistance and the beginning of the softening process. This is due to the intensive removal of volatiles and the onset of the softening process.

It has been established that coal of working seam No. 1, starting from a temperature of 550 °C (resistivity 1,3 Ohm·m), monotonously decreases the resistance index and already at 700 °C it sharply loses resistance.

As can be seen from the graph of the dependence of the electrical resistivity on temperature, the coal of the Saryadyr deposit of the working seam No. 1 in comparison with the coals of the seams No. 2 and No. 3 in the temperature range 400 – 700 °C has a high electrical resistivity.

In addition, at high temperatures, the influence of softening of carbonaceous raw materials on their electrical resistance is manifested to some extent, which is expressed in a sharp decrease in the latter (Figure 2).

Of the studied coals, coal of seam No. 1 has a higher value of the softening temperature threshold. The research results showed that the value of the charge electrical resistance during non-isothermal heating to high temperatures largely depends on the chemical and mineralogical composition of the charge, as well as on the processes of phase transformations in the test sample.

Visual inspection of coal samples after cooling showed that the upper layers of the coal column of seam No. 2 underwent insignificant sintering, while most of the column of the charge was friable, and the coals of seam No. 1 were not subject to sintering (Figures 3, 4).

For the coal sample of seam No. 3, the picture is completely different; after complete cooling, the coal column is completely sintered.

For an objective assessment of metallurgical properties on the basis of the results obtained when studying

Table 1 **Technical compositions and chemical analyzes of coals of various layers of the Saryadyr deposit / wt. %**

Name	A^c	V^c	W	SiO_2	Al_2O_3	CaO	MgO	$Fe_{gener.}$	$P_{gener.}$	TiO_2
Coal seam No. 1	50,04	19,28	1,90	66,36	20,70	2,64	3,46	4,05	0,035	1,01
Coal seam No. 2	43,39	22,05	2,70	65,59	22,46	1,76	3,46	2,0	0,021	1,05
Coal seam No. 3	24,57	30,72	2,95	77,86	13,49	0,88	5,77	3,8	0,041	0,70

* where A^c – ash content of coal (^{C} on dry weight); V^c – volatile components; W – humidity.

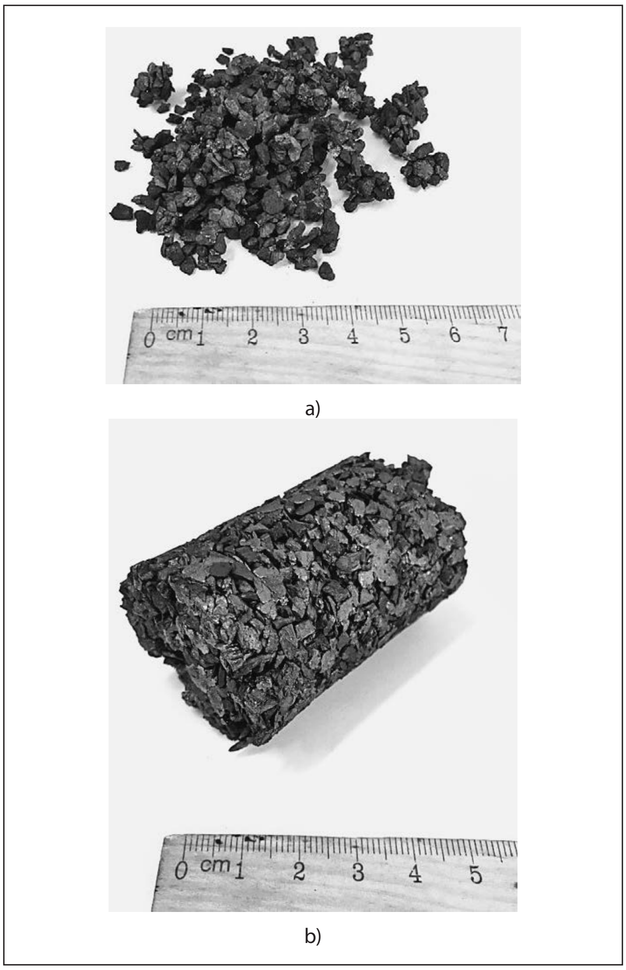

Figure 3 Coal samples after resistivity: a) coal of seam No. 1, b) coal of seam No. 2

the specific electrical resistance of pure components in the form of coals from three working seams, it was decided to study the charge mixtures based on them.

Figure 4 Sample of coal from seam No. 3 after resistivity

The tested charge mixtures were composed of coal from seam No. 1 of the Saryadyr deposit, manganese ore from the Bogach deposit, quartz from the Aktas deposit, iron shavings and lime.

In experiments on measuring the electrical resistivity, two variants of the composition of the charge were subjected to obtain a complex alloy. In the first version of the charge mixture, the ratio of the components was: coal 59,38 %, manganese ore 11,88 %, the rest quartz, shavings and lime. The ratio of the components for the second option was: coal 64,36 %, manganese ore 12,92 %, the rest quartz, shavings and lime.

Figure 5 shows the temperature dependences of the electrical resistivity (resistivity) of various charge mixtures. The mixture of charge for smelting a complex alloy of alumosilicomanganese was chosen as the most suitable for the weight.

It can be seen from the figure that the electrical resistance of the two charge options to a certain extent depends on the quantitative composition of the sample, especially at high temperatures. It was found that up to a temperature of 300 °C, the electrical resistivity of both versions of the charge and charge for smelting alumosilicomanganese is approximately the same and amounts to 1,4, 1,3, and 1,5, respectively.

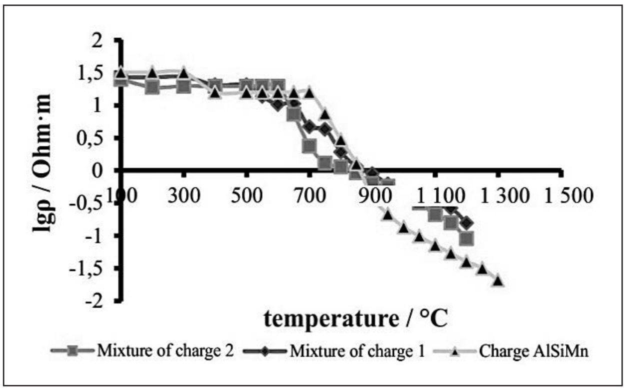

Figure 5 Comparative electrical resistivity of various charge mixtures

* where Charge AlSiMn – charge for melting of complex Alloy Alumosilicomanganese.

The charge for smelting alumosilicomanganese up to 300 °C has the highest specific electrical resistivity in comparison with the others, which decreases monotonically and already in the temperature range of 400 - 550 °C has the lowest values. In the temperature range of 400 - 650 °C for two variants of mixtures, a noticeably changing picture is observed, where at the beginning the mixture of charge No. 1, in contrast to the mixture of charge No. 2, shows higher resistivity values, which subsequently decreases. At the same time, the values of indicators for the two mixtures of charges remain at the level of 1,3 – 0,9 Ohm·m.

In the temperature range 700 - 800 °C, high performance is inherent in the mixture of charge No. 1 (0,7 Ohm·m), and at 800 °C, a sharp decrease in performance is observed for both mixtures of charge. Such a sharp difference is explained by the difference in the percentage ratio of the constituent components of the studied mixtures. At 900 - 950 °C, a sharp decline in the indicators of all mixtures begins, explained by the onset of slag formation processes, which causes a further more intensive decrease in the resistivity indicators.

In addition, with an increase in temperature, the influence of softening of the components of the charge mixture on their electrical resistance is manifested, which is expressed in a sharp decrease in the latter (Figure 6). Of the studied charge variants, the charge of the first variant has a higher value of the temperature softening threshold.

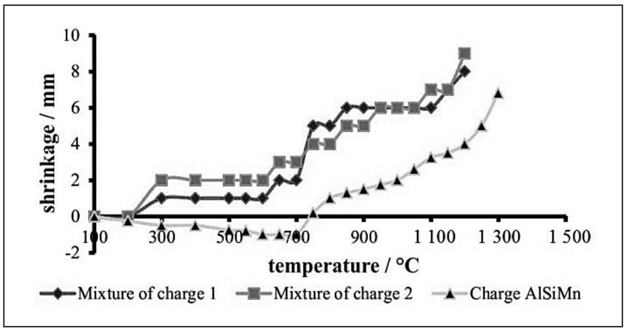

Figure 6 Softening curves of the studied charge mixtures

CONCLUSIONS

The results of the research have shown that the electrical resistance of the charge, when non-isothermal heating to high temperatures, largely depends on the chemical and mineralogical composition of the charge, as well as on the processes of phase transformations in the sample. Thus, the study of the electrical resistivity in charge materials for melting a complex alloy revealed that the properties of high-ash coal are decisive in the behavior of charge materials during electric melting. The studies carried out and the results obtained are basic and fundamental for conducting large-scale laboratory tests in low-power ore thermal furnaces.

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Note: The responsible for England language is Gauhar Yerekeyeva, Temirtau, Kazakhstan.