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INVESTIGATION OF THE ELECTRICAL RESISTIVITY OF HIGH-ASH COALS FOR THE PRODUCTION OF COMPLEX FERROALLOYS

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Abstract. Coal serves not only as a starting material for the production of electrode and carbon graphite products, but also acts as an active resistance when loading a graphite furnace, reducing agent and heat insulator. Its electrical resistivity has a significant effect on the uniformity of the distribution of electrical power in the working space of the furnace, which, in turn, affects the quality of the final product and the energy consumption of production. The relevance of the work lies in studying the possibility of using high-ash coals for the production of complex ferroalloys necessary for the metallurgical industry, including the production of ferroalloys. The Saryadyr and Borly coals were chosen as the objects of study. Laboratory tests were conducted in a high-temperature Tamman laboratory furnace. The study of the electrical resistivity of coal was carried out at a pressure of 0.02–0.04 MPa. The study of changes in the electrical conductivity of the coal was carried out in the temperature range from 25 to 1600 °C with a heating rate of 15 °C/min. The main patterns of the formation of electrical resistivity of charge materials as a function of temperature have been identified. This allows for the acquisition of detailed information about the physico-chemical properties of the charge materials using the proposed measurement method. It has been established that, during the melting of high-ash Saryadyr coal, which has a constant electrical resistivity at high temperatures, an optimal regime can be achieved.

Key words: electrical resistivity, high-ash coal, complex ferroalloy, temperature, Tamman furnace.

Introduction

An analysis of the world raw material base for metallurgy shows that every year there are fewer and fewer high-quality ore raw materials, and the requirements for metal quality, on the contrary, are growing. In this regard, there is a need for materials with new complex properties. In order to improve the quality of the metal and introduce new promising technologies, it is necessary to conduct in-depth physico-chemical research. This determines the increased role of physical chemistry, which is the basis for obtaining a metal with given properties.

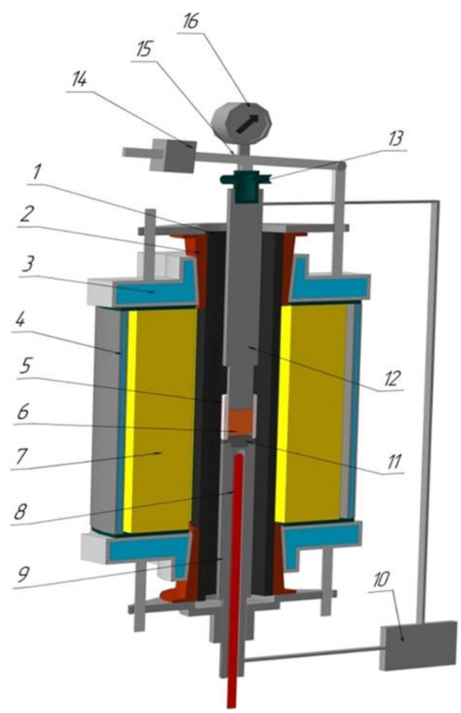
The effectiveness and feasibility of using any ferroalloys is determined not only by their chemical composition (concentration of the main elements and associated impurities), but also by their physico-chemical properties (granulometric composition, density, surface quality, melting point, etc.). The practice of steelmaking production determines not only the chemical composition of ferroalloys when assessing their quality, but also their physical properties (melting point, density, etc.) mainly determine the effectiveness of alloying steel in a bath.

The concept of the value of mineral raw materials is based on a whole complex of characteristics. In this case, the cost of raw materials should be divided into economic and metallurgical. The economic value of raw materials is explained by the costs of its extraction from the subsurface and preliminary preparation (crushing, sorting, enrichment, etc.). Factors determining the metallurgical value include: the amount of the leading element; the content and multiplicity of slag, determining the amount and composition of waste rock; harmful impurities (phosphorus, sulfur, non-ferrous metals, etc.); the ability of ore to enrich; physical and physicochemical characteristics (strength, granulometric composition, porosity, moisture capacity, reduction capacity, melting point, etc.); the size of the deposit, the conditions for the formation of ores and its geographical and economic conditions. The existing methods of metallurgical assessment of mineral raw materials can be divided into estimated, experimental and manufactured, respectively, on the basis of production indicators (according to the final technical economic indicators of the functioning of the enterprise, aggregate, etc.), which differ in different levels of accuracy for these specific conditions [1, 8].

The electrical resistance of materials is of important practical importance in the production of ferroalloys in electric ore-thermal furnaces in industry. With a change in the electrical resistance of the raw material located in the ore thermal furnace, the main parameter of this furnace – a change in the operating voltage-is associated. The power of the furnace, its electrical and heat losses, Cos φ, and therefore one of the most important technical and economic indicators of the technological process – the actual consumption of electricity depends on the amount of operating voltage.

Materials and methods of research

A lot of work has been devoted to the study of the electrical resistance of various raw materials components of electric ore-thermal furnaces and much attention has been paid to the problems of electrical resistance of individual concentrates and raw materials used for smelting various ferroalloys during the development of the production of ferroalloys in high-power electric furnaces [2, 2-5].



1-carbon-graphite tube; 2 - copper clamping ring; 3 - water - cooled cap; 4 - water - cooled body; 5 - alund glass; 6 - test device; 7-protective nail; 8-thermocouple; 9-bottom electrode; 10-digital ohmmeter; 11-graphite bottom for alund cans; 12-top electrode; 13-water cooling; 14-cargo; 15-lever; 16-electronic device for measuring shrinkage

Figure 1. Installation (cross-section) for determining specific electrical resistance and shrinkage

So, in experimental practice, the method proposed by V. I. Zhuchkov was widely used, which makes it possible to determine the electrical resistance at high temperatures with a simultaneous establishment of the degree of softening (shrinkage) of materials [3, 2].

To measure the specific electrical resistance during heating, the coarseness of the source material (for all raw component materials) was 3-5 mm. Measurements were carried out in the Tamman high-temperature laboratory furnace. Studies on changes in the electrical conductivity of raw materials were carried out in the range of 25-1600 °C, the heating rate is 15 degrees/min. Resistance measurements by the Agroskin and Shumilovsky method are made every 50 °C. To increase the information content of the received data, it is recommended to automatically record the electrical resistance in the computer's memory every 30 seconds.

For this purpose, a special scheme was developed for connecting transducers to the Tamman laboratory furnace (Figure 1). The experiment unit consists of a Tamman furnace in which the material is heated. The starting material with a height of 4 cm is placed in a cavity of alund glass (5) (vial diameter 3 cm) installed in the Tamman furnace.

Data recording was carried out using converters of signals coming from the thermocouple (8), electrodes (9, 12) and a device for measuring shrinkage. Graphite electrodes (9,12) with holes in the thermocouple (8) were installed on both sides of the material to supply voltage. The lower electrode is fixed motionless, and the upper electrode has the ability to decrease when the material shrinks under the influence of load. The weight (14) constantly presses the top electrode against the material, thus creating a tight bond. The pressure on the material was 0.02-0.04 MPA. Through the bottom electrode of the alund tube, a thermocouple is placed to isolate it from electric current.

A.A. Agroskin and S.N. Lyandyros studied the change in coal resistance in the cooling process after preheating. Studies have shown that when cooling coal heated to 400 °C, its electrical resistance returns its value to the original value. In this case, the lg ρ value of coal heated to 600 °C at room temperature is approximately halved from the initial temperature and corresponds to the resistance of coal at 400 °C. The electrical resistance of coal heated to 800 °C is slightly restored when cooled, and the electrical resistance of coal heated to 1000 °C is practically unchanged.

The electrical resistance of coal depends on the degree of their metamorphism. Coals in the middle stage of metamorphism have a maximum specific electrical resistance. Coals in the low stage of metamorphism are characterized by a fairly large electrical conductivity, and materials in the high carbonization stage with minimal electrical resistance [4, 7-8].

The amount of specific electrical resistance is affected by the amount of mineral impurities. With the increase in ash, the electrical resistance of low and medium carbonation coal at room temperature decreases, and at high temperatures it increases. This phenomenon is explained by the fact that organic matter in coal at a low stage of metamorphism has a significantly higher electrical resistance than mineral impurities. When heated, the electrical resistance of all coal increases with an increase in their ash content [5, 5-9].

The electrical resistance of the bulk layer of carbon materials consists of the resistance of the material itself and the resistance of the transition contacts between the reducing parts. The electrical resistance of the raw component increases with a decrease in the size of the carbon reducing agent. The bath of the ferroalloy furnace is a volumetric conductor of the electric field. The distribution of current and power here depends mainly on the electrical resistance of the raw component, which, in turn, is determined by the electrical conductivity of the reducing agent.

Results and their discussion

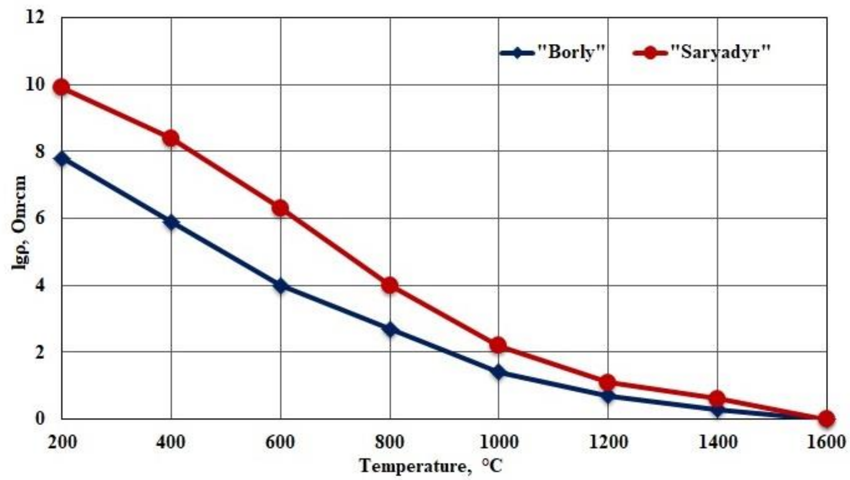


Figure 2. Electrical resistance of coals depending on temperature

Figure 2 shows the dependence of the temperature effect on changes in the electrical resistance of «Borly» and «Saryadyr» coals. The curve can be divided into three temperature parts. The first is from 200 to 400 ℃, where there is a slight decrease in resistance, the second is from 400 to 1000 ℃, and the last section is from 1200 to 1600 ℃.

The bend of the curve between 200 and 400 ℃ is due to the high moisture content in the sample, which helps to increase the conductivity, and when moisture is removed at high temperatures, the resistance level is equalized. The resistance of coal is slightly reduced from 400 to 1000 ℃. This is explained by the release of volatile substances with a slightly increased electrical resistance. At 800 ℃, a sharp decrease in electrical resistance can be observed.

Conclusions

The high electrical resistance of the raw component allows you to increase the working voltage, and therefore the power of the furnace. At a given power of the furnace, increasing the component of the raw-compound conduction current reduces the arc conduction current. The high electrical conductivity of the upper part of the bath leads to heating and agglomeration ("hot shock") of the koloshnik, a low position of the electrodes. The use of a carbon reducing agent with a high electrical resistance contributes to a deep and stable seating of the electrodes, a decrease in the conductivity current of the raw material and the concentration of heat in the lower areas of the bath.

The physico-chemical properties of high ash coal used for smelting complex ferroalloys were studied. It was found that the specific electrical resistance of coal from the «Borly» and «Saryadyr» deposits is relatively high when heated from 25 to 1600 ℃, which satisfies the process of complex ferroalloy smelting in an ore-thermal furnace with deep immersion of the electrode.

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КЕШЕНДІ ФЕРРОҚОРЫТПАЛАРДЫ АЛУ МҮМКІНДІГІ ҮШІН ЖОҒАРЫ КҮЛДІ КӨМІРДІҢ МЕНШІКТІ ЭЛЕКТР КЕДЕРГІСІН ЗЕРТТЕУ

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Аңдатпа. Көмір электрод және көміртекті графит өнімдерін өндірудің бастапқы материалы ретінде ғана емес, сонымен қатар графитация үшін пешке, тотықсыздандырғышты және жылу оқшаулағышты жүктеу кезінде белсенді қарсылық рөлін атқарады. Оның меншікті электр кедергісі пештің жұмыс кеңістігінде электр қуатының біркелкі таралуына айтарлықтай әсер етеді, бұл өз кезегінде соңғы өнімнің сапасына және өндірістің энергия шығындарына әсер етеді. Жұмыстың өзектілігі металлургия өнеркәсібіне, оның ішінде ферроқорытпалар өндірісіне қажетті кешенді ферроқорытпаларды балқыту үшін жоғары күлді көмірлерді қолдану мүмкіншілігі зерттелді. Зерттеу нысаны ретінде «Сарыадыр» және «Борлы» көмірлері таңдалды. Зертханалық зерттеу жұмыстары жоғары температуралы Тамман зертханалық пешінде орындалды. Көмірдің меншікті электр кедергісін зерттеу 0,02–0,04 МПа қысыммен жүргізілді. Көмірдің электр өткізгіштігінің өзгеруі бойынша зерттеулер қызу жылдамдығы 15град/минутта 25-1600°С температура аралығында жүргізілді. Температураға байланысты шикіқұрам материалдардың меншікті электр кедергісі пайда болуының негізгі заңдылықтары анықталды. Ұсынылған өлшеу әдісі бойынша шикіқұрам материалдарының физика-химиялық қасиеттері туралы терең ақпарат алуға мүмкіндік береді. Жоғары күлді «Сарыадыр» көмірі жоғары температурада тұрақты меншікті электр кедергісіне ие бола отырып, балқу кезінде оңтайлы режимге қол жеткізуге болатындығы анықталды.

Түйін сөздер: электр кедергісі, жоғары күлді көмір, кешенді ферроқорытпа, температура, Тамман пеші.

ИССЛЕДОВАНИЕ УДЕЛЬНОГО ЭЛЕКТРОСОПРОТИВЛЕНИЯ ВЫСОКОЗОЛЬНЫХ УГЛЕЙ ДЛЯ ВОЗМОЖНОСТИ ПОЛУЧЕНИЯ КОМПЛЕКСНЫХ ФЕРРОСПЛАВОВ

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Аннотация. Уголь служит не только исходным материалом для производства электродной и углеграфитовой продукции, но также выполняет роль активного сопротивления при загрузке печи для графитации, восстановителя и теплоизолятора. Его удельное электрическое сопротивление оказывает существенное влияние на равномерность распределения электрической мощности в рабочем пространстве печи, что, в свою очередь, влияет на качество конечного продукта и энергозатраты производства. Актуальность работы заключается в исследовании возможности применения высокозольных углей для получения комплексных ферросплавов, необходимых для металлургической промышленности, в том числе для производства ферросплавов. В качестве объекта исследования были выбраны угли «Сарыадыр» и «Борлы». Лабораторные исследования проводились в высокотемпературной лабораторной печи Тамман. Исследование удельного электрического сопротивления угля проводилось при давлении 0,02–0,04 МПа. Изучение изменений электропроводности угля проводилось в диапазоне температур от 25 до 1600 °С со скоростью нагрева 15 °С/мин. Были выявлены основные закономерности формирования удельного электрического сопротивления шихтовых материалов в зависимости от температуры. Это позволяет получить подробную информацию о физико-химических свойствах шихтовых материалов с использованием предложенного метода измерений. Установлено, что при плавлении высокозольного угля «Сарыадыр», обладающего постоянным удельным электрическим сопротивлением при высоких температурах, может быть достигнут оптимальный режим.

Ключевые слова: электрическое сопротивление, высокозольный уголь, комлпексный ферросплав, температура, печь Таммана.