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INVESTIGATION OF THE ELECTRICAL RESISTIVITY OF CALCINED PETROLEUM COKE

Calcined coke is used to manufacture prebaked anode blocks which are used in electrolytic cells for smelting non-ferrous metals, electrodes for electric arc furnaces for smelting steel, ferroalloys as well as graphite products. This study investigates the specific electrical resistivity (SER) of calcined petroleum coke produced at the Installation of Calcined Petroleum Coke. Measurements were carried out using the V. I. Zhuchkov method on a laboratory high-temperature Tamman resistance furnace. The coke samples were crushed and sieved into +3 mm and -5 mm fractions, with a layer thickness of 30 mm. The temperature range of the experiment was 25–1500 °C. It was found that the SER of the coke decreases from 761 μOhm×m at 25 °C to 536 μOhm×m at 1500 °C, corresponding to a reduction of more than 29 %. The results confirm the high electrical conductivity and thermal stability of calcined petroleum coke, making it suitable for use in high-temperature electrothermal and metallurgical processes.

Keywords: specific electrical resistivity, calcined petroleum coke, temperature, resistance furnace, V. I. Zhuchkov method.

Introduction

At present, petroleum coke is one of the most demanded carbon-containing materials widely used in ferrous and non-ferrous metallurgy, as well as in the production of electrode and anode materials [1; 2; 3]. Considerable interest in this product is due to its high chemical stability, developed porous structure, and relatively low cost compared to other forms of carbon. In Kazakhstan, the Pavlodar Calcined Petroleum Coke Plant operates, providing high-quality calcined coke for aluminum and ferroalloy industries.

Coke calcination is a complex physicochemical process occurring under high temperatures and accompanied by parallel and sequential decomposition and compaction of green petroleum coke. During calcination, the material undergoes destructive decomposition, forming coke and depleting it of hydrogen. This hydrogen is released into the combustion chamber as methane and other hydrocarbons, followed by combustion. The entire process is accompanied by changes in the structure and density of the coke. Coke calcination increases the material's resistivity and mechanical strength, increases its apparent and actual density, and completely removes moisture and volatile matter. The main factors influencing the quality of the finished product and the completeness of the process are the temperature in the calcination zone and the residence time of the coke in the furnace. Other important calcination factors include the particle size distribution of the feedstock, the ratio of feed volume to furnace volume, and the amount of air required to burn off volatile matter.

Petroleum coke is a collective term for the products of deep petroleum refining - solid substances consisting primarily of carbon. Petroleum coke is the primary raw material for the production of aluminum electrolytic cell anodes. The quality of the coke largely determines the technology, ecology, and economics of aluminum production [4].

Calcined coke is used to manufacture prebaked anode blocks which are used in electrolytic cells for smelting non-ferrous metals, electrodes for electric arc furnaces for smelting steel, ferroalloys, carbides as well as graphite products [5].

High volatile content, lack of electrical conductivity, low density, and mechanical strength make green coke unsuitable for anode production. Before use in production, green coke undergoes pre-calcination at 1100-1300 °C in a reducing atmosphere. This removes moisture and volatiles, causes shrinkage and compaction of the structure, forms a crystalline lattice, and significantly increases thermal and electrical conductivity [6].

The key quality characteristics of calcined petroleum coke for the production of prebaked anodes are specific electrical resistance (SER), actual density, and impurity content. SER determines the efficiency of electrical energy transfer, influencing energy consumption and the quality of the resulting aluminum. Actual density plays a crucial role in ensuring the stability of the anode mass. Impurity content directly impacts the quality of the finished product, as they can reduce its purity during electrolysis [7].

The development of aluminum and ferroalloy production in the Republic of Kazakhstan is accompanied by an increasing demand for domestically produced carbon materials capable of replacing imported analogues. The use of local raw materials and domestic technologies for petroleum coke processing contributes to enhancing the technological independence and economic efficiency of the country's metallurgical sector [8; 9]. Therefore, the assessment of the electrophysical properties of domestically produced calcined petroleum coke is of particular relevance.

One of the most important parameters determining the suitability of carbon materials for high-temperature electrothermal metallurgical processes is the specific electrical resistivity (SER). This parameter is closely related to the structure of the carbon material, the degree of graphitization, and the impurity content [10; 11; 12]. Understanding the dependence of SER on production conditions and subsequent thermal treatment makes it possible to evaluate the quality and potential applications of the material.

To determine the electrophysical characteristics of carbon materials, the method developed by V. I. Zhuchkov is widely used, providing high measurement accuracy and reproducibility of results [13]. The use of this method allows the investigation of conductivity features of petroleum coke at various temperatures and the identification of technological factors influencing the formation of its properties.

The aim of the present study is to investigate the specific electrical resistivity of calcined petroleum coke using V. I. Zhuchkov's method to evaluate its electrophysical characteristics and determine its applicability in electrode materials.

Materials and methods

The study of the specific electrical resistivity (SER) of calcined petroleum coke using the method developed by V. I. Zhuchkov was carried out on a laboratory high-temperature resistance furnace of the Tamman type.

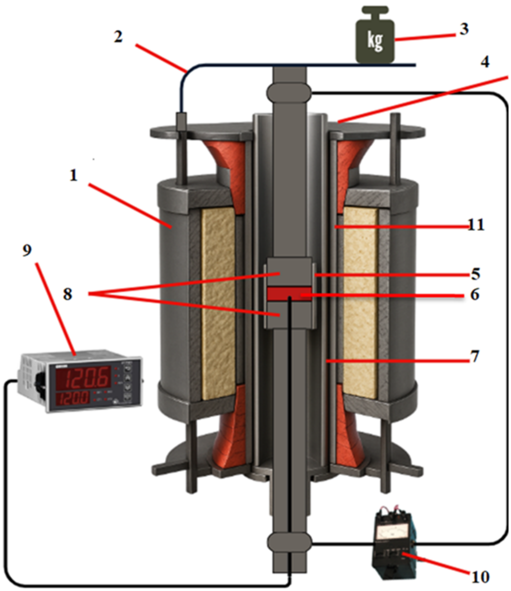
The Tamman furnace is a laboratory apparatus consisting of a graphite tube whose ends are tightly clamped by copper plates to ensure reliable electrical contact.

The furnace body is made of a steel casing, the inner cavity of which is filled with fine-grained refractory material that provides effective thermal insulation and uniform temperature distribution.

The upper cover and the bottom of the furnace are made of an aluminum alloy and equipped with a water-cooling system to prevent overheating of structural components during the experiment.

For the SER measurements, the calcined petroleum coke was preliminarily crushed and sieved into fractions of +3 and –5 mm. The thickness of the coke layer placed in the graphite tube was 30 mm. The temperature range of the study was from 25 °C to 1500 °C.

A schematic diagram of the SER measurement setup is shown in Figure 1.



1 – Tamman furnace; 2 – load holder; 3 – load; 4 – furnace cover;
5 – alumina tube; 6 – material under study; 7 – graphite tube;
8 – electrode; 9 – VR 5/20 power supply; 10 – SER measuring unit;
11 – refractory base.

Figure 1 – Setup for determining the SER of charge materials using the V. I. Zhuchkov method

Results and discussion

This section presents the results of measuring the specific electrical resistivity (SER) of calcined petroleum coke obtained using the V. I. Zhuchkov method.

Figure 2 shows the temperature dependence of the SER of the sample.

The obtained data demonstrate a consistent decrease in specific resistivity with increasing temperature, which is associated with enhanced mobility of charge carriers and improved electrical contact between carbon particles.

The observed changes indicate the thermally stable behavior of the studied coke and its high electrical conductivity within the operating temperature range, which is important for its application as a reducing agent and conductive component in metallurgical processes.

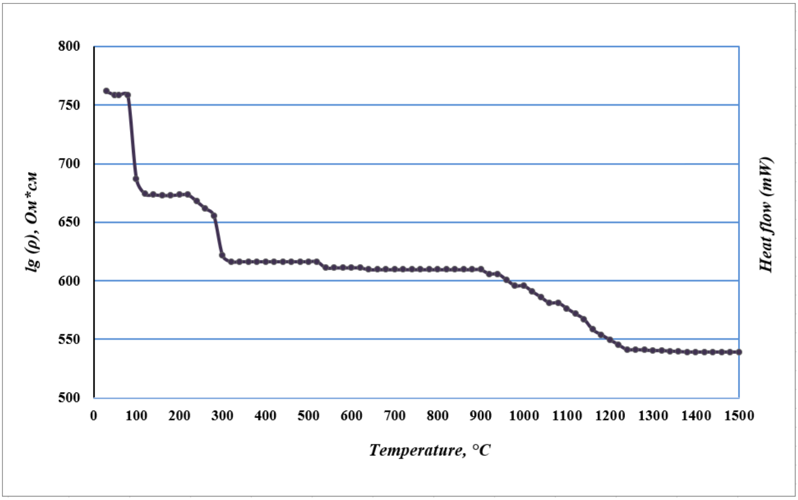


Figure 2 – Temperature dependence of the SER of calcined petroleum coke

As shown in Figure 2, the specific electrical resistivity (ser) of calcined petroleum coke gradually decreases with increasing temperature in the range of 25–1500 °C.

At room temperature (25 °C), the resistivity is about 762 μOhm×m, indicating relatively low electrical conductivity of the material in its initial state.

In the temperature range up to 400 °C, a noticeable decrease in SER is observed, which is attributed to degassing and the removal of residual volatile components.

With a further temperature increase from 400 °C to 1000 °C, the resistivity changes only slightly, indicating stabilization of the carbon structure.

At 1200 °C, the SER drops to ≈ 547 μOhm×m; at 1300 °C, it reaches ≈ 539 μOhm×m; and at 1500 °C, it further decreases to ≈ 536 μOhm×m. Thus, increasing the temperature promotes the electrical conductivity of petroleum coke as a result of structural transformations typical for carbon-containing materials under high-temperature treatment.

Conclusion

The study demonstrated that the specific electrical resistivity (SER) of calcined petroleum coke strongly depends on temperature.

In the temperature range of 25–1500 °C, a steady decrease in SER was observed – from 761 μOhm×m to 536 μOhm×m, corresponding to a reduction of more than 29 %.

The decrease in resistivity with increasing temperature is attributed to the enhanced mobility of charge carriers and improved particle-to-particle contact, which is typical for carbon-based materials.

The obtained results confirm that calcined petroleum coke exhibits high thermal stability and electrical conductivity, making it a promising material for high-temperature electrothermal processes and metallurgical applications.

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КҮЙДІРІЛГЕН МҰНАЙ КОКСЫНЫҢ МЕНШІКТІ ЭЛЕКТРЛІК КЕДЕРГІСІН ЗЕРТТЕУ

Күйдірілген кокс анод блоктарын алу үшін қолданылады, олар түсті металдарды балқытуға арналған электролиттік ұяшықтарда, болат, ферроқорытпалар және графит өнімдерін балқытуға арналған доғалық пештерге арналған электродтарды өндіруде қолданылады. Бұл жұмыста мұнай коксын күйдіру қондырғысында шығарылған күйдірілген мұнай коксының меншікті электр кедергісі (МЭК) зерттелді. Өлшеулер В. И. Жучков әдісі бойынша жоғары *температуралы Тамман зертханалық кедергі пешін пайдалана отырып жүргізілді. Зерттеулер үшін кокс алдын ала ұсақталып, +3 мм және -5 мм ірілікке сұрыпталды, зерттелетін қабат қалыңдығы 30 мм құрады. Зерттеу температурасының диапазоны 25–1500 °С құрады. Температураның өсуімен кокстың меншікті электр кедергісі 25 °С -та 761 мкОм×м-ден 1500 °С -та 536 мкОм×м-ге дейін төмендейтіні анықталды, бұл 29 %-дан астам төмендеуге сәйкес келеді. Алынған нәтижелер күйдірілген мұнай коксының жоғары электрокернеулігі мен термиялық тұрақтылығын растайды, бұл оны жоғары температуралы электротермиялық және металлургиялық үрдістерде қолдануға ұсынуға мүмкіндік береді.*

Кілтті сөздер: меншікті электрлік кедергі, күйдірілген мұнай коксы, температура, кедергілі пеш, В. И. Жучков әдісі.

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ИССЛЕДОВАНИЕ УДЕЛЬНОГО ЭЛЕКТРИЧЕСКОГО СОПРОТИВЛЕНИЯ ПРОКАЛЕННОГО НЕФТЯНОГО КОКСА

Прокаленный кокс используется для изготовления предварительно обожженных анодных блоков, которые применяются в электролизерах для плавки цветных металлов, электродов для дуговых печей для выплавки стали, ферросплавов, а также графитовых изделий. В данной работе исследовано удельное электрическое сопротивление (УЭС) прокаленного нефтяного кокса, произведенного на установке прокалки нефтяного кокса. Измерения проводились по методу В. И. Жучкова с использованием лабораторной высокотемпературной печи сопротивления Таммана. Для эксперимента кокс был предварительно дроблен и отсортирован по фракциям +3 мм и –5 мм, толщина исследуемого слоя составляла 30 мм. Температурный *диапазон исследования составил 25–1500 °C. Установлено, что с повышением температуры удельное электрическое сопротивление кокса снижается с 761 мкО×м при 25 °C до 536 мкОм×м при 1500 °C, что соответствует снижению более чем на 29 %. Полученные результаты подтверждают высокую электропроводность и термическую устойчивость прокаленного нефтяного кокса, что позволяет рекомендовать его для использования в высокотемпературных электротермических и металлургических процессах.*

Ключевые слова: удельное электрическое сопротивление, прокаленный нефтяной кокс, температура, печь сопротивления, метод В. И. Жучкова.

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