Electrical Conductivity of Graphitized Cathode Carbon Block Based on Eddy Current Technology

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Abstract

With aluminium reduction cells evolving towards larger size, energy efficiency, and environmental sustainability, graphitized cathode carbon blocks have become the inevitable choice for large-scale aluminium reduction cells due to their excellent electrical conductivity and resistance to electrolyte corrosion. The cathode carbon block serves as the carrier of the cell current. If carbon blocks with significantly different electrical conductivities are combined and constructed in the same cell, it will inevitably hinder the uniform distribution of the cell current and the stable operation of the electrolytic cell during the electrolysis process. Resistivity is a key indicator for evaluating electrical conductivity. However, individually sampling and testing the resistivity of cathode carbon blocks, or passing a current through the blocks and measuring the voltage drop to calculate the resistivity, both suffer from the drawback of being unable to balance efficiency and reliability effectively. Eddy current is an electromagnetic induction phenomenon generated in a conductor by a changing magnetic field, where the distribution and magnitude of eddy currents are related to the conductor's electrical conductivity. This paper elaborates on a method for measuring the resistivity of graphitized cathode carbon blocks based on eddy current technology and introduces a novel detection device. Through test comparisons, it has been verified that this method can rapidly and non-destructively measure the resistivity of cathode carbon blocks, providing a novel method for detecting the resistivity of graphitized cathode carbon blocks.

Keywords: Graphitized cathode carbon block, Electrical conductivity, Eddy current, Detection, Resistivity.

1. Introduction

The cathode carbon block is a key component of the aluminium reduction cell's cathode lining. It serves as lining material to contain molten aluminium and electrolyte, and as a conductive material to transmit cell current. Its performance significantly impacts the energy consumption and operational stability of the electrolytic cell. Electrical conductivity - resistivity is a key performance indicator of cathode carbon blocks. Cathode carbon blocks with good electrical conductivity help reduce the voltage drop at the bottom of electrolytic cells, thereby saving energy consumption [1]. A large aluminium reduction cell typically requires the installation of approximately 20–30 cathode carbon blocks. If cathode blocks with significantly different electrical conductivity are installed in the same cell, it will adversely affect the stability and uniformity of cathode current distribution, increase horizontal currents in the molten bath region, and consequently impair cell operation stability and reduce current efficiency [2].

With aluminium electrolysis cells evolving toward larger capacity, higher current density, energy efficiency, and environmental sustainability, graphitized cathode carbon blocks have become the inevitable choice for modern large-scale aluminium reduction cells due to their superior performance in aluminium electrolysis, which reduces energy consumption, enhances production

rate and current efficiency, while minimizing environmental pollution from spent cathode carbon blocks [3].

2. Electrical Conductivity of Graphitized Cathode Carbon Blocks

The graphitized cathode carbon block is a cathode carbon product manufactured using high-quality petroleum coke and artificial graphite fragments as aggregates, with coal tar pitch as the binder. It undergoes processes including mixing, shaping, roasting (or additional impregnation and roasting), and finally high-temperature graphitization. The graphitization process enhances the ordered arrangement of carbon atoms [4], thereby improving the electrical conductivity, thermal conductivity, thermal shock resistance, and sodium erosion resistance of the cathode carbon block, making it suitable for aluminium electrolysis production.

The resistivity of a conductor quantitatively characterizes its electrical conductivity, with lower resistivity indicating better electrical conductivity. Table 1 presents the resistivity indicators of cathode carbon blocks produced by selected international manufacturers, while Table 2 shows China's current resistivity indicators for cathode carbon blocks.

Table 1. Resistivity (μΩ·m) of cathode carbon blocks from selected international manufacturers for three kinds of grade [5].

	Semi-graphitic (Graphite content > 50 %)	Graphitic (Graphite content 100 %)	Graphitized
Company A	24–32	18–23	11–13
Company B	15–30	12–18	8–14
Company C	23	16	14
Company D	28	13	11

Table 2. Resistivity of cathode carbon blocks in China [6, 7].

Grade	Semi-graphitic(Graphite content > 50 %)	Graphitic (Graphite content 100 %)	Graphitized
Resistivity, μΩ·m	< 30	< 21	< 12

Therefore, the resistivity of graphitized cathode carbon blocks is lower than that of semi-graphitic cathode carbon blocks. The use of graphitized cathode carbon blocks can reduce the bottom voltage drop of aluminium reduction cells by more than 90 mV compared to semi-graphitic cathode carbon blocks [8], demonstrating significant energy-saving effects.

3. Testing of Resistivity

The Chinese non-ferrous industry standard YS/T 63.2-2023 specifies the principle and method for measuring the resistivity of cathode carbon blocks [9]. This method is based on Ohm's law and the definition of resistivity of conductor, deriving the resistivity calculation equation:

8. References

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