Investigation on Small Current Resistivity Measurement of Graphite Electrode Body

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Abstract. Graphite electrode resistivity measurements of ontology is the last line of carbon product enterprise important parameters in the production process of testing process, in the decades of testing technology in the process of continuous development, appeared many kinds of test methods and test system, each have each advantage, each have each characteristic, first introduced in this paper, from the early large current test system, to the analysis of current detection and finally draw a high cost performance measurement methods and measuring current.

Keywords: Graphite electrode, Resistivity, Dc current, Small current

1 Measurement Method of Resistivity of Graphite Electrode Body

The measurement of bulk resistivity of graphite electrode is an important test item in the processing process of carbon products enterprises. It is an important parameter reflecting the conductivity of graphite electrode and an important reference for steelmaking enterprises to verify the power consumption of graphite products. Therefore, carbon products enterprises attach great importance to the measurement of bulk resistivity of graphite electrode.

Through years of continuous exploration, there are three methods to test the bulk resistivity of graphite electrode, namely, double-bridge method, micro-ohmmeter method and dc probe step-down method. At present, the most commonly used method is dc probe step-down method[1-5], as shown in figure 1.1.

![Figure 1.1 dc probe step-down method](image)

Figure 1.1 dc probe step-down method

Dc probe step-down method is measured according to the principle of resistivity formula, as shown
in formula (1).

\[ \rho = \frac{U \cdot S}{I \cdot \frac{L}{m}} \]  

(1)

Type:
- \( \rho \): the resistivity (\( \mu \cdot \Omega \cdot m \))
- \( U \): voltage between probes (mV)
- \( I \): flowing current in graphite electrode (A)
- \( S \): graphite electrode cross sectional area (mm\(^2\))
- \( L \): distance between L probes (mm)

During the production field test, the graphite electrode extreme area \( S \) is unchanged, and the distance length \( L \) between the probes is also fixed\(^6\). The only change is the current \( I \) flowing through the electrode and the voltage \( V \) at both ends of the probe. It can be seen from formula (1) that the test system can calculate the resistivity by substituting the detected voltage value and current value into the formula.

Early graphite electrode resistivity measurement system according to standards of gb 1 A/cm design\(^7\), in order to ensure that this standard, need to three-phase ac rectifier, step-down and pressure regulation process, adjust the dc current size, to adapt to different specifications of graphite electrode resistivity measurement, so the test system components, relatively large volume, equipment cost, generally for hundreds of thousands of yuan, equipment cost is high.\(^2\) During the production process, due to equipment failure, the detection system was not cut off in time, and the electrode passed current of 1 ampere or above for a long time, causing damage to the detection instrument and electrode products. With the passage of time, many equipment and components have been unable to buy spare parts, replacement is also very inconvenient, maintenance costs are high.

With the development of science and technology, it is now possible to measure small signals with high precision. Therefore, the low current resistivity detection system has become the preferred solution for carbon enterprises.

2 Hardware Design of Small Current Resistivity Detection System

This system is composed of measuring PLC, constant-current source, measuring instrument, diverter, touch screen and other instruments and actuators. Measurement PLC according to the electrode signal control current source is up and running, through the shunt and the probe on both ends of the voltage value, and setting good electrode resistivity calculation specification parameters, it is concluded that the graphite electrode resistivity value and displayed in the touch screen, as for the data storage and network transmission does not belong to this paper discusses the content, no longer. In the whole system, the selection of constant-current source is the key. To determine the size of dc current on the premise of ensuring measurement accuracy and stability is the main task of system design, and also the most important work. Therefore, in the early stage of system design, the constant current range is set to no more than 150A.
3 Graphite Electrode Resistivity Data Test

3.1 Measurement Method of Measuring Rod

At present, some enterprises use the rod method for simple measurement. Although the resistivity formula is applied, it is not carried out in strict accordance with the end face current mode. The electrode cylinder is dc current, and the voltage is detected with the voltage probe in the middle of the dc probe, and the resistivity is calculated and displayed. In fact, this method does not have the stability and accuracy of data.

To verify this conclusion, in addition to testing a large number of finished graphite electrodes, another electrode was selected and made into an experimental rod with a diameter of 200cm and a length of 1500cm for repetitive testing.

The distance between the dc probes of the measuring rod is 1400cm, which can also be disassembled for face current. The voltage probe distance is 600cm. After verification, the electrode is laid flat on the ground, and the insulation between the electrode and the ground has no effect on the measurement results.

First, 20A dc is applied at different positions on the electrode end face. The voltage is measured at different positions on the cylinder from top to bottom, and the resistivity is calculated, as shown in figure 3.1.

![Figure 3.1 measured value of resistivity of input current at end face point contact](image)

The position distance of the voltage probe remains the same, and the distance between the two current probes is changed. The voltage probe and the current probe are distributed on a straight line.
The resistivity measured from the input current on the electrode cylinder is shown in figure 3.2.

![Figure 3.2 measurement of resistivity of cylinder input current value](image1)

These two line charts are two representative sets of data selected from a large number of data. It can be seen from this that when the resistivity is measured with a measuring rod and the input current is constant at 20A, when the current probe changes the measuring position and distance and the voltage probe changes the measuring distance, the final measurement value will change without fixed value and stability. The data in the experiment clearly showed that the dc current was input on the cylinder surface, the voltage was distributed in an arc shape between the current probes, and the ratio of voltage to current was not constant, so the measured value could not be used as the measured value of the resistivity of the graphite electrode.

### 3.2 Terminal Input Current Method

In this way, the graphite electrode is clamped by a copper plate with an area larger than the electrode end surface and is charged by direct current[8]. The voltage probe measures the voltage from the cylinder surface, so as to calculate the resistivity. It is known from experience and actual measurement that when direct current is applied to both ends of the electrode, the longitudinal voltage on the electrode cylinder is evenly distributed. Therefore, the distance between the voltage probes is determined by the specific size of the detection line. All measurements in this paper are 600cm.

Since the large current measurement is designed in accordance with the standard for measuring the resistivity of the graphite electrode body, there will not be too much testing and analysis. In the following content of this paper, all the measurement data are obtained by means of small current measurement.

![Figure 3.3 measured values of different current resistivity of end-face contact input current](image2)
Several electrodes of the same specification and grade were selected, and several graphite electrode bodies of different specifications and grades were tested. Measurements were made by repeated measurements at different positions of the same electrode, and the measured data were drawn into curves\[^9-10\]. From a large number of test data, figure 3.3 data is taken as representative illustration. When the input current is small, the voltage between the voltage probes fluctuates greatly, and the measured resistivity value is unstable. When the current increases to a certain value, the value will vary due to different specifications and grades. No matter how much the current increases, the pressure drop per unit length on the cylinder will show a stable trend, that is, the ratio of voltage to current is a constant value. Therefore, when substituted into formula (1), the resistivity is also a stable value. All the data show that the current density in the small-current measurement method is far less than the standard of 1A/cm, but the accuracy of resistivity measurement is not affected.2Among all the data, the resistivity tends to be stable when the current reaches about 40A. Considering the influence of electrical interference factors in the long field operation and test stability, it is advisable to set the dc current above 40A.

The electrode body involved in the measurement was measured on the original multiple high-current detection systems, and the final measured values were compared and the data were basically the same. The small-current measurement was better in terms of repeatability and stability. The large current resistivity detection system has a capacity of tens of kilowatts\[^11\] and costs hundreds of thousands of yuan. The small current resistivity detection system has a capacity of several hundred watts and a cost of tens of thousands of yuan. Equipment is simple, maintenance and repair work is simple.

4 Conclusion

After measuring the input dc current at different positions, detecting voltage at different positions, adjusting current size and other methods, it can be seen that the measured value of the measuring rod cannot be regarded as a qualitative conclusion of resistivity measurement. The standard dc probe step-down method is adopted to input the current at the end face and adjust the current to more than 40A, which completely satisfies the measurement of the bulk resistivity of the graphite electrode. This method of small current resistivity measurement is far superior to the large current detection system in terms of stability and cost performance. It can not only provide good quality inspection for graphite products enterprises, but also greatly reduce the production cost and maintenance cost for enterprises, which is worthy of promotion and application.

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