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Metallic Materials - Resistivity Measurement Method

金属材料 电阻率测量方法

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Metallic Materials - Resistivity Measurement Method

1 Scope

This Standard specifies the terms and definitions, test equipment, sample, test, test results and calculation, test records and reports for the resistivity measurement of the metallic materials.

This Standard is applicable to the measurement of the electrical properties such as volume resistivity, mass resistivity, electrical conductivity and direct-current resistance ratio, etc.

The method provided in this Standard is an arbitration measurement method and a conventional measurement method for measuring the resistivity, under the standard conditions, in a range of $0.01\Omega\cdot mm^2/m \sim 2.0\Omega\cdot mm^2/m$.

2 Normative References

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) are applicable to this document.

YB/T 081 Rule for Rounding Off of Numerical Values and Judgement of Testing Values for Technical Standards of Metallurgy

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Resistance per unit length

It indicates, at the temperature of 20°C, the resistance of a conductor per unit length.

3.2 Volume resistivity

It indicates, at the temperature of 20°C, the resistance of conductor per unit length and per unit cross-sectional area.

3.3 Mass resistivity

when the sample resistance is no less than 10Ω, the Wheatstone bridge shall be used. Other instruments that conform to the provisions of 4.4 can also be used.

4.2 When clamping the sample by the special tool, the blades on the voltage terminals shall be sharp and parallel to each other, and perpendicular to the same axis. See Appendix A for a schematic diagram of common conductor clamping tools.

4.3 Th distance between the voltage terminal and the corresponding current terminal shall be no less than 1.5 times of the circumference of the cross section of the sample.

4.4 The total error of the bridge measurement system shall not exceed ±0.15%. The total error includes calibration error of the standard resistance, comparison error between the sample and the standard resistance, error caused by the contact potential and the thermoelectrical potential, and the error arising from the sample heating caused by the measuring the current.

4.5 Thermometer: the indication error shall not exceed 0.1°C.

4.6 Micrometer: the minimum division value shall not exceed 0.01mm.

Vernier caliper: the minimum division value shall not exceed 0.1mm.

4.7 Precision balance: the minimum division value shall not exceed 0.1mg.

5 Sample

5.1 The sample shall be straight. When the sample can't be straightened by hand, place it on the surface of a soft material such as wood or rubber, and straightened with a slight force by a wooden hammer or a rubber hammer.

5.2 The surface of the sample shall be free of visible cracks or defects with a length greater than 1mm, as well as grease, rust and other contaminants to ensure good contact.

5.3 In order to ensure the measurement accuracy, the sample shall be, together with bridge, standard resistance and other measuring equipment, placed under the same environment for at least 1h.

5.4 The gauge length of the sample shall be no less than 300mm; other dimensions shall be compatible with the measuring equipment.

6 Test

6.1 Temperature control

π – Pi, take the value of 3.142;

d – arithmetic mean of the sample diameter, in mm.

6.3.2 Weighing method

For sample without the simple cross-section, or if the cross-sectional area error measured and calculate directly does not meet the requirements of Table 1, the cross-section area shall be calculated as per Formula (3) by weighing method:

$$A = \frac{m}{L_1 \cdot d_S} \quad \cdots\cdots (3)$$

Where:

A – cross-section area of the sample, in mm^2;

m – sample mass, in g;

L_1 – sample length, in mm;

d_s – sample density, in g/mm^3.

When the density of the sample is unknown, the density is measured by weighing in still water. Removing the gas, oil stains absorbed on the surface of the sample, the mass of the sample in air and still water is weighed by a precisions balance with a division value of 0.1mg. When weighing in air, the extension of the hanging wire shall be immersed in the still water to eliminate the influence of the surface tension. The diameter of the hanging wire shall be as small as possible; when it exceeds 0.05mm, use the hanging wire with twice diameter to weigh for twice, the mass difference for the twice measurements shall not exceed ±0.01 [d_L / (d_S - d_L)] % of the apparent mass of the sample in still water. The temperature of water is the same as the ambient temperature, meanwhile preventing the effects of the cross-ventilation on the weighing. The sample density shall be calculated as per the Formula (4):

$$d_S = \frac{m_A d_L - m_L d_A}{m_A - m_L} \quad \cdots\cdots (4)$$

Where:

d_S – sample density, in g/mm^3;

m_A – apparent mass of the sample measured in the air, in g;

d_L – water density during the measurement, in kg/m^3;

shall be calculated as per Formula (5):

$$R_{20} = \frac{R_t}{1 + \alpha_{20}(t - 20)} \quad \cdots\cdots\cdots\cdots (5)$$

Where:

R_{20} – resistance value on the gauge length of the sample at 20°C, in Ω;

R_t – the really-measured resistance value on the gauge length of sample at the test temperature t, in Ω;

α_{20} – resistance temperature coefficient of sample at 20°C, in 1/°C; for the black metallic materials, its value is 0.00455;

t – ambient temperature during the test, in °C.

7.3 Calculation of resistance per unit length

The resistance per unit length is calculated as per the Formula (6):

$$R_{L_{20}} = \frac{R_{20}}{L_2} \quad \cdots\cdots\cdots\cdots (6)$$

Where:

R_{L20} – resistance per unit length of sample at 20°C, in Ω/m;

R_{20} – resistance of sample at 20°C, in Ω;

L_2 – gauge length of sample at 20°C, in m.

7.4 Calculation of volume resistivity

The volume resistivity shall be calculated as per the Formula (7):

$$\rho_{20} = R_{20} \cdot \frac{A_{20}}{L_2} \quad \cdots\cdots\cdots\cdots (7)$$

ρ_{20} – volume resistivity of sample at 20°C, in μΩ•m or Ω•mm²/m;

R_{20} – resistance of sample at 20°C, in Ω;

A_{20} – cross-section area of sample at 20°C, in mm^2;

L_2 – gauge length at 20°C, in m.

7.5 Calculation of mass resistivity

7.8 Calculation of direct-current resistance ratio

At the standard temperature of 20°C, the direct-current resistance ratio of the sample shall be calculated as per Formula (11):

$$k_{20} = \frac{R_2}{R_1} \quad \cdots\cdots (11)$$

Where

k_{20} – direct-current resistance ratio of the sample at 20°C;

R_1 – standard temperature resistance of sample during the first measurement, in Ω;

R_2 – standard temperature resistance of sample during the second measurement, in Ω.

7.9 Numerical rounding off

The results of the test measurement shall be rounded off according to the requirements of relevant product standards. If there are no specific provisions of the product standards, it shall be rounded off according to the provisions of YB/T 081.

8 Test Records and Reports

8.1 The test records generally include the following contents:

a) Sample number;

b) Material types of the sample;

c) Sample length, gauge length;

d) Sample mass;

e) Average cross-section area of the sample; standard deviation of the average cross-section area under the number of tests and test temperature;

f) Measurement type: arbitration test or routine test;

g) Ambient temperature during the measurement;

h) Equipment type;

i) Under the measured temperature, the sample's resistance, standard deviation of arithmetic mean and average resistance;

------ The End ------