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Guides for methods of measurement of the magnetic properties of permanent (magnetically hard) materials by pulsed field magnetometry

永磁(硬磁) 脉冲测量方法指南

(IEC TR 62331:2005, Pulsed field magnetometry, NEQ)

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Guides for methods of measurement of the magnetic properties of permanent (magnetically hard) materials by pulsed field magnetometry

1 Scope

This Standard specifies the method for measuring the magnetic properties of permanent magnet (magnetically hard) materials using a permanent magnet pulse measuring instrument.

This Standard is applicable to the measurement of magnetic properties of permanent magnet materials with high intrinsic coercivity, such as rare earth cobalt and rare earth iron boron.

The method specified in this Standard is an open circuit measurement method. The measurement method for the magnetic properties of permanent magnet materials in a closed magnetic circuit is specified in GB/T 3217. The comparison of measurement curves between this Standard and GB/T 3217 for the same test object can be found in Annex A.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 2900.60, *Electrotechnical terminology -- Electromagnetism* [IEC 60050(121)]

GB/T 3217, *Method of test of the magnetic properties of permanent magnetic (magnetically hard) materials* (IEC 60404-5)

GB/T 9637, *Electrotechnical terminology -- Magnetic materials and components* [IEC 60050(221)]

IEC 60050 (151), *International electrotechnical vocabulary – Part 151: Electrical and magnetic devices*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 2900.60,

5 Specimen sizes

All results in this Standard are based on cylindrical specimens with a size range from a maximum diameter of 30 mm and a maximum length of 25 mm to a minimum diameter of 5 mm and a minimum length of 5 mm. But the specimen is measured in an open magnetic circuit, so there is no direct limitation on the size of the specimen. If the eddy current effect can be compensated for and the design of the testing instrument meets the requirements of a uniform magnetic field zone, then both large and small specimens can be measured.

6 Basic components

6.1 Software and hardware conditions for testing

The permanent magnet pulse measurement method shall have the following software and hardware conditions:

- Magnetic field generator; including:

  • Capacitive discharge power supply;

Magnetized solenoid.

- Magnetic polarization strength and magnetic field strength testing coil;

- Data collection and digitization equipment; including:

  • integrator;

  • Digital devices.

- Data processing software with the following functions:

  • "Zero signal" processing;

  • Positioning of J (H) hysteresis loop;

  • Self demagnetization correction;

  • Low pass filtering;

  • Eddy current correction.

6.2 Magnetic field generator

6.2.1 Overview

Under conditions where the energy is sufficient to saturate the specimen magnetization, the repeatability of the capacitor charging voltage is relatively unimportant. The only sensitivity to voltage repeatability is the correction of the "zero signal" (see 6.5.2). ±1% voltage repeatability is relatively easy to achieve. Reaching this level shall not affect the correction of the 'zero signal'. In general, the voltage repeatability can reach ±0.1%.

6.2.3 Magnetized solenoid

6.2.3.1 Peak magnetic field strength

The impedance of a magnetized solenoid can affect the strength of the magnetic field. The peak magnetic field strength generated by the magnetized solenoid shall cause the specimen to reach magnetization saturation in both positive and negative directions, with a margin of+10%. The required magnetic field strength depends on the material, orientation, and self-demagnetization factor of the specimen.

6.2.3.2 Dimensions

The magnetized solenoid shall have a certain volume to accommodate the specimen and test coil system.

6.2.3.3 Magnetic field uniformity

The magnetic field uniformity within the entire specimen area shall be within ± 1%.

6.2.3.4 Magnetic field frequency

The magnetic field shall have a low time change rate dH/dt to avoid generating large eddy currents in conductive samples and to facilitate the correction of eddy current effects.

6.3 Magnetic polarization strength and magnetic field strength test coil

6.3.1 Overview

The permanent magnet pulse measurement method uses the values of the magnetic polarization intensity of the specimen induced by the test coil and the magnetic field intensity of the specimen. The test coil includes:

- Magnetic polarization strength testing coil (J coil);

- Magnetic field strength testing coil (H coil).

6.3.2 J coil

The J coil is composed of a test coil and a compensation coil connected in series and reversed. The test coil and the compensation coil have equal ampere turns, but the degree of coupling with the specimen is different, so the measured magnetic polarization strength of the specimen does not include the magnetic field signal. The J to become measurement results.

After the above processing, the J signal plots the synchronized H signal to obtain the J (H) hysteresis loop. The B (H) hysteresis loop can be obtained by converting the J (H) hysteresis loop.

For the measurement results of conductive permanent magnet specimens, the influence of eddy currents needs to be corrected.

6.5.2 "Zero signal"

Perform a permanent magnet pulse measurement without loading the specimen. The apparent magnetic polarization signal obtained by the system at this time is generally referred to as the "zero signal". For a precisely designed and manufactured testing system, the signal shall be smaller and have good repeatability compared to the signal generated by the specimen.

The "zero signal" is caused by eddy currents within the conductive material of the magnetized solenoid and other factors within the magnetization field region. The amplitude and waveform of the signal shall vary under different magnetic field strengths.

Before measuring the sample, the "zero signal" shall be measured in advance under the same magnetic field conditions without the sample. The sample measurement results can only proceed to the next step of data processing after deducting this "zero signal".

If the "zero signal" accounts for 1% of the entire measurement signal and the change in the "zero signal" between two measurements is 10%, then the measurement error of magnetic polarization intensity J caused by the "zero signal" is about 0.1%.

6.5.3 Positioning of J (H) hysteresis loop

Although the external magnetic field increases from zero and eventually returns to zero, the initial magnetic polarization strength of the specimen is unknown (the initial magnetic polarization strength signal is related to the magnetization state of the specimen). Therefore, it is necessary to perform positioning processing on the return line. If the specimen reaches magnetization saturation in both positive and negative directions, the midpoint between the positive and negative residual magnetic polarization values can be considered as J=0.

6.5.4 Self demagnetization correction

The permanent magnet pulse measurement method adopts open magnetic circuit measurement. In order to obtain the intrinsic magnetic properties of the specimen, a self-demagnetization factor shall be used to correct the test results. This is also a common problem faced by all open circuit measurement methods. The self-demagnetization factor depends on the geometric dimensions of the specimen and the generating heat, the temperature of the specimen can increase. On the other hand, the heating of the magnetized solenoid shall also increase the temperature of the specimen inside it. The design of a magnetized solenoid shall consider both the maximum magnetization field and the factors causing heat transfer to the specimen due to the heating of the solenoid. The magnetized solenoid circulating cooling system can effectively reduce the temperature rise of the specimen caused by the heat conduction of the magnetized solenoid.

7.2 Temperature measurement

The temperature of the specimen can be determined by various methods. The method of direct contact temperature measurement between thermocouple and specimen can be used. Laser temperature measurement method can also be used. Laser is directed towards the magnet through the bottom opening of the magnetized solenoid, enabling non-contact temperature measurement.

8 Calibration

The calibration of permanent magnet pulse measuring instruments mainly focuses on the calibration of the H channel and J channel.

8.1 H channel calibration

Place the H coil in a uniform, static magnetic field calibrated by a nuclear magnetic resonance magnetometer. Quickly remove this coil to determine the overall accuracy of the test coil and integrator.

8.2 J channel calibration

The pure nickel standard specimen has a determined theoretical saturation magnetic polarization strength. The eddy currents generated internally are basically the same as those in pure copper specimens. The total eddy currents in the magnetic saturation region of pure nickel specimens are independent of their relative magnetic permeability. Therefore, the saturation magnetization state of pure nickel standard specimens can be used for calibration of the J channel.

Under identical magnetic fields, two pure nickel and copper specimens with identical shapes and sizes are measured using a permanent magnet pulse measuring instrument. Using an iterative method, by adjusting the eddy current scaling factor of the pure copper standard specimen, the eddy current in the pure copper standard specimen is subtracted from the measurement results of the pure nickel standard specimen until the eddy current influence in the saturation region of the hysteresis loop of the pure nickel standard specimen is completely removed. After the above processing, the theoretical saturation magnetic polarization intensity of the pure nickel standard specimen can be used for calibration of the J channel.

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