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**Measurement method of irreversible magnetic flux loss due
to high temperature of rare earth permanent magnet**

稀土永磁材料高温磁通不可逆损失检测方法

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Measurement method of irreversible magnetic flux loss due to high temperature of rare earth permanent magnet

1 Scope

This document specifies the measurement method of irreversible magnetic flux loss due to high temperature of rare earth permanent magnet.

This document applies to the measurement of irreversible magnetic flux loss due to high temperature of NdFeB permanent magnet.

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 6379.2, *Measurement methods and results - Accuracy (trueness and precision) - Part 2: Determine the standard methods of measurement repeatability and reproducibility of the basic method*

GB/T 8170, *Rules of rounding off for numerical values and expression and judgement of limiting values*

GB/T 9637, *Electrotechnical terminology - Magnetic materials and components*

GB/T 38437, *Methods of measurement of the magnetic dipole moment of a ferromagnetic material specimen by the withdrawal or rotation method*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 9637 as well as the followings apply.

3.1 irreversible magnetic flux loss due to high temperature

The part where the magnetic flux cannot be restored when the magnet is heated from normal temperature to high temperature and then returned to normal temperature.

NOTE: It is measured in percentage (%).

3.2 load line

The locus of the operating point of a permanent magnet forming part of a given magnetic circuit when the magnitude of its magnetization varies.

NOTE: The operating point of a permanent magnet is a point on the demagnetization curve or return line of a permanent magnet forming part of a given magnetic circuit. Its coordinates are the working magnetic flux density and magnetic field strength.

[Source: GB/T 9637-2001, 221-04-11]

3.3 high temperature aging

The test that the permanent magnet is kept at a certain temperature in the high temperature test box for a period of time, and the high temperature environment is simulated to test the thermal stability.

4 Method principle

Use Helmholtz coils and fluxmeters, at the same room temperature, to measure the irreversible loss of magnetic flux (magnetic dipole moment) of a magnet with saturated magnetization before and after high temperature aging test. It is expressed in percent.

5 Test conditions

5.1 Normal temperature magnetic flux test: the ambient temperature is $23^{\circ}\text{C}\pm 3^{\circ}\text{C}$.

5.2 Optional temperatures for high temperature aging of NdFeB permanent magnets: 65°C , 85°C , 100°C , 120°C , 150°C , 180°C , 200°C , 250°C . If the customer has special needs, it shall be determined through negotiation between the two parties.

6 Instruments and equipment

6.1 Magnetic flux measurement device: mainly composed of a fluxmeter and a Helmholtz coil. The maximum display deviation of the fluxmeter shall be less than 1%.

6.2 High temperature test chamber: the inner wall and interlayer of the test chamber shall be made of non-ferromagnetic materials. The high temperature test chamber shall be able to adjust the heating rate and holding time. The maximum temperature deviation of the working space of the test chamber shall be less than 1°C . During the constant temperature period, the temperature fluctuation shall not exceed 1°C .

7 Sample

7.1 The samples are finished or machined semi-finished permanent magnets.

7.2 The sample shall be saturated and magnetized along the direction of easy magnetization.

8 Test steps

8.1 Initial flux test

Place the sample at room temperature for no less than 2 h after magnetization and saturation. Make sure that the specimen temperature is consistent with room temperature. The sample is placed in the homogeneous space of the Helmholtz coil. The easy magnetization direction of the sample is parallel to the axis of the Helmholtz coil. Then measure the magnetic flux according to the provisions of GB/T 38437. Repeatedly measure each sample for 3 times. Take the average value of the displayed values of magnetic flux (magnetic dipole moment) as the measured value before the test.

8.2 High temperature aging test method and sample placement

8.2.1 Open-circuit mode

The test sample needs to be placed in a non-ferromagnetic sample frame. During the test, avoid the sample close to the magnetic material. In order to avoid the mutual adsorption of the samples during the test operation, causing damage to the samples and injuring the test personnel, it is necessary to customize a special sample frame or a fixing scheme with the same effect. If the aluminum alloy plate is fixed with high-temperature-resistant adhesive tape, the distance between the specimens shall not be less than 8 times the maximum side length of the specimen.

8.2.2 Semi-open-circuit mode

8.2.2.1 The sample is adsorbed on a pure iron plate with a thickness of $1.0\text{mm}\pm 0.1\text{mm}$. The easy magnetization direction of the specimen shall be perpendicular to the surface of the iron plate. The distance between specimens shall not be less than 4 times the side length of the same direction of the specimen. The direction of the N poles of the samples shall be the same.

8.2.2.2 The inner arc of the tile-shaped magnet is adsorbed on the iron plate downward. For samples that are inconvenient to be placed by magnetic pole surface adsorption or samples with special shapes, place them on the principle of safety and convenience. Indicate in the test report.

8.3 Determination of high temperature aging heating and heat preservation

Keys:

- 1 - Semi-open-circuit magnetic flux mode which the sample is placed on a 1mm thick iron plate;
- 2 - Open-circuit magnetic flux mode in which the sample is placed on a glass plate.

Figure A.1 -- The law of irreversible magnetic flux loss due to high temperature of the same rare earth permanent magnet specimen in the open-circuit and semi-open-circuit magnetic flux aging modes changing with temperature (sintered NdFeB magnet, $\phi 10.055\text{mm} \times 2.017\text{mm}$ 40SH, constant temperature for 2 h at each temperature point)

A.2 Variation law of operating point of rare earth permanent magnet and position of inflection point of B-H curve

A.2.1 The reason for the irreversible loss of magnetic flux is the relative change of the operating point of the permanent magnet relative to the position of the inflection point of the B-H curve of the magnetic material. Since the temperature coefficient of remanence and intrinsic coercive force of rare earth permanent magnets above room temperature is negative, and the absolute value of the temperature coefficient of coercive force H is larger than the absolute value of the temperature coefficient of magnetic flux density B , the higher the temperature, the higher the corresponding B-H curve inflection point. See Figure A.2.

Example 1: In Figure A.2, when the temperature rises from 100°C to 120°C , the inflection point of the B-H curve rises from point C_1 to point C_3 .

A.2.2 In a static magnetic circuit, the permanent magnet operating load line is a straight line. The operating point of the permanent magnet goes down along the load line with increasing temperature.

Example 2: In Figure A.2, the 40SH $\phi 10.055\text{mm} \times 2.017\text{mm}$ sintered NdFeB magnet is in the open-circuit state. When the temperature rises from 100°C to 120°C , its operating point moves downward from point A_1 to point A_3 . That is, move down from above the inflection point C_1 of the B-H curve to below the inflection point C_3 of the B-H curve.

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