

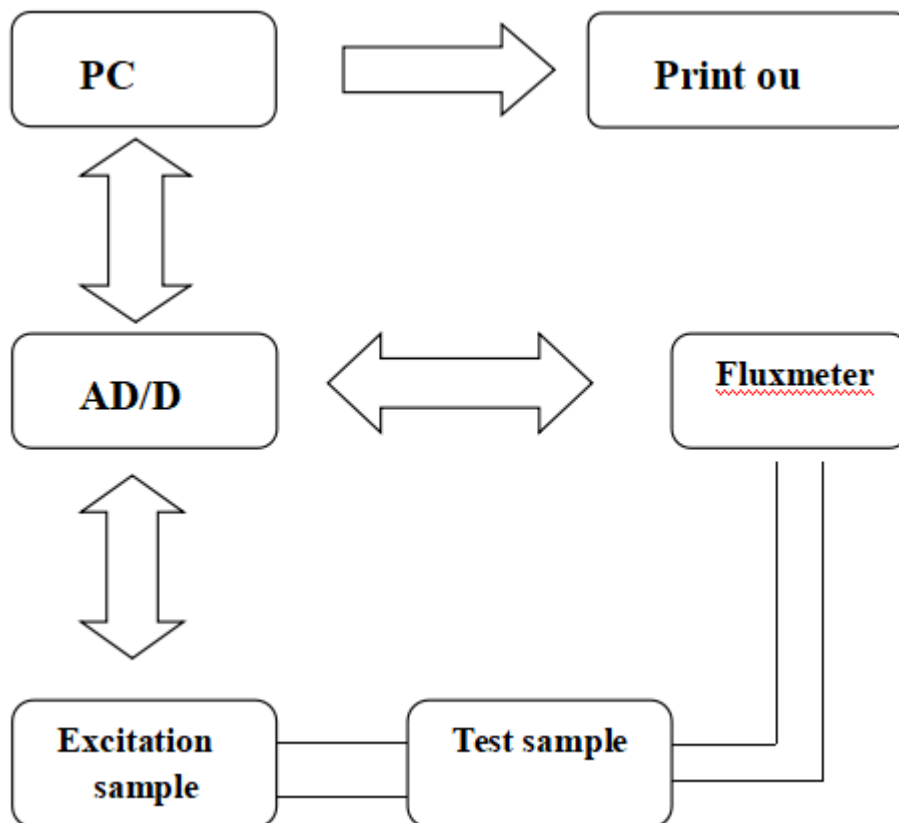
The user manual of DX-2012 Soft magnetic material DC test system

Chapter 1 Composition of DC measuring system for soft magnetic materials

1. The composition is as following:

- 1.1 Excitation power supply
- 1.2 Fluxmeter
- 1.3 DA/AD module
- 1.4 Computer
- 1.5 Printer

2. The interrelationship is shown in the figure below:





Chapter 2 The hardware of DX-2012SD DC measuring system for soft magnetic materials

1 Excitation current source

Power supply requirements: 220V \pm 10%, 5A, 50Hz.

Output range: \pm 50V/20A.

Current range: 2mA, 4mA, 10mA, 20mA, 40mA, 100mA, 200mA, 400mA, 1,2A, 4A, 10A, 20A.

Stability: 0.05%.

Resolution: 0.2mA.

Accuracy: 0.1%.

2 Electronic integrator

Magnetic flux range: 0.25mWb, 0.5mWb, 1mWb, 2mWb, 2.5mWb, 5mWb, 10mWb, 20mWb.

Resolution: 0.0001mWb.

Accuracy: 0.3%.

Drift: 0.002mWb/min.

3 DA/AD module

AD converter: 12-bit AD, speed 2000-20000 channels/second.

Channel input impedance: 1 megaohm.

System accuracy: \pm 0.1% FSR.

Resolution: 12 bits.

Noise (peak): less than \pm 1LSB (typical, 500 sampling points)

4 Computer

Recommended configuration: CPU dual-core 2.4GHz or above, memory 2G or above, hard disk 100G or above, motherboard G41 or above, display 19 inches, Windows XP or above operating system.

5 Printer

PC compatible printer

6 Accuracy of system test

Measurement index of ring sample (please pay attention to temperature and other factors for different material samples)

Test parameters	Bs	Br	Hc	Pu	μ_i	μ_m
Uncertainly	1.0%	1.0%	1.5%	1.0%	5.0%	2.0%
Repeatability (constant temperature)	\pm 0.3%	\pm 0.3%	\pm 0.5%	\pm 0.5%	\pm 2.0%	\pm 1.0%

Chapter 3 The software of DX-2012SD DC measuring system for soft magnetic materials

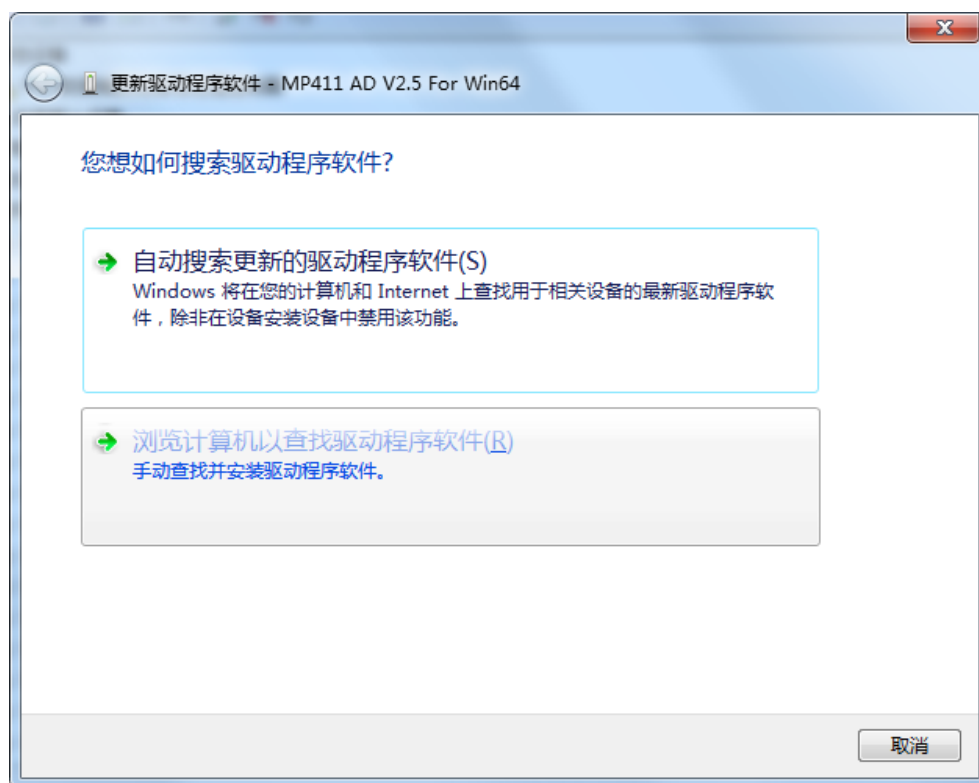
DX2012SD soft magnetic DC measurement system test software is green version, which can be directly opened and used without complicated installation process. However, in order to better protect the common interests of users and the company, the software needs to be registered to operate normally.

The platform on which the software system runs is based on .NET3.5. The required data acquisition module also needs to be installed to use, so the software installation process is as follows:

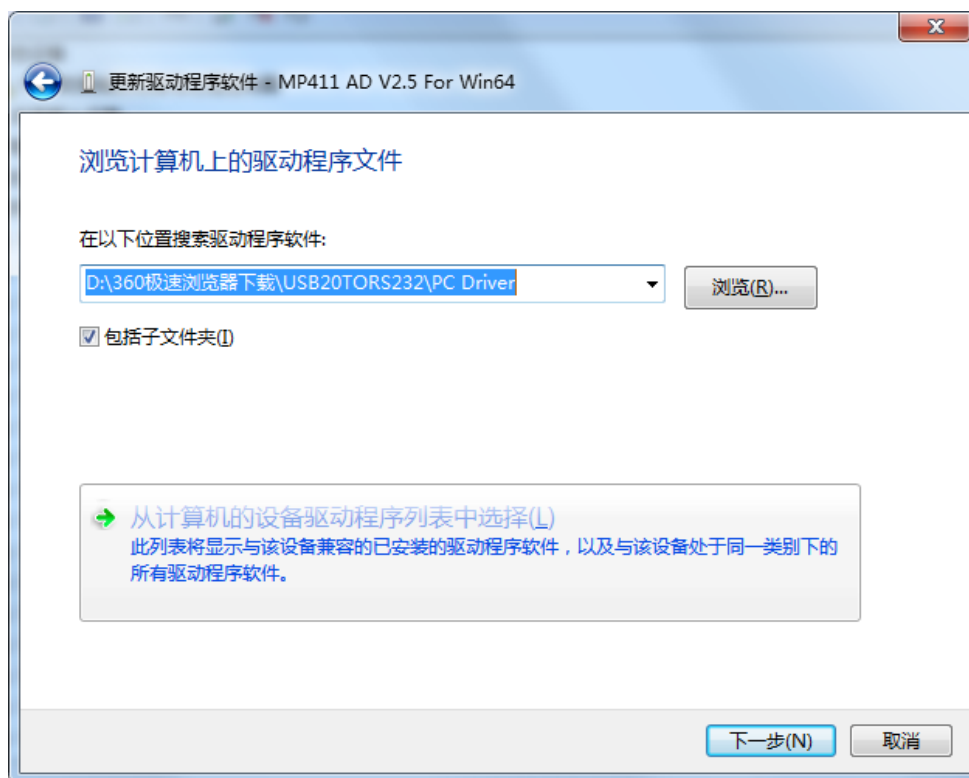
1 Copy the test software package DX2012SD to the computer on which the system has been installed, and connect all power cables and connecting cables of the entire test system.

2. Install the sampling drive

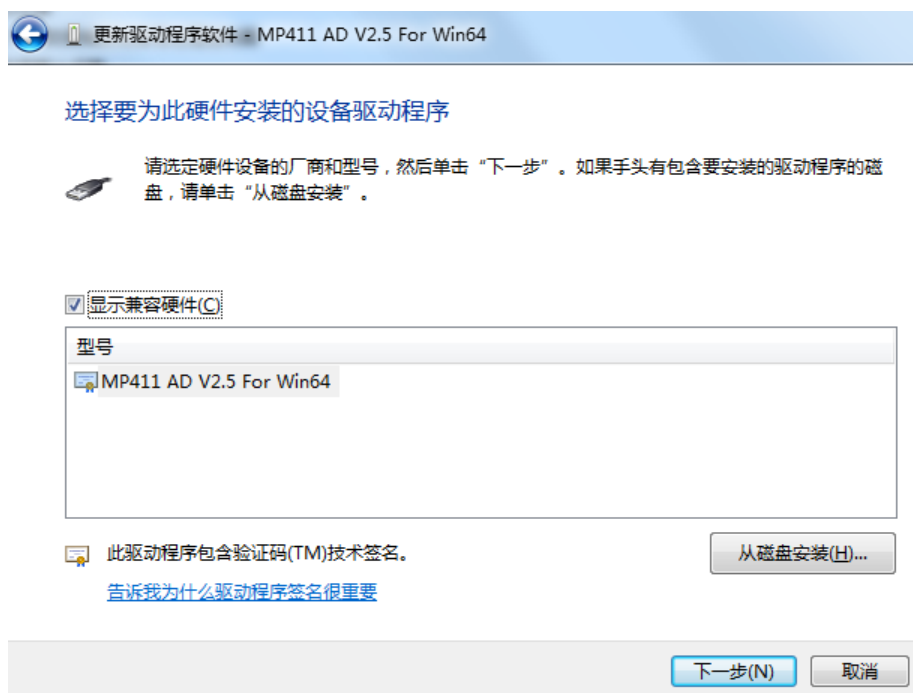
The computer will automatically detect the data acquisition module and prompt for installation, as shown in the following figure:



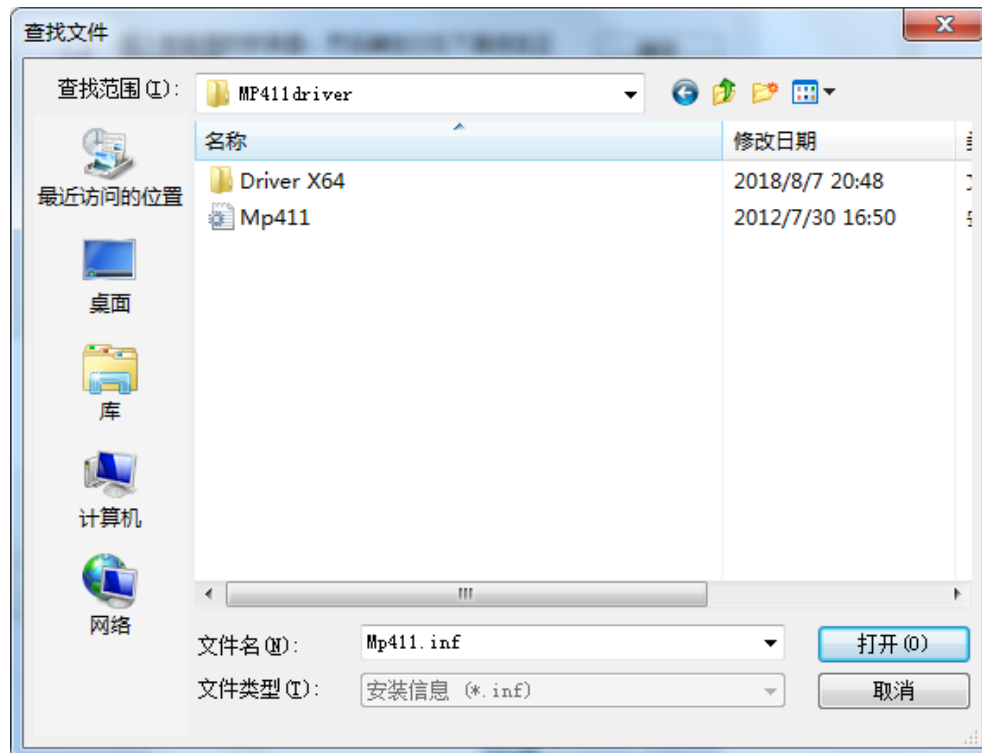
Then select "Browse the computer to find the driver software(S)", as shown in the following figure



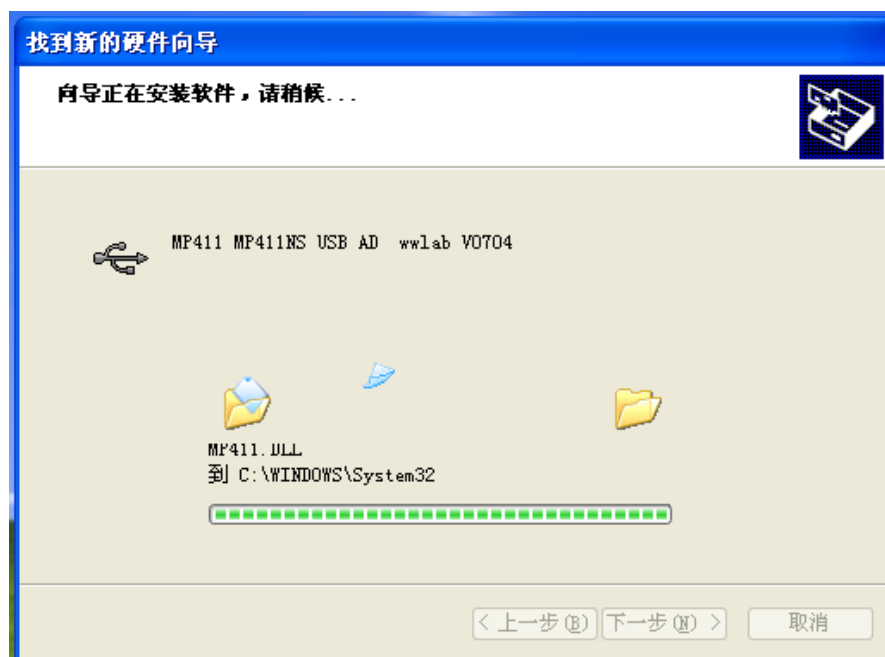
Then click "Select from the list of computer device drivers", and the computer will pop up the following window:

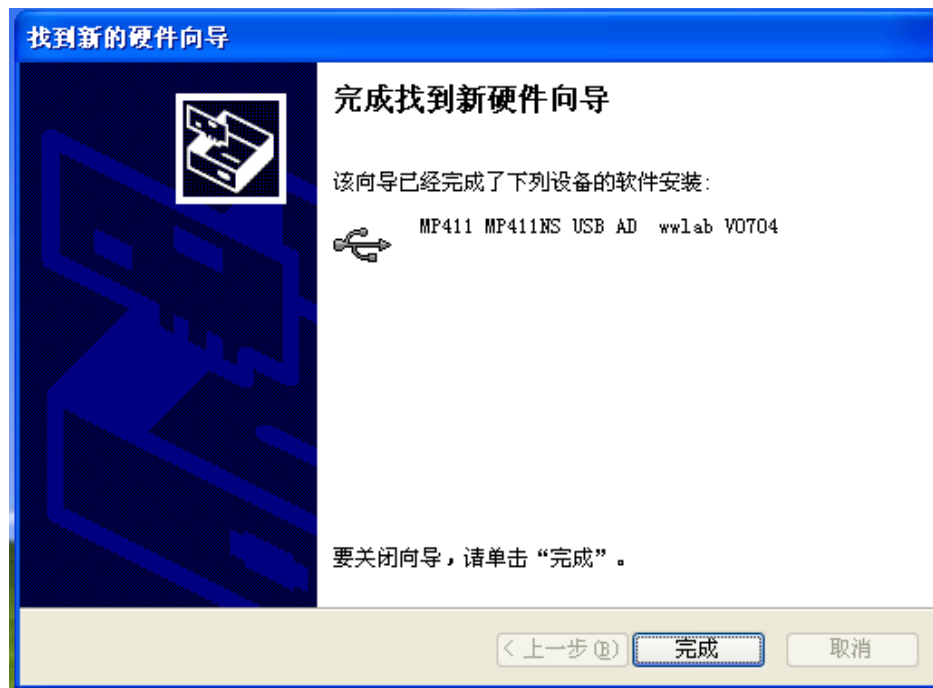


Click "Install from Disk", and a "Install from Disk" window will pop up on the computer. Then find the "driver" under this test software package and select it, as shown in the following figure

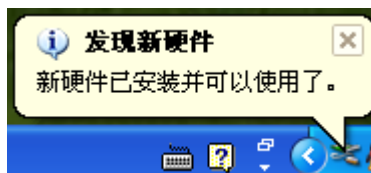


Then click "OK", and then click "Next". The computer starts to install the sampling module driver, as shown in the following figure:





Click "Finish" to complete the installation of the computer, and the prompt is as follows:



This completes the installation of the sampling driver.

3. Install the .NET 3.5 platform.

Double click dotNetFx35setup.exe under the dotNetFramework folder, and follow the prompts to click "Next" to complete the installation.

The installation process may take more than ten minutes, please be patient and wait.

Please restart the computer after installation.

4 Register the software.

Double click on the application DX2012SD.EXE, and a registration window will pop up the first time the software runs, prompting you to register. Please contact the supplier for relevant registration information.



Chapter 4 Operating Instructions for DX-2012SD Soft Magnetic Material DC Measurement System

In order for you to use this instrument better and faster, please read the instructions in this chapter carefully before using this instrument.

Scope of use: The DX2012SD DC measuring device for soft magnetic materials is mainly used to measure the basic magnetization curve and hysteresis loop of various soft magnetic materials such as soft ferrite, pure iron, silicon steel, permalloy, amorphous and nanocrystalline under DC static state, and accurately measure their initial magnetic permeability μ I. Maximum magnetic permeability μ Static magnetic characteristic parameters such as saturation magnetic induction strength B_s , remanence B_r , and coercive force H_c .

1. The initial permeability μ i: Defines the ratio of the magnetic induction B of a material to the excitation field strength H when the excitation field strength H is close to infinity. It is a very important technical index for judging magnetic materials. The test data is required to be completed within the Rayleigh region of the material. The Rayleigh range of commonly used magnetic materials is shown in the following table:

Electrician Pure Iron	Electrical silicon steel	Ferrite magnet	Permalloy	Nanocrystalline
$\angle 8$ A/m	$\angle 1$ A/m	$\angle 3$ A/m	$\angle 0.8$ A/m	$\angle 0.08$ A/m

For high nickel alloy materials, under the action of a very low magnetic field, the magnetic permeability exhibits significant nonlinearity, which cannot meet the laws of the Rayleigh region. Generally, using measurable but not real μ I to give a close initial permeability. The regulations for magnetic fields in various countries are shown in the following table:

Japan	Russia	USA	China	Ministry of Metallurgy
$\angle 0.005$ Oe	$\angle 0.005$ Oe	20G correspond H	$\angle 0.001$ Oe	$\angle 0.002$ Oe

2. Maximum magnetic permeability μ m: Take the maximum value corresponding to B/H as the maximum magnetic permeability of the material. In theory, the impact method is used for measurement. The more test points, the smaller the test step, and the more realistic the maximum magnetic permeability of the tested material.



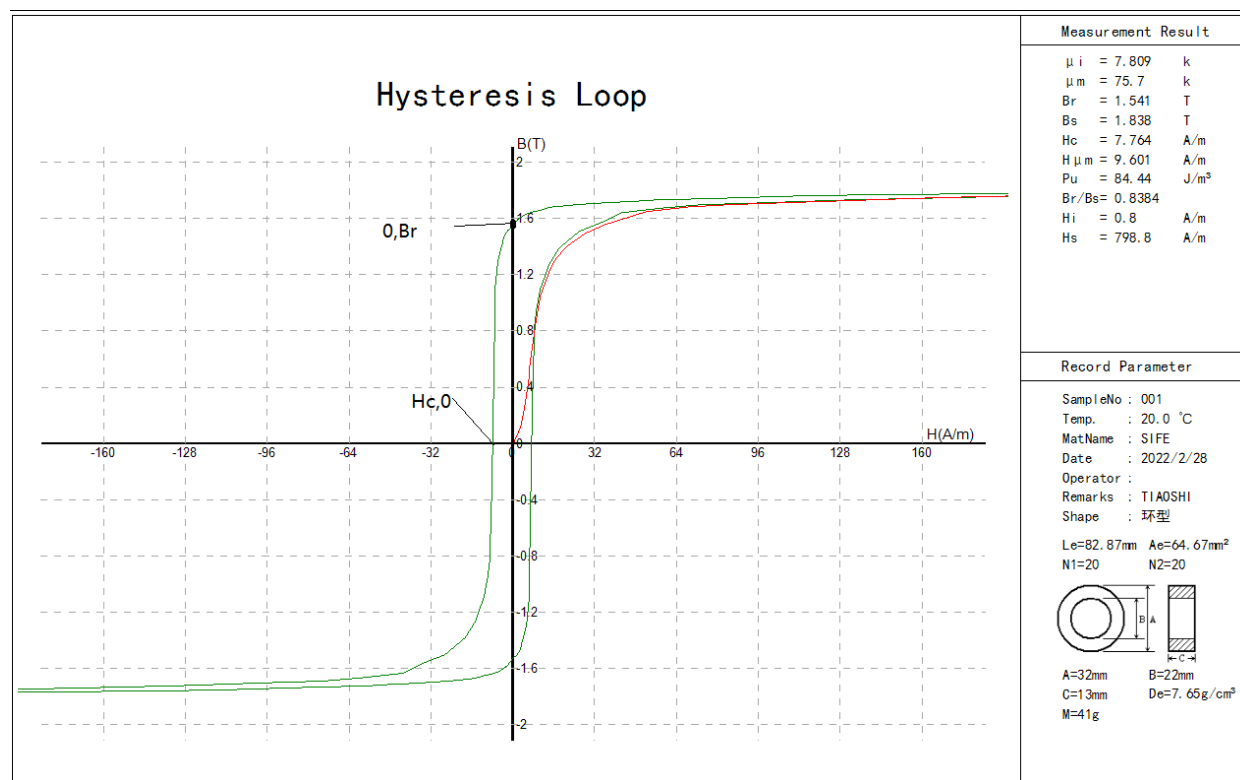
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3. Saturated magnetic induction strength B_s : refers to the magnetic induction strength B of a material that does not change after the excitation magnetic field strength H reaches a certain strength. The corresponding magnetic induction strength is defined as the saturated magnetic induction strength B_s of the material. For different materials, the saturation magnetic induction strength B_s varies, and currently available soft magnetic materials are generally below 2.8T.

4. Residual magnetism B_r : After saturation magnetization of the material, remove the applied external field H (when $H=0$), and the sample still has a residual magnetic induction strength. We define the residual magnetic induction strength at this time as the residual magnetism of the material.

5. Coercive force H_c : After the material is saturated with magnetization, the excitation field strength is removed and the material retreats to the remanence B_r point. At this time, a reverse excitation magnetic field is applied to make the magnetic induction strength of the material reach zero. The applied reverse excitation magnetic field H is defined as the coercive force H_c of the material



Chapter 5

1. DX-2012SD Inspection of Soft Magnetic DC Measuring System Accessories

Please check whether the system accessories are complete, and all accessories are as follows:

- 1.1. A set of computer (or notebook) with DX2012SD software installed;
- 1.2. One DX2012SD excitation power supply;
- 1.3. A pair of gold plated test clips;
- 1.4. One power cord;
- 1.5. One USB cable;

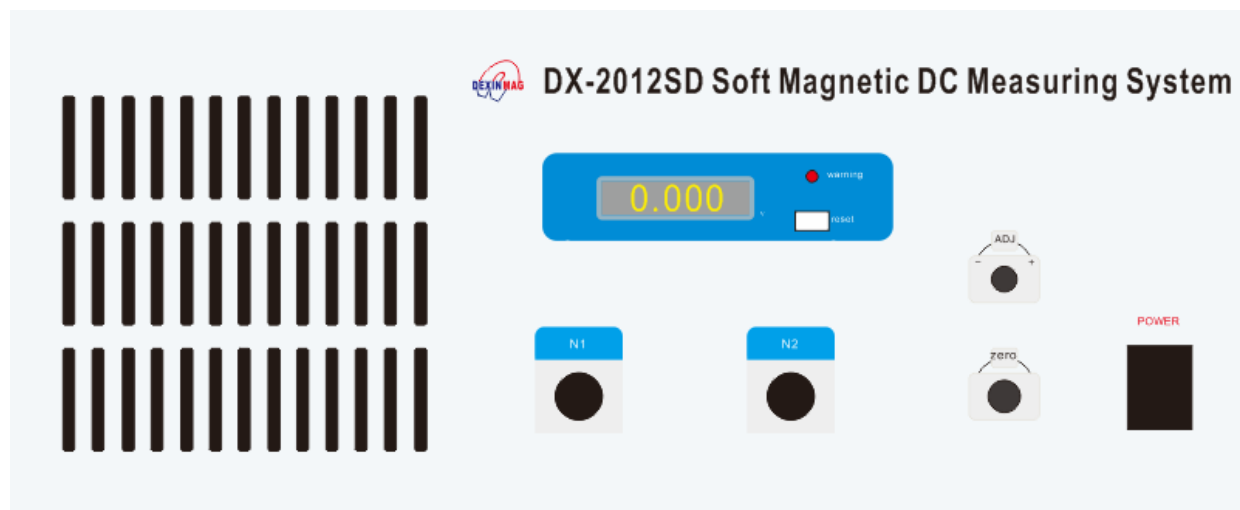
Please connect all the connecting wires after all the accessories are complete.

The following mainly introduces DX-2012SD excitation power supply and DX-2012SD measurement software.

2. Excitation power supply of DX-2012SD

The excitation current source, electronic integrator, and data acquisition module of this test system have been assembled in a single cabinet, and its front and rear panels are shown below.

2.1 Front panel



The left side of the panel is a heat dissipation air inlet, with a 4-digit and half digital display on the meter head and an alarm indicator light;

N1, N2: connect the primary excitation coil and magnetic pole induction coil of the sample respectively;

ADJ: Fluxmeter drift adjustment potentiometer. Rotating this potentiometer can change the speed and direction of the fluxmeter drift. When rotating clockwise, the fluxmeter reading drifts in the positive direction, while when rotating counterclockwise, the fluxmeter reading drifts in the negative direction.

ZERO: Fluxmeter reset switch, press to reset

POWER: Power switch

Meter head: In standby mode, this meter head should display "0.000", while in operation, it displays real-time output, and the meter range is "19.99".



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Res fluxmeter reset key: Press this key to reset the fluxmeter meter reading on the software interface.

2.2 Back panel

Cooling fan: Heat the power amplifier of the excitation power supply. Please ensure the smooth and normal operation of this vent.

Data interface: Connect the USB interface of the computer to supply power to the data acquisition module and communicate data.

Power socket: connected to mains 220V/50Hz, with a built-in fuse at the lower end of the socket, which is 10A.

3. Test software

The entire software testing interface can be divided into the following nine parts:

A Software menu: includes file, edit, measure, report, and help.

B Sample shape, size, and number of turns

C Test method and test conditions

D Sample record column

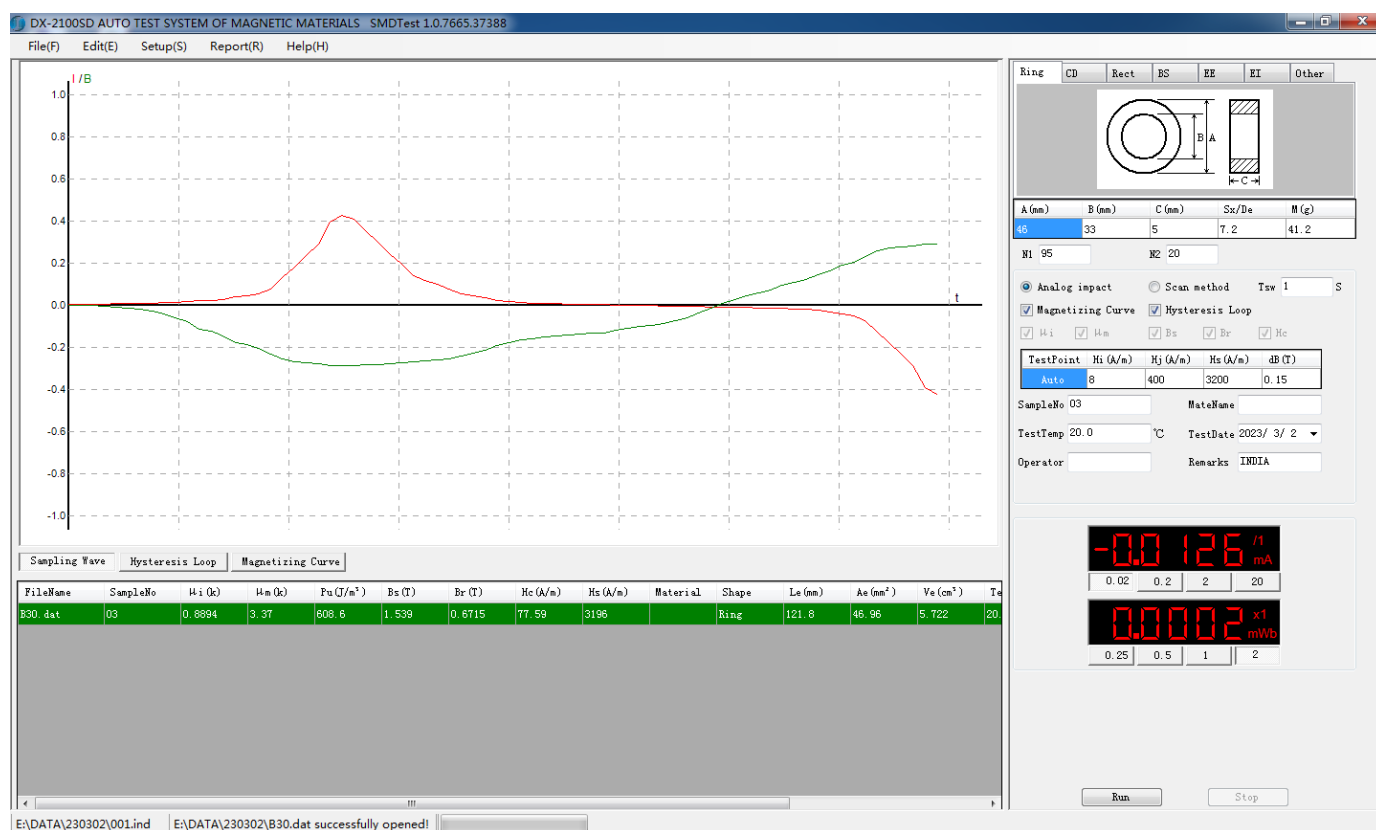
E Ammeter and fluxmeter

F Test key and cancel key

G Software status bar and path

H Result curve: including sampling waveform, hysteresis loop, and magnetization curve.

I Magnetic parameter result table: includes the magnetic parameter data results and sample parameters of the sample.

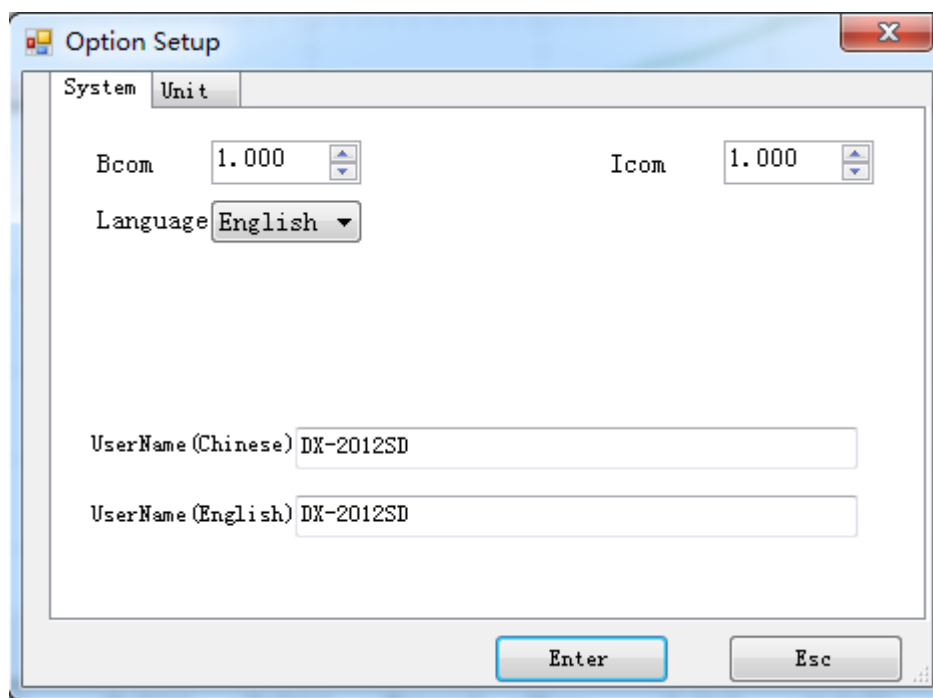


3.1 Software men

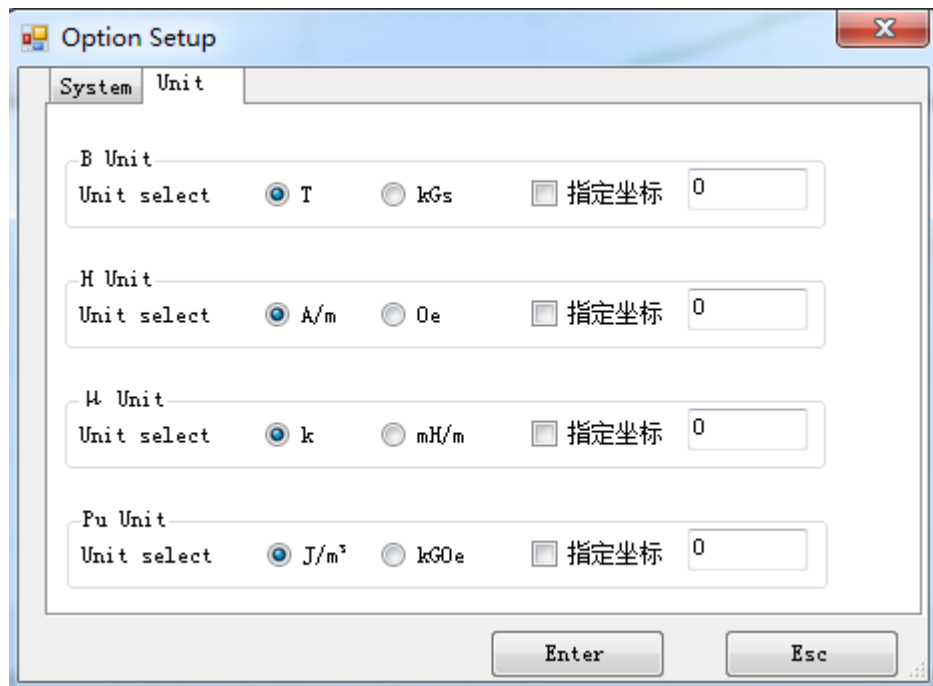
File: There are four drop-down menus: "New File", "Open File", "Load File", and "Exit Software"; Under "New File", there are "New Index" and "New Data". An index is equivalent to a table of contents file that can hold hundreds of test data. The software can only display test data under one index at a time. The test data below the index should not be too much, as this may cause the computer to run stuck when the software opens the index. It is recommended that the operator create a new index before each test.

Edit: There are "Delete Data", "Delete All", and "Refresh Data"; "Delete Data" refers to deleting the current data, and the table color of the current data is orange. You can double-click different file names to select different test data. "Delete All" clears all test data under the current index. All deletions are not recoverable, please operate with caution! "Refresh Data" refers to changing one or more parameters based on existing test data, and then clicking "Refresh Data". The software will recalculate a new test data, which needs to be saved again.

Measurement: There is only one "option setting", but there are three settings interfaces under "option setting": system settings, unit settings, and report settings. As shown in the following figure:



System settings include magnetic flux and current correction factors, language selection, and the header name displayed in the test report



The user can freely choose the SI or CGS unit system for magnetic quantity units in the unit settings.

Specify the coordinate range. Check the box to select the specified coordinate display range, and uncheck to select the default automatic coordinate range. When there is a significant difference between Hc and Hs or Br and Bs, you can select the specified coordinate range to view the curve in a small range.

Reports: There are "Print Preview", "Print Settings", "Export Picture", "Export Report", and "Export Table". "Export Picture" only exports the current result curve of the current data, and it only has a graphical portion. "Export Report" is to export the current result curve and data results in the format of a picture. If a user wants to report a hysteresis loop or magnetization curve, he or she needs to select the hysteresis loop or magnetization curve first. "Export Table" is to export all the magnetic parameter result tables under the current index as Excel tables. Users can experience the actual operation.

Help: There are "System Calculator", and "About DX-2012SD"

3.2 Sample shape, size, and number of turns

Sample shapes can be selected: annular, CD, R, BS, EE, EI, and others. Let's choose some commonly used and representative shapes to illustrate.

Before explaining, let's supplement two magnetic formulas, which are the basis of our measurement.

One is the definition of magnetic field strength: the amount of current flowing per unit of magnetic circuit length

$$H = \frac{N \times I}{L_e} \quad (\text{A/m})$$



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H: Magnetic field strength, in A/m; N: The number of turns of the primary coil, in units of 1; I: Primary coil current, in amperes; Le: The effective magnetic path length of the sample, in meters.

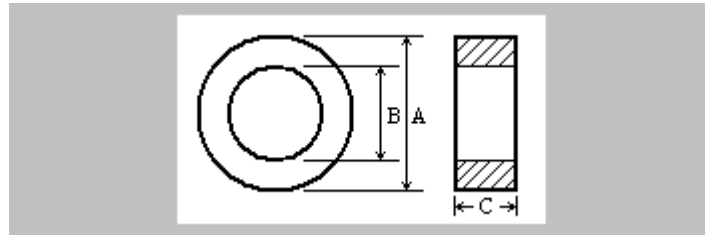
The other is the definition of magnetic induction intensity: the number of magnetic lines of force that pass through a unit area, that is:

$$B = \frac{\Phi}{N \times Ae} \quad (T)$$

B: Magnetic induction strength or magnetic flux density, in T, Φ Magnetic flux, in Wb; N: Number of turns of secondary coil, unit: 1; Ae: Effective cross-sectional area of the sample, in m².

Therefore, we must first determine the effective magnetic path length Le and the effective cross-sectional area Ae of the sample. These can be calculated from the size of the sample.

Ring: As shown in the following figure:



A is the outer diameter of the sample, B is the inner diameter of the sample, and C is the height of the sample, all in millimeters.

There are two options for Sx/De: Sx is the lamination coefficient or the filling coefficient, in%; De is the density of the sample, in g/cm³. If the sample is solid, we enter "100" to represent a fill factor of 100%; So, how do they participate in calculating the effective magnetic path length Le and the effective cross-sectional area Ae of the sample?

According to the SJ/T10281 standard, the core constants C1 and C2 of the sample are calculated first, and then Le and Ae are calculated based on the core constants. This is a calculation method strictly implemented in accordance with the standard.



$$C1 = \frac{2\pi}{C \times \ln \frac{A}{B}} \text{ mm}^{-1}$$

$$C2 = \frac{4\pi(\frac{1}{B} - \frac{1}{A})}{C^2 \times \ln^3 \frac{A}{B}} \text{ mm}^{-3}$$

$$Le = \frac{C1^2}{C2} \text{ mm}$$

$$Ae = \frac{C1}{C2} \times Sx\% \text{ mm}^2$$

If the sample is wound from a strip into a circular shape, such as amorphous strip, with a filling coefficient of about 75% and a density of 7.25 g/cm³, then we can enter "75" or "7.25", and the software will judge based on a limit of 10. Greater than 10 is considered the filling coefficient, and less than 10 is considered the density. M is the weight of the sample, in grams. How did they participate in the calculation of the effective magnetic path length Le and the effective cross-sectional area Ae of the sample?

If the filling factor Sx "75" is entered, the system will calculate it according to the above formula; If you enter Density De "7.25", then

$$Le = \frac{C1^2}{C2} \text{ mm}$$

$$Ae = \frac{1000W}{De \times Le} \text{ mm}^2$$

If we do not calculate the magnetic core constant according to SJ/T10281 standard, but use ordinary mathematical formulas to calculate Le and Ae, this calculation method differs greatly from the standard.

$$Le = \frac{\pi(A+B)}{2} \text{ mm}$$

$$Ae = \frac{A-B}{2} \times C \text{ mm}^2$$

BS shape



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This category is open circuit samples, where L is the length of the sample, in mm; De is the density of the sample, in g/cm³; W is the weight of the sample, in grams; Nd is the demagnetization factor, in units of 1; Sj is the effective area of the test coil, in mm²; Rj is the DC resistance of the test coil, in ohms.

Nd demagnetization factor, demagnetization field Hd. When a finite size sample is magnetized by an external magnetic field, the free magnetic poles appearing at both ends of it will generate a magnetic field opposite to the direction of magnetization, which is called the demagnetization field Hd. The strength of the demagnetization field Hd is related to the shape of the magnet and the strength of the magnetic pole, and there is a relationship:

$$Hd = -Nd \times M \quad (A/m)$$

Nd: Demagnetization factor, which is only related to the shape of the material; For example, for an elongated sample magnetized along the long axis, the demagnetization factor Nd is close to zero, while for a thick and short sample, the demagnetization factor Nd is large. For magnets of general shape, it is difficult to calculate the magnitude of the demagnetization factor Nd. The shape of the sample that can strictly calculate its demagnetization factor is only an ellipsoid, which can prove that there is a simple relationship between the demagnetization factors in the three main axes of the ellipsoid as follows:

$$Nd_x + Nd_y + Nd_z = 1$$

For ordinary shaped ellipsoids, the demagnetization factor Nd for magnetization along the long axis is shown in the following table:

Draw ratio	Cylinder	Prolate spheroid	Oblate spheroid
0	1.0000	1.0000	1.0000
1	0.2700	0.3333	0.3333
2	0.1400	0.1735	0.2364
5	0.0400	0.0558	0.1248
10	0.0172	0.0203	0.0696
20	0.00617	0.00675	0.0369
50	0.00129	0.00144	0.01472
100	0.00036	0.000430	0.00776
200	0.00009	0.000125	0.00390
500	0.000014	0.0000236	0.001567
1000	0.0000036	0.0000066	0.000784
2000	0.0000009	0.0000019	0.000392

Therefore, the thinner the sample, the easier it is to magnetize, and the better the test results will be.

Other:

Le: effective magnetic path length of the sample, in mm; Ae: Effective cross-sectional area of the sample, in mm²; Ve: effective volume of the sample, in cm³; We: sample mass, unit: g;



The effective magnetic path length L_e of the sample and the effective cross-sectional area A_e of the sample can be calculated according to the formula mentioned above. The effective volume V_e of the sample is the product of the effective magnetic path length L_e of the sample and the effective cross-sectional area A_e of the sample.

Finally, we will explain the determination of the number of turns of primary coil N_1 and secondary coil N_2 . Starting from the two basic magnetic formulas mentioned earlier,

$$H = \frac{N \times I}{L_e} \quad (\text{A/m})$$
$$B = \frac{\Phi}{N \times A_e} \quad (\text{T})$$

So

$$N_1 = \frac{H \times L_e}{I}$$
$$N_2 = \frac{\Phi}{B \times A_e}$$

The maximum value of H is the test condition H_s , the saturation magnetic field strength of the sample; The maximum value of I is the maximum range of the magnetizing power supply (10A); Therefore, the minimum number of turns of primary coil N_1 is

$$N_1 \geq \frac{H_s \times L_e}{10}$$

The maximum value of B is B_s , the saturation magnetic induction strength of the sample (currently, the saturation magnetic induction strength of soft magnetic materials is below 2.5T); The maximum value of Φ is the maximum range (20mWb) of the fluxmeter (electronic integrator), and the minimum value of Φ is 20% of the minimum range (0.25mWb) of the fluxmeter (we believe that the accuracy and repeatability of the measured signal can only be guaranteed if the strength exceeds 20% of the range). Therefore, the range of the secondary coil N_2 is:



$$\frac{0.25 \times 10^{-3}}{B \times Ae} \leq N2 \leq \frac{20 \times 10^{-3}}{B \times Ae}$$

There is a quick way to enter the size column according to the actual size of the sample, such as A for 40, B for 32, C for 6, Sx/De for 100, and M for 20.9. Then, enter 1 in the turn number column N1 and N2 respectively, and then enter a maximum value in the test condition column Hs, such as "100000". Finally, press "Enter". The Hs column will automatically calculate a value based on the maximum range of the magnetizing power supply, such as 80. It tells us that this sample can only be tested to a maximum of 80A/m if it is used for a primary turn. If this sample is to be tested to 8000 A/m, the primary coil of that sample should be wound at least 100 turns. For secondary N2, it is recommended to use the auxiliary calculation formula: $500 \leq N2 * Ae \leq 2000$. In some cases, it may be difficult to meet the requirement of ≥ 500 , and $N2 * Ae$ is only 100, which can also be tested. However, the secondary induction signal will be relatively weak, with a lower signal-to-noise ratio, which has a significant impact on the accuracy of the ui test.

3.3 Test methods and conditions

Simulated impact method and magnetic field scanning method.

The impact method was also an important method for early magnetic measurement. The biggest disadvantage of the early impact method is that it cannot continuously display the magnetization curve and hysteresis loop. Later developed electronic integrators overcame this shortcoming and have been widely used in magnetic measurements. The introduction of microcomputers has further changed the face of magnetic measurement, and data acquisition technology, digital analysis technology, and control interfaces closely related to microcomputers have played an important role in magnetic measurement. For example, combining data acquisition and digital integration can easily achieve long-term integration; The numerical values of various magnetic parameters can be given quickly through appropriate calculation programs; Through the control interface, temperature control, magnetization field adjustment, force balance, magnetic field compensation, etc. can be achieved; The use of microcomputers also allows measurement results to be retained for a long time, and statistical analysis can be performed to help improve product performance.

Magnetic field scanning method: By controlling the rate of magnetic flux db/dt , it can approach quasi static state. However, since the excitation voltage is a slowly changing DC voltage, and db/dt is very small, the secondary induced voltage will be very small, so the signal is very weak, which requires a very high level of electronic integrator in the later stage. Electronic integrators must have a high sensitivity and a small drift, which is an unspoken implication for electronic integrators. Especially when measuring the initial magnetic permeability, the signal is so weak that it cannot be measured. Although increasing db/dt can improve the signal strength, due to the influence of hysteresis, B lags behind H, which can also cause deviations in the measurement results. Therefore, instruments using the scanning method generally use B-speed feedback to adjust db/dt to minimize the impact of hysteresis. However, too low db/dt worsens the signal-to-noise ratio, making it difficult to balance the two.



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Tsw (corresponding to simulated impact method) and Tsp (corresponding to magnetic field scanning method) refer to the residence time at each point of testing to reduce the impact of magnetic hysteresis.

Test condition settings: including Hi, Hj, Hs, and dB.

Hi is the starting point of the magnetization field (magnetic field strength) and the minimum variation of the magnetization field, i.e., the step size.

At the same time, we test the corresponding μ To give a close initial permeability μ_i .

Theoretically, the smaller the Hi, the corresponding μ The closer it is to the initial permeability μ_i . And the more points tested, the more realistic the curve and the more accurate the data. Undoubtedly, this increases the difficulty and burden of the measurement system. If the starting section of the magnetization curve of the material is relatively flat, setting Hi higher will not cause significant errors in the results, but will make the testing process smoother. Therefore, various materials basically have a corresponding Hi, as shown in the following table:

Nanocrystalline	Permalloy	Silicon steel	Ferrite	Electrician Pure Iron
0.08A/m	0.4A/m or 0.08A/m	1A/m	3A/m	8A/m

Hj is the inflection point of the test curve, generally 20 times the value of Hi.

Hs is the maximum magnetic field strength during the test. Since the definition of DC static magnetic parameters is based on ensuring that the material is in a saturated state, Hs is the magnetic field strength value that can saturate the material. Its settings can be determined according to actual test requirements, or refer to the following table:

Nanocrystalline	Permalloy	Silicon steel	Ferrite	Electrician Pure Iron
80A/m	1600A/m	800A/m	1200A/m	10000A/m

dB is the minimum change in the point control B of the test curve, that is, the step size. Due to the use of B-speed feedback adjustment in this system, when the magnetization field H changes in step length Hi and the magnetic induction intensity B changes by more than dB, the system will adjust the magnetization field H to change by a value smaller than the step length Hi, thereby obtaining more accurate results. Using the impact method, dB is taken as 10% of Bs. If Bs is unknown, dB=0.1T can be used first. If the resulting curve is not smooth enough, adjust dB and retest again; The scanning method dB is taken as 1% of Bs

3.4 Sample record column

Including: sample number, material name, measurement temperature, measurement date, operator, and remarks. As shown in the following figure:



☒ Analog impact ☐ Scan method Tsw 1 S

☒ Magnetizing Curve ☒ Hysteresis Loop

☒ μ_i ☒ μ_m ☒ Bs ☒ Br ☒ Hc

TestPoint	Hi (A/m)	Hj (A/m)	Hs (A/m)	dB (T)
Auto	8	400	3200	0.15

SampleNo 03 MateName

TestTemp 20.0 °C TestDate 2023/ 3/ 2

Operator Remarks INDIA

These are for recording purposes only and do not participate in the calculation of test results.

3.5 Ammeters and fluxmeters

The ammeter and magnetic flux meter are shown in the following figure:



The ammeter has four gears: 0.02A, 0.2A, 2A, and 20A. Each gear has four ratios: /1, /2, /5, and /10, so there are a total of thirteen ranges: 2mA, 4mA, 10mA, 20mA, 40mA, 100mA, 200mA, 400mA, 1000mA, 2A, 4A, 10A, and 20A. The full scale display is "20.0000".

The fluxmeter has four gears: 0.25 mWb, 0.5 mWb, 1 mWb, and 2 mWb. There is also a * 10 magnification in each gear, so there are a total of eight ranges: 0.25 mWb, 0.5 mWb, 1 mWb, 2 mWb, 2.5 mWb, 5 mWb, 10 mWb, and 20 mWb.

The white key indicates the currently selected gear, so the figure above shows the 1A gear selected by current and the 0.25mWb gear selected by magnetic flux. During testing, the software automatically selects the appropriate gear. In standby mode (when not tested), the ammeter should display "0.0000", and there may be some zero points. If there is a zero point of 0.1% (corresponding to the full scale), this will not have a significant impact on the results. The reading of the fluxmeter will jump, which is the drift of the integrator. Before testing, it is necessary to manually adjust the drift speed of the integrator to the slowest possible speed.



3.6 Test key and cancel key

These two keys are located at the bottom right of the software, and click the "Start" button to start testing the software; Click the cancel button to interrupt the software test. Interrupt testing can also be implemented by pressing "Esc" on the keyboard

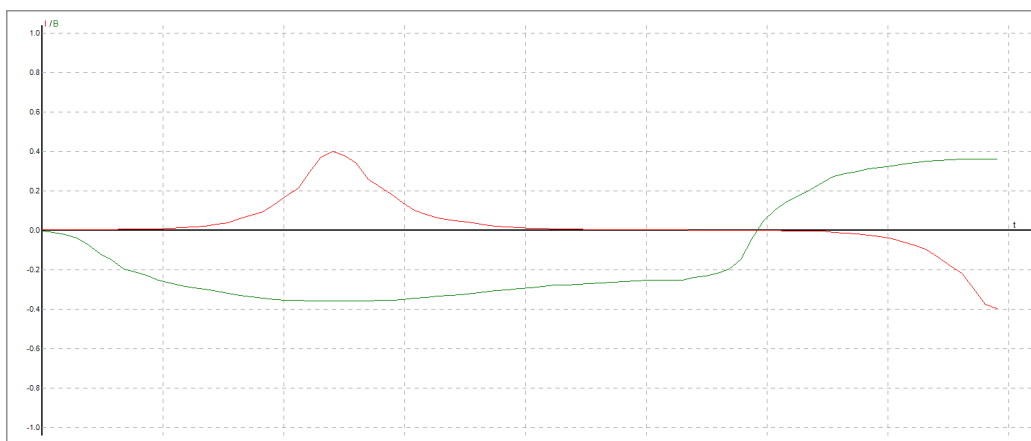
3.7 Software status bar and path

At the bottom of the software, on the far left, is the progress of the test. During the test, a blue progress bar will display the progress. The path to save the current data is displayed immediately on the right. The latest prompt is the current status of the software. "When the software is opened, a prompt will appear indicating that the file was successfully opened!"; After clicking on the test, it will prompt "DA correction", "demagnetization in progress", "testing in progress", "P1=8A/m (etc.)", "test interrupted", and "test completed".

When the prompt "DA correction failed" is displayed, it indicates that the actual output current differs too much from the system set current. This may be due to incorrect input parameters, or there may be no sample connection or poor sample contact. "The actual value in parentheses in" P1=8A/m (etc.) "should be close to the value of P, such as" 8.01 A/m ".

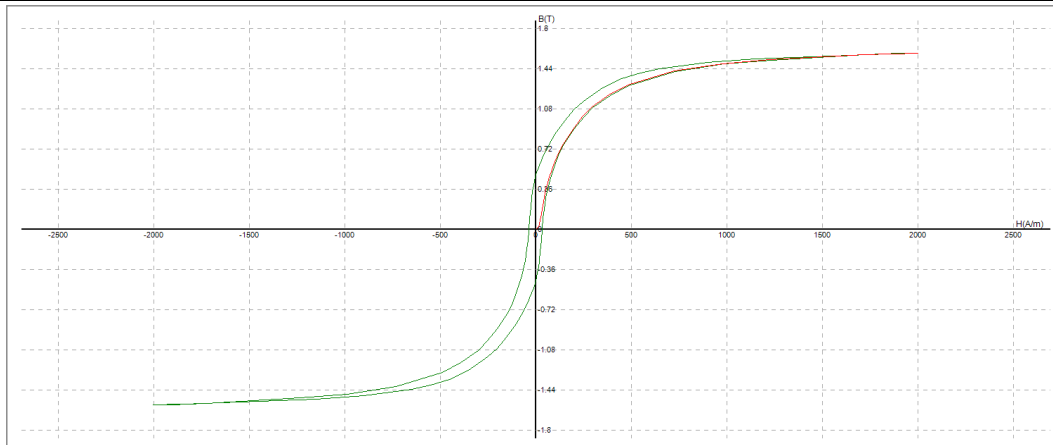
3.8 Result curves

The sampling waveform is shown below:



The sampling waveform records and displays the raw data of the primary current and secondary magnetic flux of the sample during the test process, and displays it in a proportional format (the highest, i.e., full scale, is 1). The red line is an electric current, and the green line is a magnetic flux. Users can also determine the signal strength of current and magnetic flux based on the height of the red and green lines, so as to know whether the turns of the primary and secondary circuits are appropriate. Below 0.2 is too weak, and above 0.8 is too strong

The hysteresis loop diagram includes the basic magnetization curve (red) and the hysteresis loop (green). As shown in the following figure:



The basic magnetization curve is a curve that represents the relationship between the magnetic induction strength B and the magnetic field strength H of ferromagnetic materials during magnetization, also known as the B - H curve. Unlike weak magnetic materials such as diamagnetic, paramagnetic, or antiferromagnetic materials, where the magnetization curve is a straight line, the magnetization curve of ferromagnetic materials is not a straight line, but is characterized by simultaneous hysteresis. This curve can be measured experimentally. There is a non-linear relationship between B and H (see the red line section of OA above).

First, to obtain a zero demagnetization state, applying a strong alternating magnetic field without a direct current magnetic field gradually reduces its amplitude to zero is a method. This is called the AC demagnetization method. In contrast, there is another method called thermal demagnetization. This method involves heating ferromagnetic materials above the Curie point and then cooling them without a magnetic field.

If a magnetic field is applied from the demagnetization state, within the range of weaker magnetic field strength, the magnetization curve is inclined and reversible. The linear permeability is called the initial permeability. This range is called the initial permeability range. When the magnetic field is further increased beyond this range, the magnetic domain moves irreversibly away from the stable region, and the magnetic induction intensity rises sharply. As the magnetic field further increases, the change in magnetic induction intensity becomes slow again. After reaching the B_s point, the magnetization curve gradually flattens out and finally reaches a fixed value. This value is called the saturation magnetic induction strength. Different ferromagnetic materials have different magnetization curves, and their saturation value of B is also different. However, the saturation value of B for the same material is certain.

When the ferromagnetic material reaches the magnetic saturation state, if the magnetization field strength H is reduced, the magnetic induction strength B of the ferromagnetic material does not decrease along the initial magnetization curve (see the red line section of OA above), and the change of B lags behind the change of H . This phenomenon is called hysteresis.

In a magnetic field, the relationship between the magnetic induction intensity B of ferromagnetic materials and the magnetic field intensity H can be represented by a curve. When the magnetized magnetic field undergoes periodic changes, the relationship between the magnetic induction intensity and the magnetic field intensity in ferromagnets is a closed line, which



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is called a hysteresis loop (see the green line section above). The hysteresis loop is the four quadrant curve of B-H.

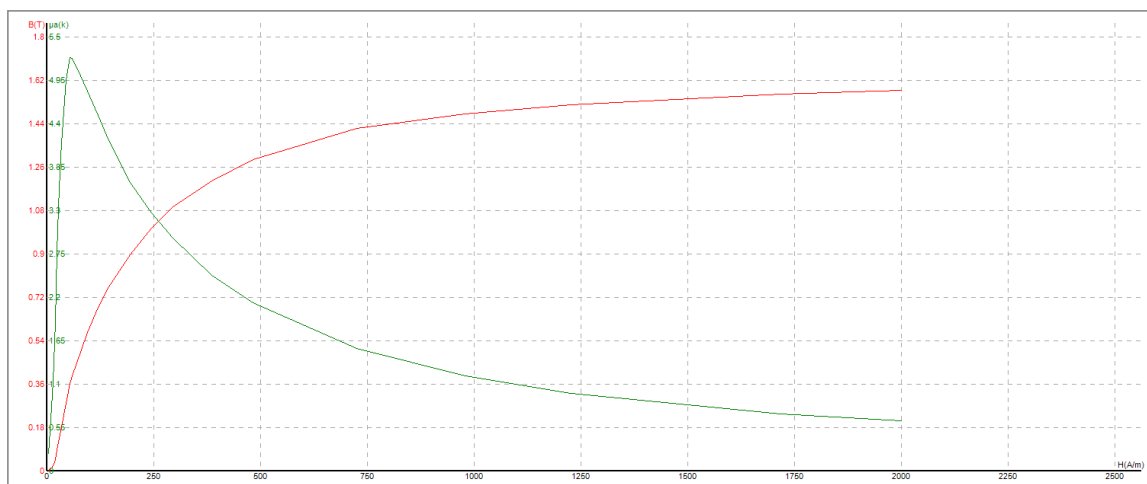
The entire periodic process is as follows: the magnetic field intensity H magnetizes the ferromagnetic material from zero (point 0), and the magnetic induction intensity B of the ferromagnetic material is now zero (point 0). Subsequently, the magnetic field intensity H monotonically increases to the saturation magnetic field intensity Hs (point a), and the magnetic induction intensity B of the ferromagnetic material correspondingly increases to the saturation magnetic induction intensity Bs (point a), and then gradually reduces the magnetization field intensity H to zero, "The magnetic induction strength B of ferromagnetic materials is now not zero, but instead decreases from point a to point b. This value is called the residual magnetic induction strength, or remanent magnetism Br.". Only when the magnetic field strength H continues to gradually decrease to point c will the magnetic induction strength B of ferromagnetic materials decrease to zero. The magnitude of this magnetic field strength H is called the coercive force Hc. The magnetic field strength H continues to decrease to - Hs, and the magnetic induction strength B of ferromagnetic materials correspondingly decreases to - Bs (point d), reaching saturation in the negative direction. Then, by increasing the magnetic field in the positive direction, the magnetic induction intensity reaches saturation in the positive direction along the defa curve. The entire abcdefa curve is a hysteresis loop. The area enclosed by this loop is represented by the following formula:

$$Wh = \oint H dI$$

It represents the energy loss per unit volume of magnetic material when the magnetization changes along the loop for one cycle, known as hysteresis loss. Also known as static hysteresis energy, in kJ/m³.

The magnetization curve includes a permeability curve (green line) and a basic magnetization curve (red).

The basic magnetization curve represents the non-linear relationship between magnetic induction intensity B and magnetic field intensity H, which is the first quadrant curve of B-H, as shown in the red line below:



The magnetic permeability curve is the curve of the ratio of magnetic induction intensity to magnetic field intensity, which is the green line shown above. It is the slope of the magnetization curve (the red line in the figure above), which can also be



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expressed by the following formula:

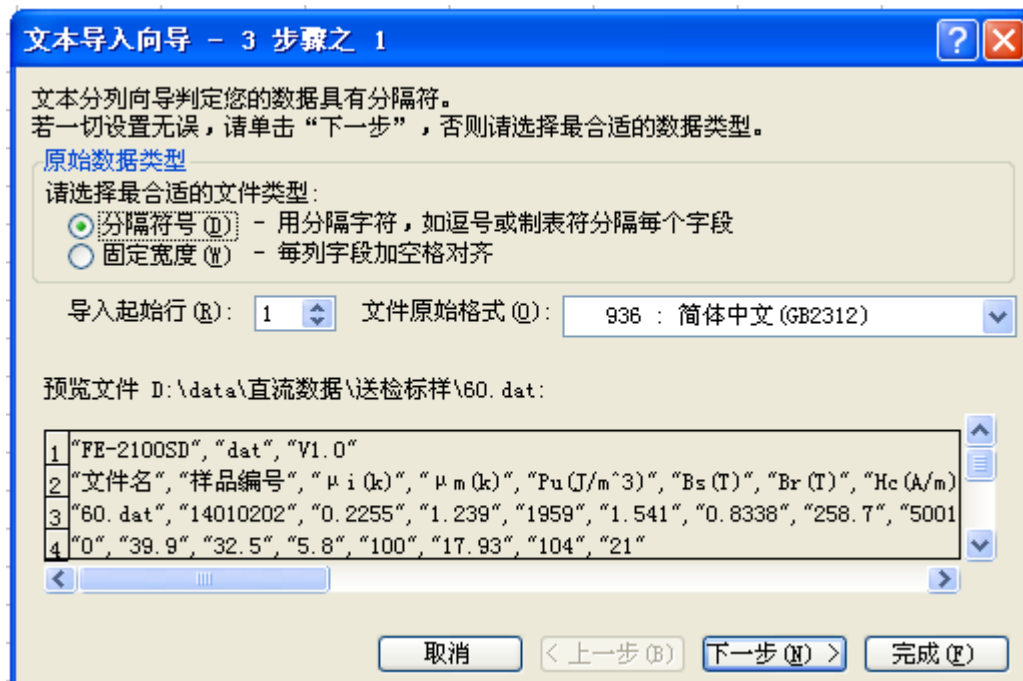
$$\mu = \frac{B}{H}$$

The magnetic permeability corresponding to the H_i point is the initial magnetic permeability μ_i . The maximum value on the magnetic permeability curve is μ_m . Its corresponding magnetic field strength is H_{μ_m} .

According to the original data measured by the software, users can draw magnetization curves and hysteresis loops themselves. The specific operations are as follows:

3.8.1 Create a new Excel table first;

3.8.2 Open the selected test data (suffix: .dat) in the newly created Excel table; The following window pops up:



3.8.3 Click "Next". The following window pops up:

文本导入向导 - 3 步骤之 2

请设置分列数据所包含的分隔符号。在预览窗口内可看到分列的效果。

分隔符号

☒ Tab 键 (T) ☐ 分号 (M) ☒ 逗号 (C) ☐ 连续分隔符号视为单个处理 (R)

☐ 空格 (S) ☐ 其他 (Q): 文本识别符号 (Q):

数据预览 (P)

FE-2100SD	dat	V1.0	μ_i (k)	μ_m (k)	P_u (J/m ³)	B_s (T)	B_r (T)	H_c (A/m)	H_s (A/m)	材料
文件名	样品编号									
60.dat	14010202	0.2255	1.239	1959	1.541	0.8338	258.7	5001		
0	39.9	32.5	5.8	100	17.93	104	21			

取消 < 上一步 (B) 下一步 (N) > 完成 (F)

3.8.4 Place a check mark at the "comma (C)" and click "Done". The original data is opened in a table format. As shown in the following figure:

文本导入向导 - 步骤 2 (共 3 步)

请设置分列数据所包含的分隔符号。在预览窗口内可看到分列的效果。

分隔符号

☒ Tab 键 (T) ☐ 分号 (M) ☒ 逗号 (C) ☐ 连续分隔符号视为单个处理 (R)

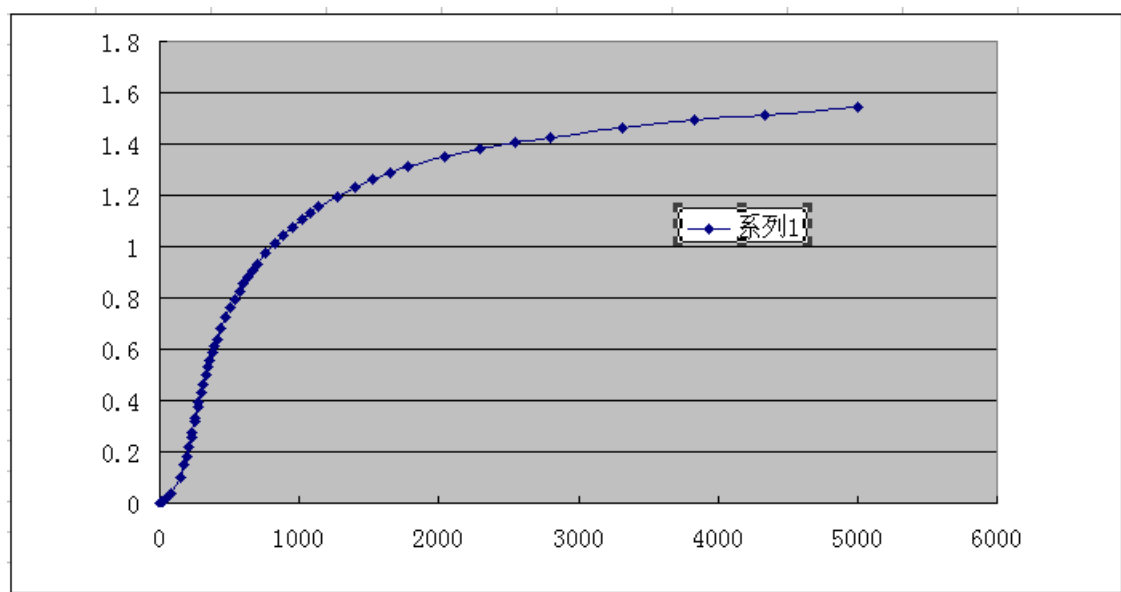
☐ 空格 (S) ☐ 其他 (Q): 文本识别符号 (Q):

数据预览 (P)

QZ-4000SD	dat	V1.0	μ_i (k)	μ_m (k)	P_u (J/m ³)	B_s (T)	B_r (T)	H_c (A/m)	H_s (A/m)	材料名称	样品形状
文件名	样品编号										
A38.dat	1	0.742	2.365	37.66	0.9288	0.05672	14.95	599.8			
1	20	16	40	45	7.18	443	20	2			

取消 < 上一步 (B) 下一步 (N) > 完成 (F)

3.8.5 Select the data in columns H and B to make the magnetization curve and hysteresis loop. The following diagram shows the magnetization curve:



3.9 Magnetic parameter result table

The magnetic parameter result table includes the test conditions, sample parameters, magnetic parameter data results, and test date and other recorded parameters of the sample.

The results of magnetic parameter data include: initial magnetic permeability μ_i , Maximum magnetic permeability μ_m , static hysteresis energy P_u (i.e. Wh), saturation magnetic induction strength B_s , residual magnetism B_r , and coercive force H_c .

The basic requirements for soft magnetic materials (materials that can quickly respond to changes in external magnetic fields and achieve high magnetic induction strength with low loss) under static conditions are:

A Initial magnetic permeability μ_i and maximum magnetic permeability μ_m must be high;

The coercivity H_c of B should be small;

C The saturation magnetic induction strength B_s is higher;

D High stability.

Magnetic permeability is an important parameter of soft magnetic materials, mainly the initial magnetic permeability from the perspective of usage requirements μ_i . Other magnetic permeability such as μ_m , μ_r et al. and μ There is an inherent connection, so only the initial permeability will be discussed below μ_i .



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During actual magnetization, the initial magnetic permeability μ This is the superposition of the two processes of domain switching magnetization and displacement magnetization, and it is proportional to the square of the saturation magnetic induction strength B_s of the material; And the anisotropic constant K_1 and magnetostrictive coefficient of the material λ S is inversely proportional; And internal stress in the material σ And impurity concentration β In inverse proportion. Among the influencing factors in the above aspects, B_s , K_1 , and λ " S " is the basic magnetic characteristic parameter of a material, which is the main factor determining magnetic permeability, and does not vary substantially with processing conditions and application conditions. And internal stress σ And impurity concentration β Is a secondary factor in determining magnetic permeability, internal stress σ And impurity concentration β The magnitude of and its impact on magnetic permeability will vary depending on processing conditions and actual conditions.

Magnetic materials with low coercivity H_c can quickly respond to changes in external magnetic fields and exhibit a sensitive response at low magnetic fields.

The demagnetization process of soft magnetic materials is mainly achieved through domain wall displacement, so the internal stress fluctuations and the content and distribution of impurities in the material become the main factors affecting the coercive force H_c . For materials where internal stress is not easily eliminated, emphasis should be placed on reducing λ s ; For materials with high impurity content, it is important to consider reducing the value of K_1 . It can be found that soft magnetic materials can reduce the coercive force H_c and improve the initial magnetic permeability μ The method of i is consistent. Therefore, for soft magnetic materials, the initial magnetic permeability is improved μ While achieving the goal of reducing the coercive force H_c .

Soft magnetic materials usually require high saturation magnetic induction strength B_s , which not only can achieve high initial magnetic permeability μ i . It can also save resources and achieve miniaturization of magnetic devices. Suitable formula ingredients can be added to soft magnetic materials to improve the saturation magnetic induction strength B_s . In fact, it is generally not possible to have a significant change in the saturation magnetic induction strength B_s of a material.

The development of high technology, especially highly reliable engineering technology, requires that soft magnetic materials not only be high μ I . High B_s , and more importantly, high stability. The high stability of soft magnetic materials means that the temperature stability of magnetic permeability should be high, the decrease should be small, and the aging over time should be as small as possible to ensure its long life working in space, the seabed, underground, and other harsh environments. Factors affecting the stable operation of soft magnetic materials include low temperature, humidity, electromagnetic fields, mechanical loads, ionizing radiation, and so on. Under the influence of these factors, the basic characteristic parameters of soft magnetic materials change, resulting in changes in performance. This should be particularly noted when we test samples.

4. Operating Steps of DX-2012SD Soft Magnetic DC Measurement System

4.1 Checking

After checking that all accessories are complete, please connect all connecting wires, etc.

4.2 Turn on system

Start the computer first, then run the test software, and then close the "POWER" switch on the front panel of the power supply chassis. The header on the front panel of the power supply chassis should display "0.00", so as to preheat for ten minutes



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4.3 Prepare the samples

4.3.1 Prepare the sample ring for testing, measure the size, and weigh it

4.3.2 Winding of primary and secondary coil turns.

The selection of coil turns can vary depending on the magnetic field strength required for testing. For example, for a sample with an outer diameter of 40mm, an inner diameter of 32mm, and a height of 4mm, and a test condition of $H=800\text{A/m}$, how many turns are suitable for winding? "We can select the corresponding specification in the condition column of the software and enter the actual size. The default number of turns is 1:1, and H_s enters 1000. Then, press Enter, and the 1000 entered by H_s automatically changes to 80.". As shown in the following figure.

Ring	CD	Rect	BS	EE	EI	Other
Effective parameter of sample						
Le: Effective length(mm)						
Ae: Effective area(mm ²)						
Ve: Effective volume(cm ³)						
We: Effective weight(g)						
Le (mm)	Ae (mm ²)	Ve (cm ³)	We (g)			
112.2	30	3.366	1			
N1 56	N2 27					
<input checked="" type="radio"/> Analog impact <input type="radio"/> Scan method Tsw 1 S						
<input checked="" type="checkbox"/> Magnetizing Curve <input checked="" type="checkbox"/> Hysteresis Loop						
<input checked="" type="checkbox"/> μ_i <input checked="" type="checkbox"/> μ_m <input checked="" type="checkbox"/> Bs <input checked="" type="checkbox"/> Br <input checked="" type="checkbox"/> Hc						
TestPoint	Hi (A/m)	Hj (A/m)	Hs (A/m)	dB (T)		
Auto	5	160	2000	0.15		
SampleNo	03	MateName	pc40			
TestTemp	20.0 °C	TestDate	2023/ 3/ 2			
Operator		Remarks				

This means that the sample $N1=1$ turn can only be tested to 80A/m. If 800 A/m is to be tested, $N1$ should be greater than 20, and an alarm should be given considering that the current of the power supply may be too large to exceed the maximum output (20A). We should leave a 50% margin, so $N1=10 * 1.5 \text{ turns}=15 \text{ turns}$, and the reference formula for determining $N2$ is: $500 \leq N2 * Ae \leq 2000$. Some samples may not be able to reach $500 \leq N2 * Ae$, and $N2 * Ae$ can only reach 100 at most, which can also be tested. However, in this case, the magnetic flux signal will be very small and the signal-to-noise ratio will be low, It has a significant impact on the accuracy of ui testing. $N1$ needs to flow a large current, up to a maximum of 20A. It is recommended to use enameled wire with a diameter of more than 1.0mm. The current in $N2$ coils is very small, and very fine enameled wire, such as enameled wire with a diameter of 0.2mm, can be used.

The number of primary and secondary turns conforms to the following formula:



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Calculation formula for magnetic field strength: $H=N \times I / L_e$

Where: H is the magnetic field strength, in A/m; N is the number of turns of the excitation coil; I is the primary excitation current (measured value), in A (maximum I is 10A, limited by current source); L_e is the effective magnetic circuit length of the test sample, in meters.

Calculation formula for magnetic induction strength: $B= \Phi / (N \times A_e)$

Where: B is the magnetic induction intensity, in T; Φ Is the secondary induced magnetic flux (measured value), in Wb (Φ 20 mWb maximum, electronic integrator range limit); N is the number of turns of the induction coil; A_e is the effective cross-sectional area of the test sample, in m².

In this way, we can also derive the appropriate range of turns based on these two formulas combined with the actual situation, which will not be discussed more here

4.4 Test process

4.4.1 Create a new index, save it as a file, and name the folder. The folder can be named according to company regulations or personal preferences. The general principle is to facilitate searching and archiving.

4.4.2 Select the corresponding sample specification and enter the size and number of turns of the sample.

4.4.3 Select "Simulated Impulse Method", input Tsw for 1 second, and tick before "Measuring Magnetization Curve" and "Measuring Hysteresis Loop".

4.4.4 Enter the test conditions.

H_i is the test starting point and the minimum test step size. Different materials have different values, as their settings directly affect the initial magnetic permeability μ_i . Therefore, the test can be set according to the actual test requirements, or refer to the following table

Nanocrystalline	Permalloy	Silicon steel	Ferrite	Electrician Pure Iron
0.08A/m	0.4A/m or 0.08A/m	1A/m	3A/m	8A/m

H_j is the inflection point of the test point trend, which is generally taken as ten times the value of H_i .

H_s is the test condition and the maximum magnetic field strength during the test. Since DC static magnetic parameters are measured to ensure that the material is in a saturated state, H_s is the magnetic field strength value that must be able to saturate the material. Its settings can be determined according to actual test requirements, or refer to the following table:

Nanocrystalline	Permalloy	Silicon steel	Ferrite	Electrician Pure Iron
80A/m	1600A/m	800A/m	1200A/m	10000A/m

ΔB is the step length of B, typically taken as 3% of B_s . You can also refer to the following table:



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Nanocrystalline	Permalloy	Silicon steel	Ferrite	Electrician Pure Iron
0.02T	0.015T	0.04T	0.01T	0.03T

4.5 Fluxmeter drift adjustment.

Connect the sample, observe the reading trend of the magnetic flux meter head on the software interface, and then rotate the multi turn potentiometer on the front panel of the power supply chassis to slowly stabilize the reading of the meter head. Then press the reset button on the front panel to reset the reading of the meter head to zero. Repeat this step if the reading on the gauge head changes quickly.

4.6 Test

Click "Test" of the software, and the system starts demagnetizing the sample. After demagnetization, the software will automatically start testing until the testing is complete.

During the test process, abnormal conditions such as excessive test current may occur, and the test power supply will also give an alarm. At this time, we can proceed as follows: First, press the "ESC/Exit" button on the keyboard or click the "Cancel" button on the lower right side of the software, and the software will interrupt the test. Then, press the "Alarm" button on the power supply chassis to interrupt the alarm. Recheck if it is caused by incorrect parameters or conditions, or if it is caused by a short circuit in the test clamp or test coil, and readjust and retest.

5. Result processing

5.1 Observe the data results. Observe the reasonableness of the curve and parameter results, and if necessary, adjust the parameters and turns to retest.

5.2 Save the data. Facilitate future data processing or archiving.

5.3 Remove the samples, clean the site, and wait for the next batch of samples to be tested.

5.4 Document the data results or print a report.

6. Turn off the system

6.1 Ensure that the sample has been removed and turn off the power supply to the power supply cabinet.

6.2 Close the test software.

6.3 Turn off the computer.

6.4. Clean the site.

Due to the continuous improvement and update of this system, any changes are subject to change without notice.