Ferromagnetic hysteresis

Related topics

Induction, magnetic flux, coil, magnetic field strength, magnetic field of coils, remanence, coercive field strength.

Principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded.
The remanence and the coercive field strength of two different iron cores can be compared.

Equipment

Coil, 600 turns	06514.01	2
Iron core, U-shaped, solid	06491.00	1
Iron core, solid	06490.00	1
Iron core, U-shaped, laminated	06501.00	1
Iron core, short, laminated	06500.00	1
Commutator switch	06034.03	1
Power supply, univ., anal. disp.	13501.93	1
Rheostat, 10 Ohm, 5.7 A	06110.02	1
Hall probe, tangent., prot. cap	13610.02	1
Barrel base -PASS-	02006.55	1
Right angle clamp -PASS-	02040.55	1
Support rod, l = 150 mm	02030.15	1
Connecting cord, l = 750 mm, red	07362.01	4
Connecting cord, l = 750 mm, blue	07362.04	4
Cobra3 BASIC-UNIT	12150.00	1
Cobra3 power supply	12151.99	1
Force/Tesla measuring module	12109.00	1
Cobra3 Software Force/Tesla	14515.61	1
RS 232 data cable	14602.00	1

PC, Windows® or higher

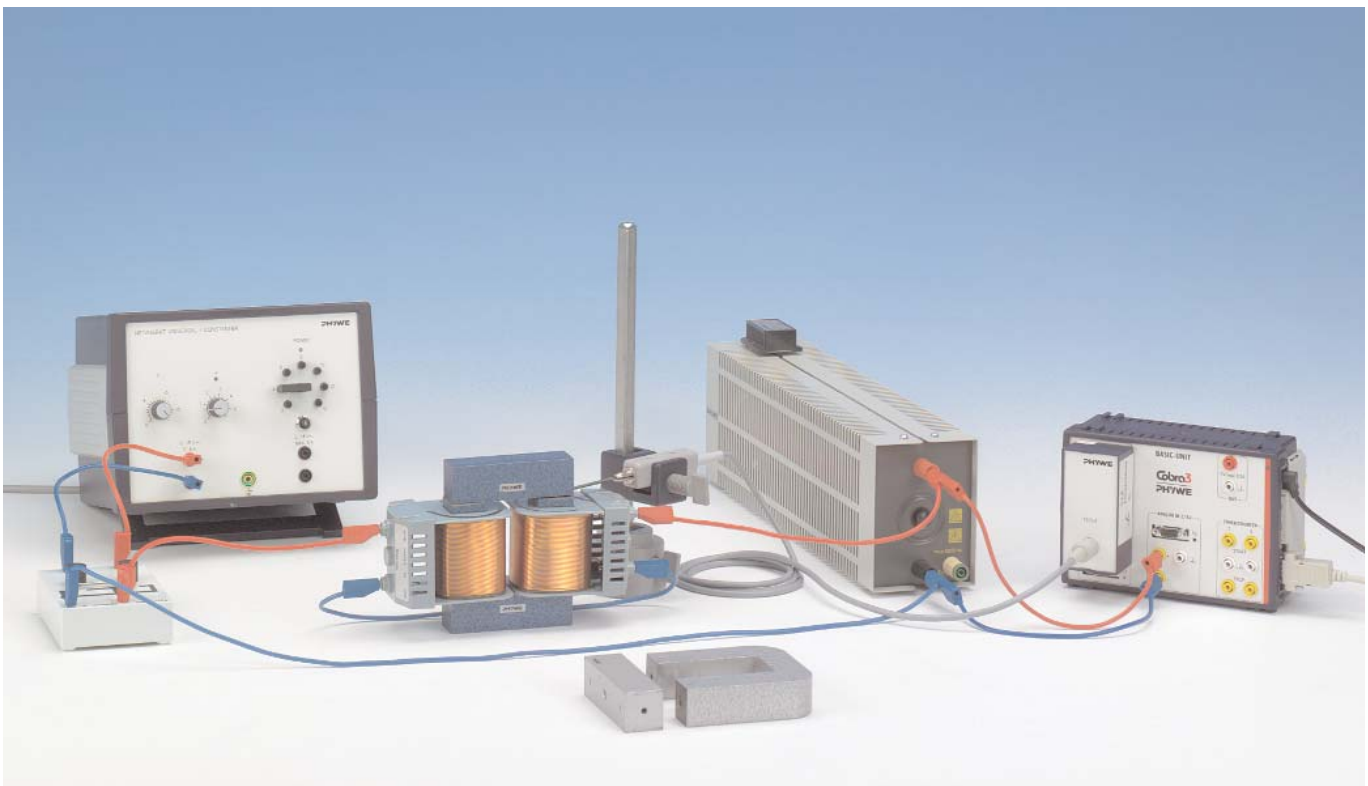
Tasks

Record the hysteresis curve for a massive iron core and for a laminated one.

Set-up and procedure

The experimental set-up is shown in Fig.1.
Connect the variable transformator to an electric socket which is as far as possible from the one chose for the interface and, if possible, which uses another electrical phase.
In addition, position the coil set-up far from the computer and from the Cobra device to avoid errors during the transfer of data due to interference by the strong magnetic fields.
Put the Force/Tesla module on the module port of the BASIC-UNIT and connect the voltage U which is measured across the resistor to the analogue input 2 of the BASIC-UNIT.
Connect the cable of the Hall probe with the Force/Tesla Module and attach the Hall probe under the yoke in such a manner that the sensor is located directly adjacent to the borehole for the positioning pin.
The magnetic field of the coils should be reversed with the commutator switch only at a voltage of 0 V as otherwise voltage spikes are generated which can affect data transfer.
The flux density B_0, measured by the hall probe, and the current I through the coils are recorded.

Fig.1: Experimental set-up for the ferromagnetic hysteresis



Therefore, set the measuring parameters in the software according to Fig. 2a and Fig. 2b.

Chose the icon ”continue” to enter the graphical illustration during the measurement.
Here, the actual values of the flux density and the current are displayed (Fig. 3).

Set the rheostat to 10 V.
If residual magnetism is present in the iron core, demagnetise the core as follows:
Set the commutator switch in such a manner that an opposing field is generated.
Briefly increase the voltage far enough for the flux density to assume a zero value; repeat a number of times.
Set current limiter on the power supply to 5 A.
After pressing the icon ”Start measurement”, increase the voltage slowly and uniformly from zero upwards and decrease it to zero again. Simultaneously, record every value on key press, i.e. press ”enter” or ”space” after every change of the voltage.
Using the commutator switch reverse the polarity of the voltage.
Again increase and then decrease the voltage slowly and uniformly.
Once again reverse the polarity of the voltage with the commutator switch and increase the voltage.
Stop the measurement and press the ”close” button.
Reset the voltage to 0 V.
The recorded values are represented graphically as flux density as a function of current.

Remarks

A good resolution of the hysteresis is received with an increment of the current about 20 mA.
The flux density should not exceed 1000 mT because of the sensor.
As the measured values are not combined in the order of recording but in the order of increasing x-axis-values, the curve does not look like a hysteresis, at first.

Fig. 3: Appearance of the program during the measurement

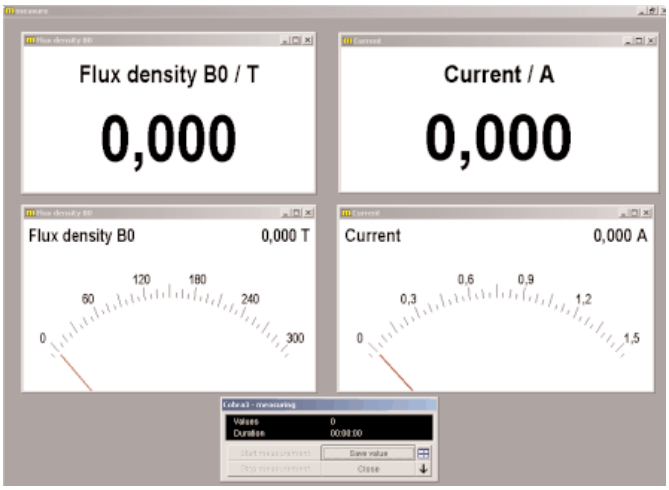


Fig. 2a: Measuring parameters for the ferromagnetic hysteresis

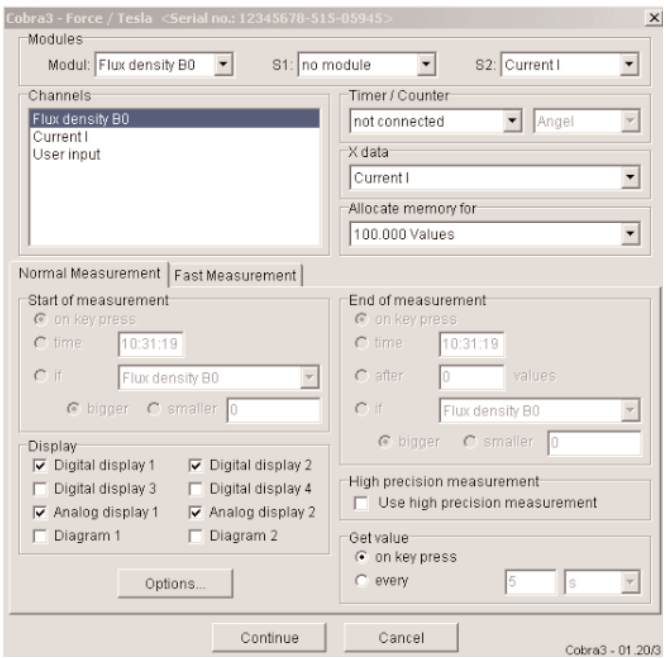
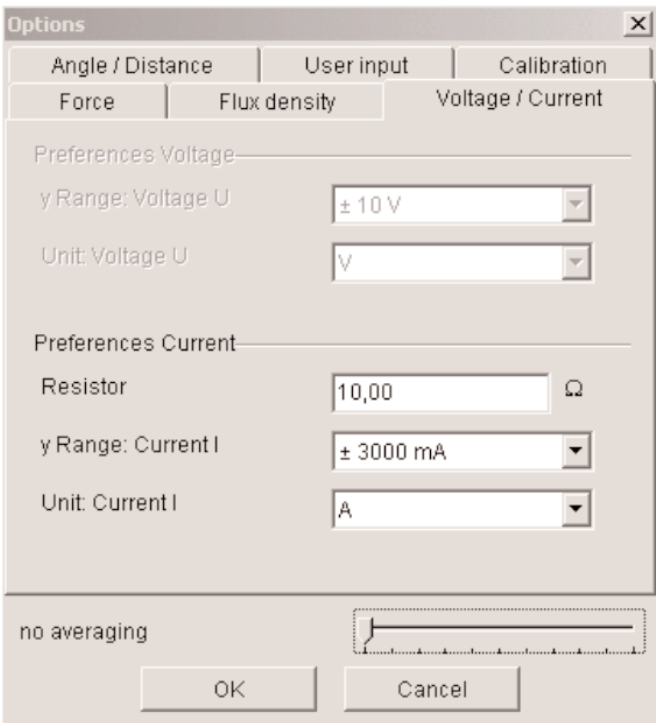


Fig. 2b: Measuring parameters for the ferromagnetic hysteresis



To obtain a clear graphical illustration, change the ”display options” according to Fig. 4.

Fig. 4: Display options

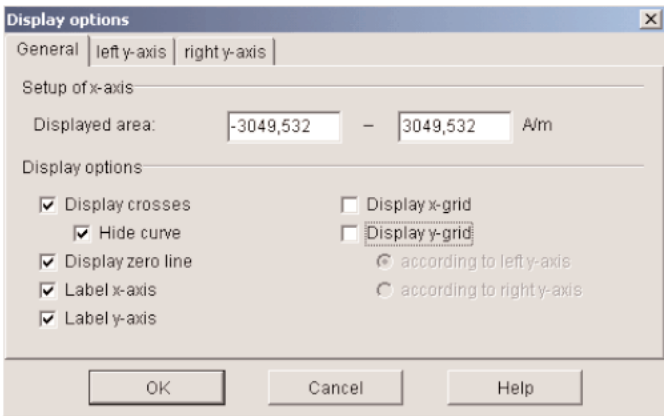


Fig. 5: Channel modification of the x-axis for a solid iron core

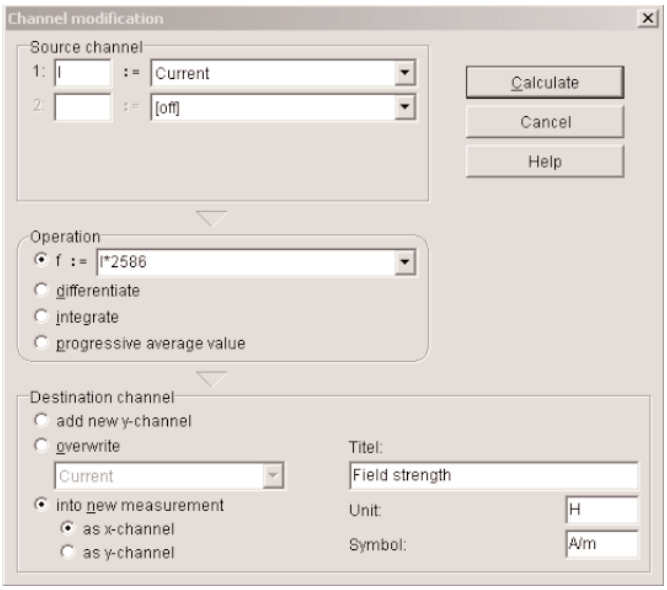


Fig. 6a: Hysteresis for a massive iron core

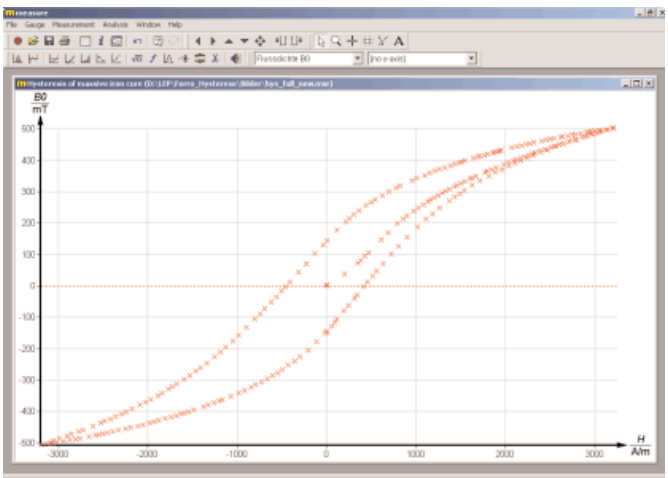
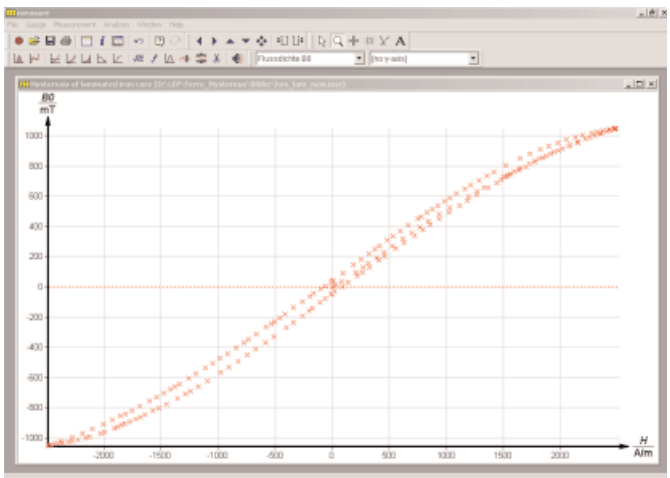


Fig. 6b: Hysteresis of a laminated iron core



Theory and evaluation

Since the Cobra3 interface measures voltages, the current measurement is performed with the aid of a 10 Ω rheostat.

$$I = U/10\ \Omega$$

Furthermore, the field strength is calculated with the formula

$$H = I \cdot n/L$$

where H = field strength
n = number of turns in the coil (600 turns)
L = average field line lengh in the core.
(solid core: L = 232 mm
laminated core: L = 244 mm)

The factor n/L changes due to the different dimensions of the two iron cores as follows:

Solid iron core: n/L = 2586 in 1/m
Laminated iron core: n/L = 2459 in 1/m

The calculation of the field strength can be combined with a change of the x-axis in the visualization.

Therefore, choose ”channel modification” and set the parameters according to Fig. 5.
The factor in the mathematical ”Operation” depends on the used iron core and is equal to n/L.

Now, the coercive field strength and the remanence can be extracted from the hysteresis. Therefore, use the ”zoom” function in the region of the intersection of the axes and then choose ”survey” to obtain the points of intersection of the x- and y-axis with aid of the cursor lines, which can be freely moved and shifted.
A comparison of Figs. 6a and 6b shows that the remanence and coercive field strength are substantially greater in a solid iron core than in a laminated one.

Typical values for this experimental set-up are:

iron core:	massive	laminated
coercive field strength:	436 A/m	80 A/m
remanence:	143 mT	41 mT