1. Experimental Contents

1) Measure magnetic induction intensity of residual magnetism in sample with Teslameter; acquire the relationship between magnetic induction intensity B and position X of the sample; and determine the range of uniform magnetic field in X direction.
2) Learn to demagnetize a magnetic sample and measure the initial magnetization curve.
3) At magnetic saturation, conduct magnetic exercise to the sample, and measure magnetic hysteresis loop.
4) Learn to apply Ampere's circuit law in magnetic measurement.

2. Experimental Details

A connection schematic of the experimental setup is shown in Figure 4.

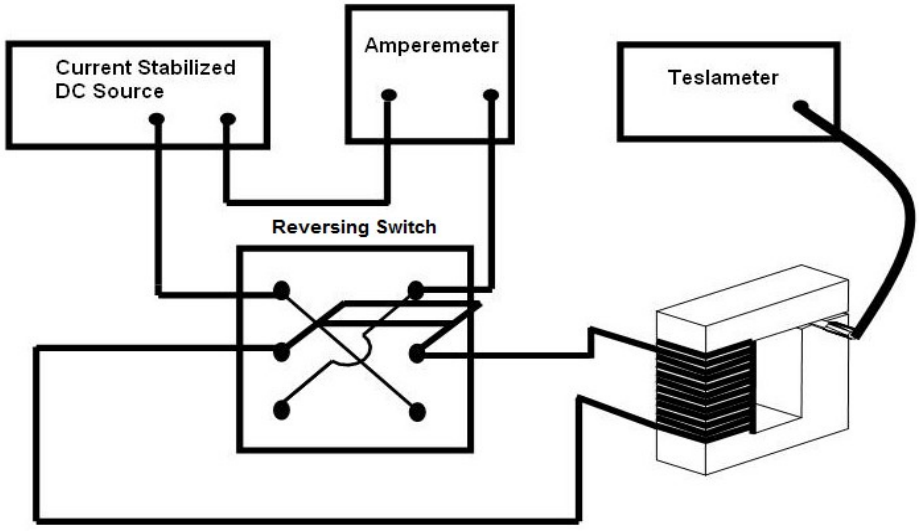

Figure 4 Connection schematic of the experimental setup

A. Measure magnetic induction intensity B versus position X

1) Measure magnetic induction intensity B of the residual magnetism in a sample along X direction using a Teslameter; record data in the table below:

X (mm)	B (mT)	X (mm)	B (mT)	X (mm)	B (mT)	X (mm)	B (mT)
-10.0	158.5	-4.0	161.6	1.0	161.8	6.0	161.6
-9.0	161.3	-3.0	161.7	2.0	161.9	7.0	161.6

-8.0	161.7	-2.0	161.4	3.0	161.9	8.0	162.7
-7.0	161.8	-1.0	161.5	4.0	161.9	9.0	109.3
-6.0	161.6	0.0	161.7	5.0	161.6	10.0	69.9

* Data in this table are for reference purpose only. If the residual magnetism is too low to be measured, a proper magnetization current (e.g. 150 mA) can be applied to the magnet to create a magnetic field for this measurement.

2) Acquire the relationship between magnetic induction intensity B and position X of the sample by plotting X-B graph;
3) Determine the range of uniform magnetic field in X direction.

B. Measure initial magnetization curve

1) Prior to the measurement, the sample needs to be demagnetized as follows: reverse the magnetization current I_m continuously while gradually reducing current from maximum to zero. Eventually, the magnetic induction intensity B of the residual magnetism in the sample will be minimized (ideally to zero). A step-by-step process is as below:

   a) Increase the magnetization current from 0 to 600 mA;
   b) Reduce current from 600 mA to 0;
   c) Reverse the toggle switch to reverse the current;
   d) Increase the magnetization current from 0 to 500 mA;
   e) Reduce current from 500 mA to 0;
   f) Reverse the toggle switch again to reverse the current;
   g) Repeat steps a) to f), but reduce the current by a step size of 100 mA for each cycle.

   When the residual magnetic field is less than 100 mT, use a smaller step size for current reduction and repeat steps a) to f) until the residual magnetic field is less than 2 mT. A schematic of the demagnetization process is shown in Figure 5.

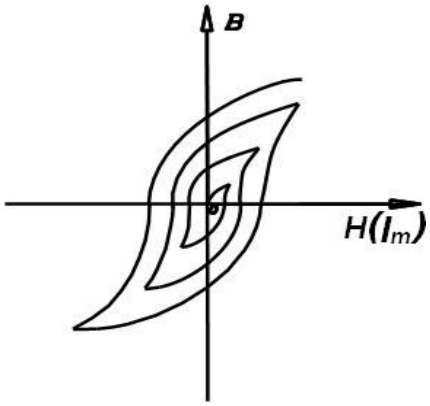

Figure 5 Schematic of demagnetization process

2) Measure initial magnetization curve (*B*-*H* relationship)

a) Increase magnetization current starting from 0 mA gradually,

b) Record corresponding magnetic induction intensity *B* at each current value,

c) Increase current till *B* reaches saturation.

d) Plot I_m-*B* curve. Since I_m is proportional to *H*, I_m-*B* curve is also *H*-*B* curve, i.e the initial magnetization curve.

C. Measure the saturated hysteresis loop of die steel sample

1) First, conduct magnetic exercise to the die steel sample as follows:

a) Based on the initial magnetization curve, set magnetization current at saturation I_m.

b) Keep I_m unchanged while reversing the toggle switch back and forth 50-100 times.

2) Measure the hysteresis loop of die steel

a) Reduce the magnetization current from saturation current I_m to 0 gradually at a step size of 50 mA while recording magnetic induction intensity B_m at each current value.

b) Reverse the toggle switch.

c) Increase magnetization current from 0 to $-I_m$ gradually at a step size of 50 mA while recording magnetic induction intensity B_m at each current value.

d) Repeat steps a) to c), i.e. $(H_m, B_m) \rightarrow (-H_m, -B_m)$, and then $-(H_m, -B_m) \rightarrow (H_m, B_m)$ while recording all data pairs as (I_i, B_i).

e) Calculate H_i using Eq. (1), and get corresponding data pairs (H_i, B_i).

f) Plot *H*-*B* curve using the data pairs (H_i, B_i). This is the hysteresis loop.

g) Find the saturation magnetic field intensity H_m and coercivity H_c of the sample.

h) Measure the average magnetic path length $\bar{\ell}$ and gap width l_g of the sample.

i) Correct H_c and H_m using Eq. (5) to get more accurate results.

D. Measure hysteresis loop and initial magnetization curve of #45 steel sample

Follow the same procedures for die steel sample as described above.

3. Examples of Data Recording and Processing

Note: The following data are for reference only, not the criteria for apparatus performance:

As shown in Figure 6, the parameters of die steel sample are as follows：

a=10.00 cm; b=6.00 cm; c=d=2.00 cm; $\bar{\ell}$=10.00×2+6.00×2-2.00×4-0.20=23.8 cm; ℓ_g=0.20 cm;

$\bar{\ell}$ is the average path length; ℓ_g is the gap width.

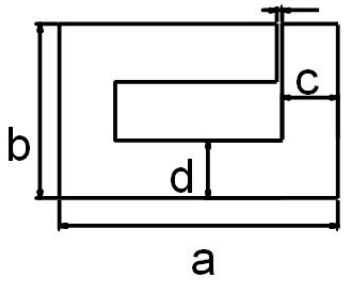

Figure 6 Drawing of die steel sample

Table 1 Initial magnetization curve *B*-*H* and hysteresis loop of die steel sample

I (mA)	*B* (mT)	*H* (A/m)
0	0	0
50.0	12.5	337
100.3	31.2	634
150.0	60.2	858
200.3	89.9	1082
250.0	123.0	1278
300.3	157.4	1471
350.0	188.4	1681
400.2	218.2	1904

450.0	245.7	2138
500.0	271.3	2387
550.0	294.5	2652
600.1	314.0	2943
624.8	324.0	3084
600.0	320.5	2899
549.9	313.6	2524
499.8	306.4	2151
450.2	296.1	1803
399.9	284.2	1460
350.1	269.9	1137
300.2	251.8	839
250.0	229.2	568
199.7	202.4	325
150.3	173.4	103
100.0	142.2	-111
50.2	110.1	-314
0	76.6	-512
-50.8	42.2	-709
-100.9	8.5	-905
-150.2	-25.4	-1092
-200.6	-60.7	-1280
-250.1	-97.8	-1448
-300.1	-137.7	-1601
-350.5	-173.4	-1786
-400.2	-202.7	-2008
-450.2	-232.4	-2229
-500.3	-261.6	-2455
-550.0	-288.0	-2696
-600.0	-314.0	-2942
-625.5	-324.2	-3088
-600.0	-320.9	-2896
-550.1	-313.8	-2524

-499.9	-305.8	-2156
-450.0	-296.2	-1801
-399.9	-283.5	-1465
-350.0	-268.7	-1144
-300.3	-250.4	-849
-250.2	-227.5	-581
-199.9	-200.3	-340
-150.1	-170.7	-120
-100.1	-139.3	90
-49.7	-106.3	293
0	-72.6	485
50.4	-38.0	678
100.5	-3.6	869
150.3	30.3	1060
200.1	64.7	1249
250.1	101.9	1420
300.1	134.5	1622
350.3	167.8	1822
400.3	198.1	2039
450.3	231.7	2235
500.0	259.6	2466
550.0	287.1	2702
600.2	312.3	2955
626.0	324.4	3091

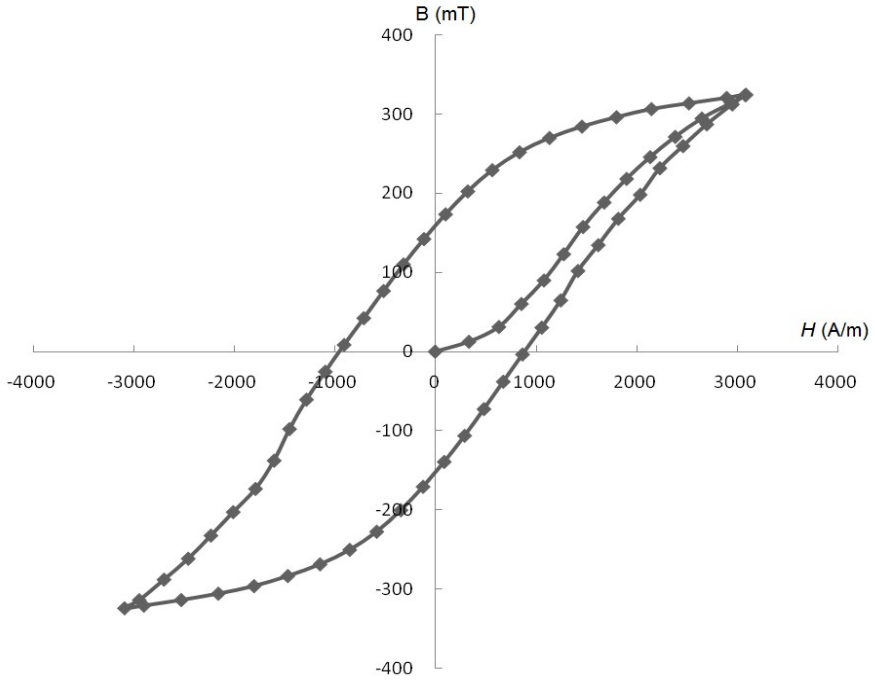

Figure 7 Saturated hysteresis loop and initial magnetization curve of sample die steel