Hyteresis loop

หนังสืออ้างอิงสำหรับเขียนทฤษฎีและเพื่อค้นคว้าทั่วไป

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HYSTERESIS MAGNETOMETER

The apparatus is designed for the examination of rod specimens. The length of the specimen should be very great compared with its diameter in order to reduce the self-demagnetising effect to a minimum. Four specimens, 33 cm long and 1 to 1.5 mm diam., are supplied with the apparatus, intended to demonstrate the widely differing behaviour of important ferromagnetic materials, The specimens are identified as follows: soft iron, steel, Mumetal, nickel,

In this apparatus a small error in locating the lower pole causes such a small difference in the magnetometer reading that a knowledge of the exact position of the pole is unnecessary. If desired, the pole can be placed exactly in the plane of the magnetometer needle by moving the specimen vertically until maximum deflection for a given magnetising force is obtained.

Theory

If a long magnet PQ, Fig. 1, of pole strength *m*, be placed vertically, and the field, due mainly to the lower pole, at a magnetometer M be perpendicular to the horizontal component H_0 of the earth's field, then we have for the resultant

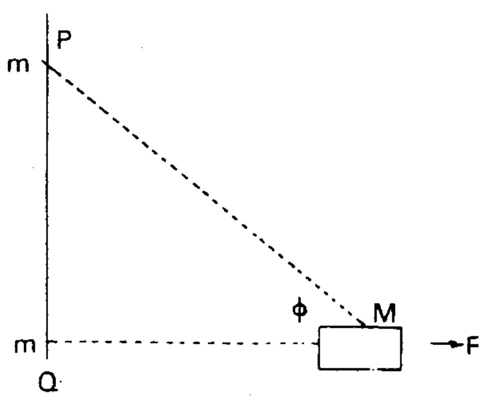
$$F = \frac{m}{(QM)^2} - \frac{m}{(PM)^2} \cos\varphi$$

$$= \frac{m}{(QM)^2} - \frac{m}{(PM)^2}\left(\frac{QM}{PM}\right)$$

$$= \frac{m}{(QM)^2}\left[1 - \left(\frac{QM}{PM}\right)^3\right]$$

if θ be the magnetometer deflecton, then

$$\tan\theta = \frac{F}{H_0} = \frac{m}{H_0 (QM)^2}\left[1 - \left(\frac{QM}{PM}\right)^3\right]$$



$$m = \frac{0.18\ (QM)^2}{\left[1 - \left(\frac{QM}{PM}\right)^3\right]} \tan\theta$$

If A be the cross-sectional area of the magnet, the intensity of magnetisation, I, is given by

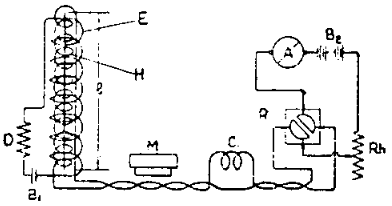
$$I = \frac{m}{A} = \left[\frac{0.18\ (QM)^2}{A\left[1 - \left(\frac{QM}{PM}\right)^3\right]}\right] \tan\theta$$

Since the bracketed term is constant, I may be written as equal to $\alpha \tan\theta$ |

In this experiment, the field H which magnetises the specimen is obtained by passing a current of *i amp* through a solenoid of *n* turns per cm. Then H is equal to

$\left(\frac{4\pi n}{10}\right)$ i which similarly may be written as equal to βi.

The quantities α and β may readily be evaluated, and I and H thus calculated. A curve can then be drawn showing the relationship between I and H. If preferred, tan θ may be plotted against i or B, which equals $(H+4\pi I)$, may be calculated and plotted against H. The general shape of the hysteresis loop is the same in all three cases.



Adjustment of the apparatus

Connect up the apparatus as shown in Fig. 2. R is a reversing switch (L73-250/05) capable also of breaking the circuit. A is an ammeter covering the range 0.2 amp. B_2 is a 6 or 8 volt accumulator; Rh a suitable reheostat (a carbon plate rheostat is convenient as it allows continuous adjustment); B_1 a 2 volt accumulator.

Use twin twisted, flexible wires and arrange that the ammeter is at some distance from the magnetometer, so that its external field shall not affect the magnetometer reading.

(a) **Compensation for the effect at the magnetometer or the horizontal component of the field due to the current flowing in the magnetising solenoid.** Set the instrument with the pointers of the magnetometer needle at zero and directed towards the axis of the solenoid. Pass about 1 amp through H and adjust the distance of the magnetometer from the solenoid to be 7-10 cm. A deflection will probably be observed. Slide the coil C in its guides to annul this deflection. Reversal of the plugs at the base may be necessary.

(b) **Compensation for the magnetising effect on the specimen of the vertical component of the earth's field.** Insert the specimen into the glass tube in the magnetising coil and demagnetise by rapid reversals and, at the sametime, gradual reduction of the current to zero. If M be still deflected, the field due to the current in earth coil is additive to that of the earth's vertical component, instead of being in opposition to it. Reverse the connections to B, therefore, and again demagnetise. If the deflection then decrease but be not reduced to zero, this is due to V being of value other than the 0.42 oersteds which the current in the earth coil E is designed to annul. In this event, replace B_1 by a 4 volt accumulator, and include in series with it the coil D an adjustable rheostat. Complete compensation can then be obtained.

It may be stated, however, that for the present purpose too much attention need not be paid to complete compensation for V. It is sufficient if V be reduced to about 10% of its standard value.

The coil D passes such current from a correctly connected 2 volt source as will, when flowing through H in all but abnormal situations, just neutralise the earth's vertical component.

(c) **Adjustment for the maximum deflection.** Switch on B_2 again, and take the current to the maximum of 2 amp. Should the magnetometer deflection be greater than 60°, move M to bring the maximum deflection between 45° and 60°. Above 60° tangent values are insufficiently accurate.

(d) **Final compensation.** If the magnetometer has been moved in order to adjust the maximum deflection, remove the specimen, and slide the coil C in its guides to annul the deflection, as described in (a). Re-insert the specimen and demagnetise as described in (b). The apparatus is now adjusted and ready for use in carrying out the following experiment.

Experiment

With the whole of the resistance Rh in circuit, switch on the current and bring its value up to 0.1 amp. Note the magnetometer deflection, reading both ends of the pointer and taking the mean, and the increase current to 0.2 amp or other suitable value to give a convenient increase of deflection (say 5°). In making this adjustment the current must not be reduced; e.g., if its value should rise to 0.22 amp, take the magnetometer reading at this value. Do not reduce to 0.20 amp. Proceed in this manner until the deflection remains constant, indicating saturation of the specimen. A current of 2 amp will, in most cases, be sufficient. Larger increments of current may be made as saturation is approached.

Now reduce the current in similar steps to zero, reading the magnetometer at each reduction. At zero current reverse the switch R and proceed to-2 amp giving saturation in the opposite direction. Adjust the current in similar steps from - 2 to 0 amp. Reverse the switch R again and proceed to former saturation. It is important to note that in traversing the cycle the current must not be cut off at any point except at zero.

Specimen Result

The current and magnetometer readings and the evaluation of I and H should be recorded as shown in the table below. The figures relate to a silver steel specimen, data of the dimensions of which, and of the calibration of the constants of the apparatus, are given.

Type of specimen: silver steel. Dimension: 33×0.101, length × mean diam. Magnetometer distance, QM: 8cm. Solenoid: 19 turns per cm.

The magnetic length of the specimen is taken as three-quarters of its actual length.

$$\alpha = \left[\frac{0.18 \times 8^2}{\frac{\pi}{4} \times 0.101^2 \left[1 - \left(\frac{8}{\sqrt{24.75^2 + 8^2}}\right)^3\right]}\right]$$

$$= \left[\frac{0.18 \times 64}{0.008\ (1 - 0.0291)}\right]$$

(The correction term for the effective of the upper pole thus amounts to less than 3%).

$$= 1477.$$

$$\therefore\ I = 147 \tan\theta$$

$$\beta = \left(\frac{4\pi \times 19}{10}\right) = 23.9$$

$$\therefore\ H = 23.9i.$$

Amp	Mean θ	Tan (Mean θ)	I lines/cm^2	H oersteds
0.0	0.0	0.000	0	0.0
0.1	0.7	0.012	18	2.4
0.2	1.4	0.024	35	4.8
0.3	5.4	0.095	140	7.2
0.4	12.6	0.224	331	9.6
0.5	19.4	0.352	520	12.0
0.6	25.1	0.468	692	14.3
0.7	30.5	0.589	870	16.7
0.8	33.2	0.654	966	19.1
0.9	36.3	0.735	1085	21.5
1.0	38.3	0.790	1166	23.9
1.2	41.1	0.872	1283	28.7
1.4	43.4	0.946	1396	33.5
1.6	44.3	0.976	1442	38.2
1.8	45.7	1.025	1514	43.0
2.0	46.5	1.054	1556	47.8
1.6	46.0	1.036	1530	38.2
1.4	45.8	1.028	1518	33.5
1.2	45.0	1.000	1477	28.7
1.0	44.3	0.976	1442	23.9
0.8	43.8	0.959	1415	19.1
0.6	43.8	0.933	1378	14.3
0.4	41.8	0.894	1320	9.6
0.2	40.0	0.839	1238	4.8
0.0	36.0	0.727	1074	0.0
−0.2	28.6	0.545	805	− 4.8
−0.3	20.6	0.378	555	− 7.2
−0.4	1.0	0.018	27	− 9.6
−0.5	−12.3	−0.218	− 322	−12.0
−0.6	−20.4	−0.372	− 549	−14.3
−0.7	−27.6	−0.523	− 773	−16.7
−0.8	−32.3	−0.632	− 934	−19.1
−0.9	−35.5	−0.713	−1053	−21.5
−1.0	−38.4	−0.793	−1170	−23.9
−1.4	−45.0	−1.000	−1477	−33.5
−1.8	−48.0	−1.111	−1641	−43.0
−2.0	−49.0	−1.150	−1698	−47.8
−1.8	−48.3	−1.122	−1657	−43.0
−1.6	−47.5	−1.091	−1612	−38.2
−1.4	−47.3	−1.084	−1600	−33.5
−1.2	−47.0	−1.072	−1584	−28.7
−1.0	−46.3	−1.046	−1544	−23.9
−0.8	−45.8	−1.028	−1518	−19.1
−0.6	−44.5	−0.983	−1452	−14.3
−0.4	−43.0	−0.933	−1378	− 9.6
−0.2	−40.7	−0.860	−1270	− 4.8
0.0	−36.2	−0.732	−1081	0.0
0.1	−33.2	−0.654	− 966	2.4
0.2	−29.1	−0.557	− 823	4.8
0.3	−22.9	−0.422	− 624	7.2
0.4	− 2.1	−0.037	− 55	9.6
0.5	12.8	0.227	335	12.0
0.6	20.7	0.378	558	14.3
0.7	26.6	0.501	740	16.7
0.8	31.0	0.601	888	19.1

continued . . .

continuation:

0.9	34.5	0.687	1014	21.5
1.0	37.3	0.762	1125	23.9
1.2	40.0	0.839	1238	28.7
1.4	42.5	0.916	1353	33.5
1.6	44.3	0.976	1440	38.2
1.8	45.4	1.014	1498	43.0
2.0	46.5	1.054	1556	47.8

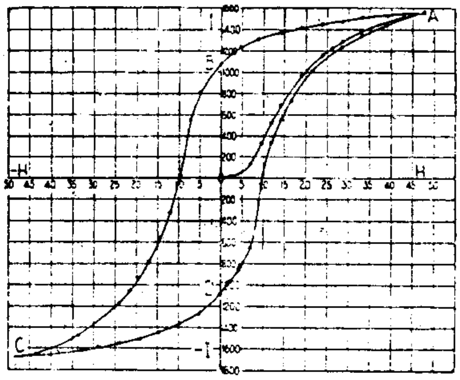


Fig.3. I-H curve

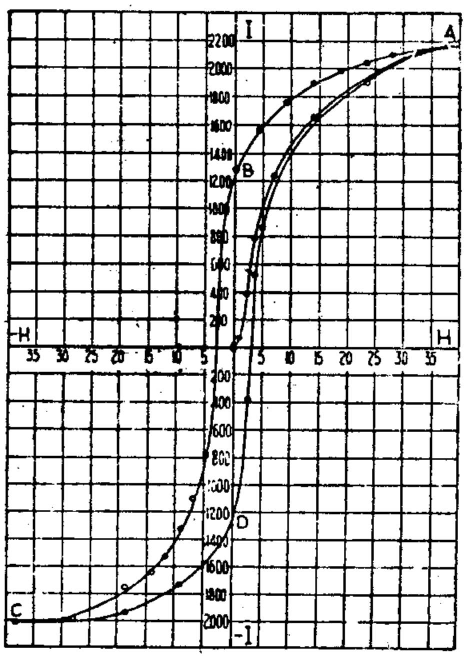


Fig.4 I-H curve

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