on meters.

Magnetic Measurements: Measurement of flux and permeability - flux meter - hall effect Gaussmeter - BH curve and permeability measurement - hysteresis measurement- ballistic galvanometer – principle- determination of BH curve - hysteresis loop. Lloyd Fisher square — measurement of iron losses

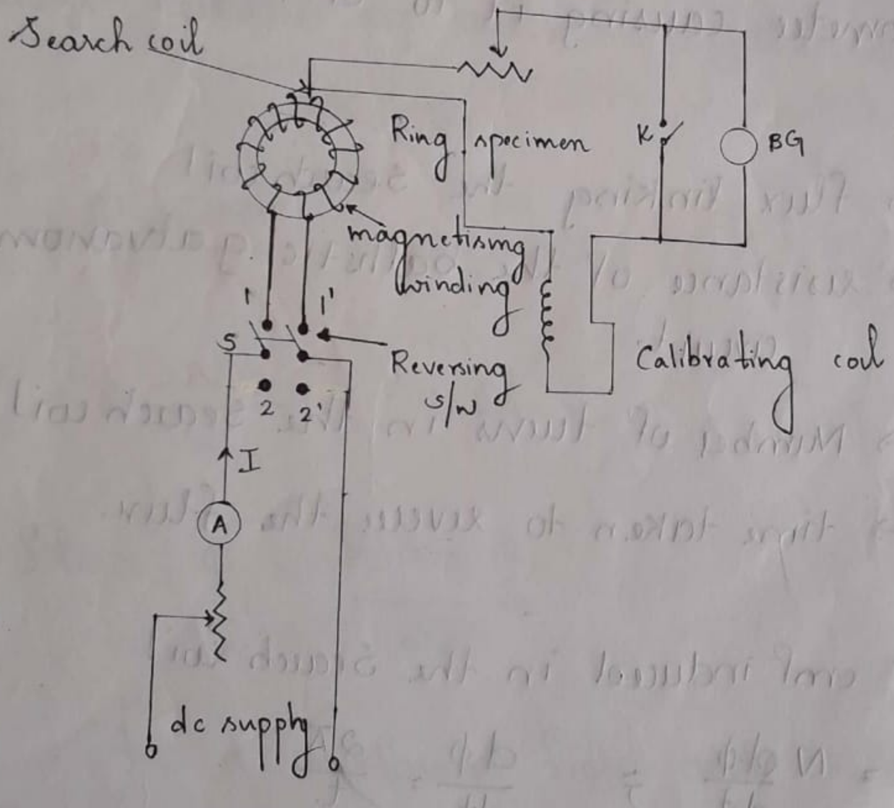
Measurement of rotational speed using proximity sensors and optical sensors.

SECOND INTERNAL EXAMINATION

1,2,7,8,12,21,23,31,32

Determination of flux Density / flux.

The measurement of flux density inside a specimen can be done by winding a Search coil over the specimen. This search coil is known as a "B coil". This Search coil is then connected to a ballistic galvanometer or to a fluxmeter.



The ring specimen is wound with a magnetizing winding which carries a current I. A search coil of convenient number of turns is wound on the specimen and connected through a resistance and calibrating coil, to a ballistic galvanometer as shown in figure.

The current through the magnetizing coil is reversed and therefore the flux linkages of the search coil change inducing an emf in it. This emf sends a current through the ballistic galvanometer causing it to deflect.

Let

$\phi \rightarrow$ flux linking the search coil

$R \rightarrow$ resistance of the ballistic galvanometer circuit.

$N \rightarrow$ Number of turns in the search coil

$t \rightarrow$ time taken to reverse the flux.

Average emf induced in the search coil

$$e = N\frac{d\phi}{dt} \quad ; \quad \frac{d\phi}{dt} = \frac{2\phi}{t}$$

$$e = \frac{N \cdot 2\phi}{t}$$

Average current through the ballistic galvanometer is

$$i = \frac{2N\phi}{Rt}$$

charge passing is

$$Q = it = \frac{2N\phi}{R}$$

Let θ_1 be the throw of galvanometer and K_q be the constant of galvanometer expressed in coulomb per unit deflection.

charge indicated by ballistic galvanometer.

$$= K_q \theta_1$$

$$Q = \frac{2N\phi}{R}$$

$$\frac{2N\phi}{R} = K_q \theta_1$$

flux $\phi = \dfrac{R K_q \theta_1}{2N}$

In a uniform field and with search coil turns at right angles to the flux density vector we have flux density

$$B = \frac{\text{flux}}{\text{area}} = \frac{\phi}{A_s} = \frac{R K_q \theta_1}{2 N A_s}.$$

$A_s \Rightarrow$ cross-sectional area of specimen.

Correction for air flux.

The search coil is usually of larger area than the specimen and thus the flux linking with the search coil is the sum of the flux existing in the specimen and the flux which is present in the air space between the specimen and search coil

Value of flux = {true value of flux in the specimen} + {flux in the air space between specimen & search coil}

$$B' A_s = BA_s + \mu_0 H (A_c - A_s)$$

$$B = B' - \mu_0 H \left[\frac{A_c}{A_s} - 1\right]$$

$B' \rightarrow$ observed [or apparent] value of flux density wb/m²

$B \rightarrow$ true value of flux density in specimen wb/m²

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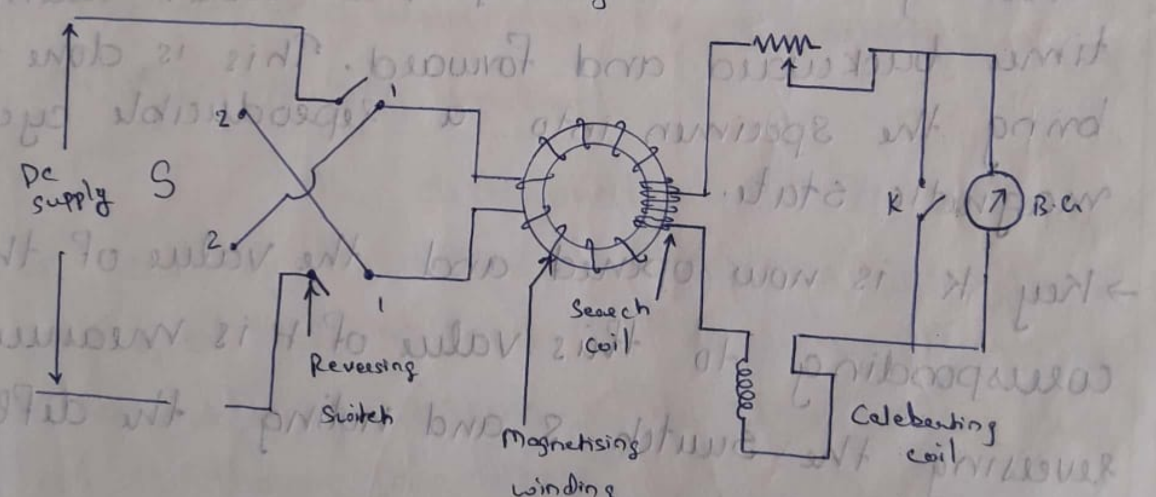
Determination of B-H curve

There are two methods by which B-H curve can be obtained for the magnetic materia specimen.

(i) Method of Reversal
(ii) Step by step method.

(I) Method of Reversal.

K - Key
A - Ammeter.
B.G - Ballistic galvanometer



For the determination of B-H curve of a ring shaped specimen whose dimension are s

A layer of thin tape is put on the ~~Search coil ring~~ ring and search coil insulated by paraffined wax is wound over the tape. Another layer of tape is put over the search coil and the magnetizing winding is wound over this tape. The test circuit is shown in fig.

Procedure

- First of all the specimen is demagnetised and then the magnetising current I is set to its lowest value.
- The Ballistic galvanometer key 'k' is closed and reversing switch 'S' is operated about twenty times backward and forward. This is done to bring the specimen into a reproducible cyclic magnetic state.
- Key K is now opened and the value of the flux corresponding to this value of H is measured by reversing the switch S and noting the deflection of galvanometer.
- The change in flux, measured by the galvanometer when the switch S is quickly revered will be twice the flux in the specimen corresponding to the value of H is applied. Thus value of H can be obtained as

$$H = \frac{NI}{l}$$

where

N → Number of turns on the magnetising ring.

I_1 → corresponding magnetising current.

l → Mean circumference length of specimen in m

→ while the flux density B is obtained by dividing the flux measured by the area of cross-section of specimen

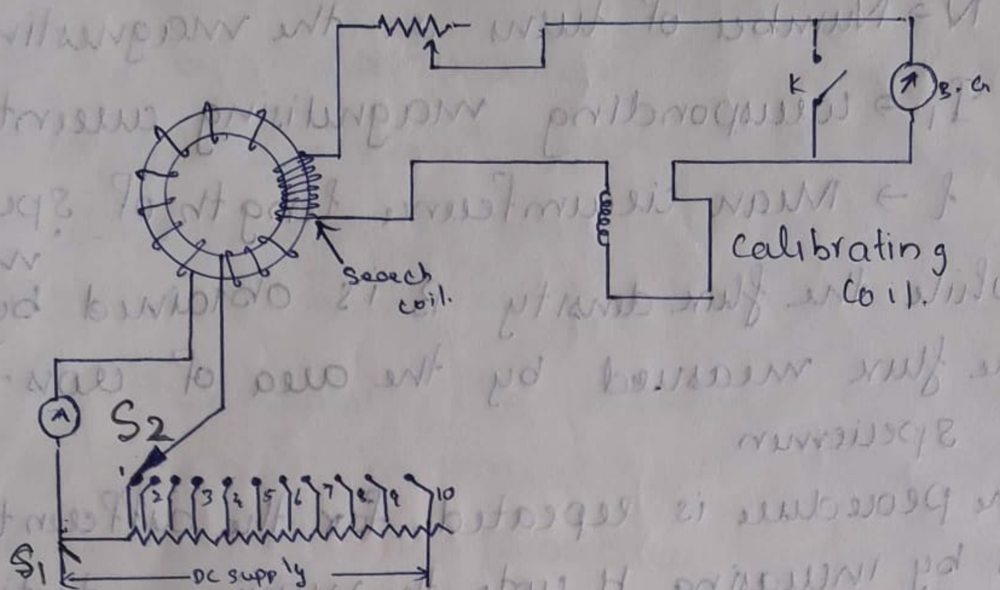
→ The procedure is repeated for the different value of H by increasing H upto the maximum testing point value. The graph of B against H gives the required B-H curve for the specimen.

(ii) Step by step method

The determination of BH curve can also be used by the step-by-step method. The special feature of this method is that there is no reversal of magnetising current. The circuit for this test is shown in figure.

The magnetising current is supplied through a potential divider. potential divider has several tapping points the resistances being chosen that the value of the magnetising current and the magnetising force H is increased or decreased th

a



Procedure.

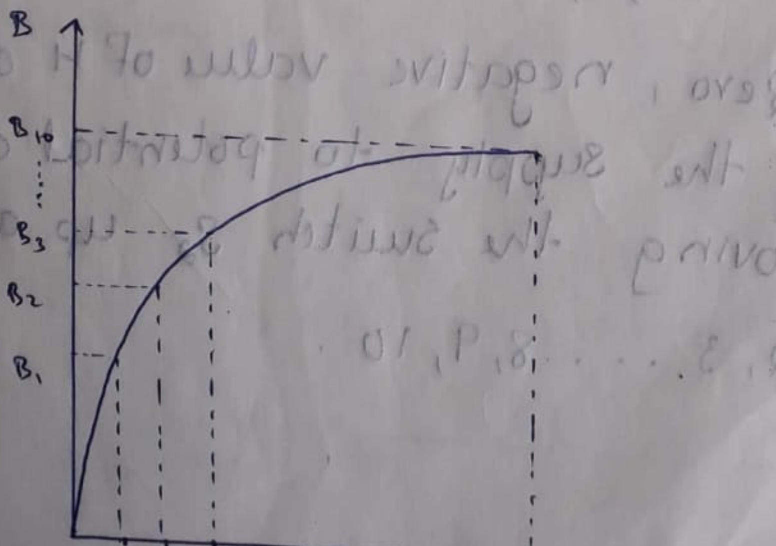
→ This specimen is completely demagnetised before starting the test.

→ The switch S_1 is closed with switch S_2 at tapping 1. The switch will be some change in the flux. Due to this there will be increase in the flux density hence from 0 to B_1.

→ This value can be obtained by obtained by observing the deflection of the ballastic galvanometer. The value of the corresponding magnetising force H_1 may be calculated from the value of current flowing in the magnetising winding at tapping 1.

⇒ The magnetising force is then increased suddenly to H_2 by instantaneously changing the position of switch S_2 from tapping 1 to tapping 2 and the corresponding increase in flux density determined from the galvanometer. ~~throw~~

⇒ The flux density B_2 correspond to magnetising force H_2 will be equal to B_1 plus increased. flux density. The procedure is repeated for various tapping till maximum value of H is achieved. The graph of B against H is then. plotted which is nothing but the B-H curve for the specimen under test. This is shown in figure below.



H

Determination of Hysterisis loop

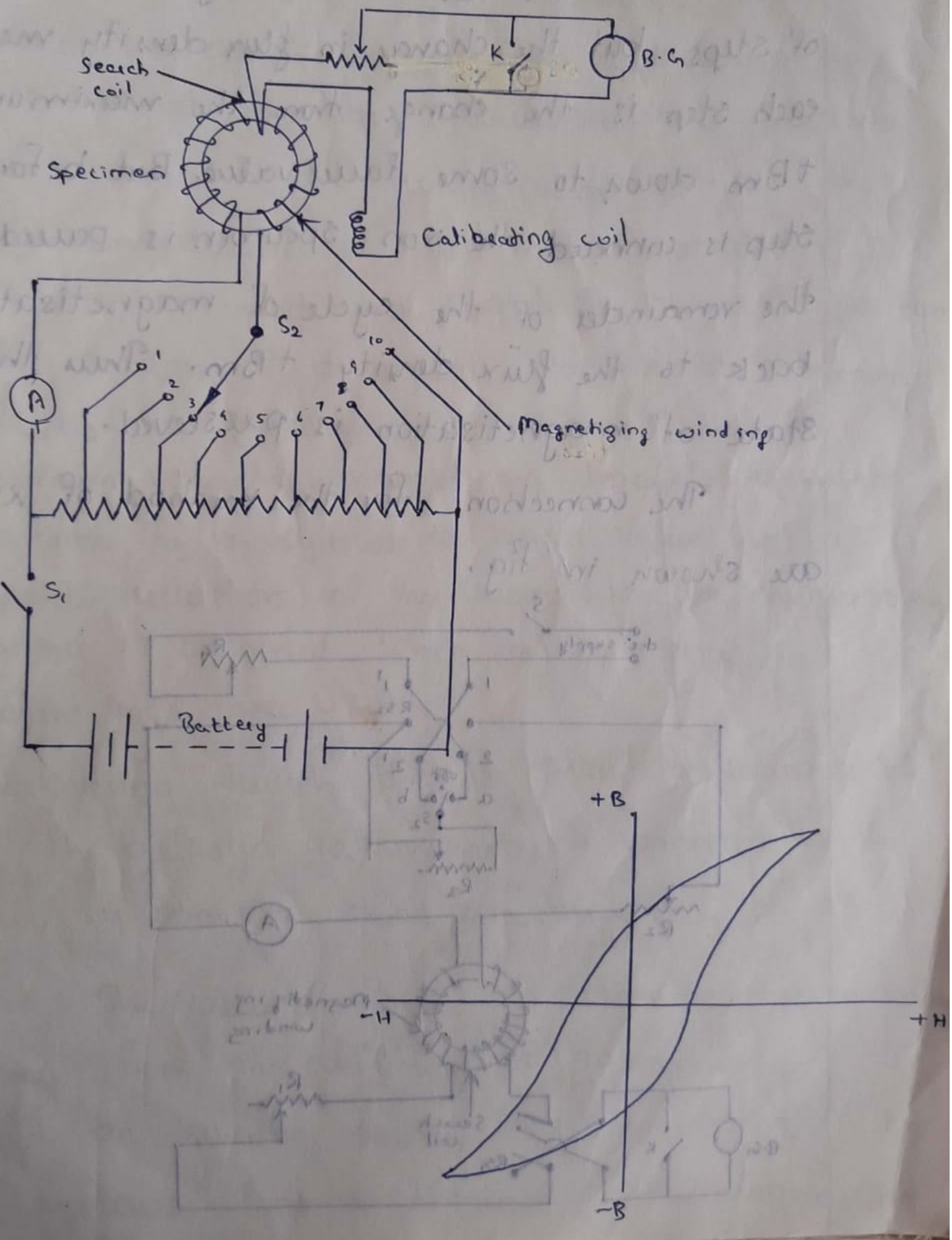
There are two methods for determination of hysterisis loop of a magnetic material specimen

(i) step-by-step method
(ii) Method of reversal.

(i) step-by-step method

The determination of Hysteresis loop this method is done by simply contin the determination of B-H curve.

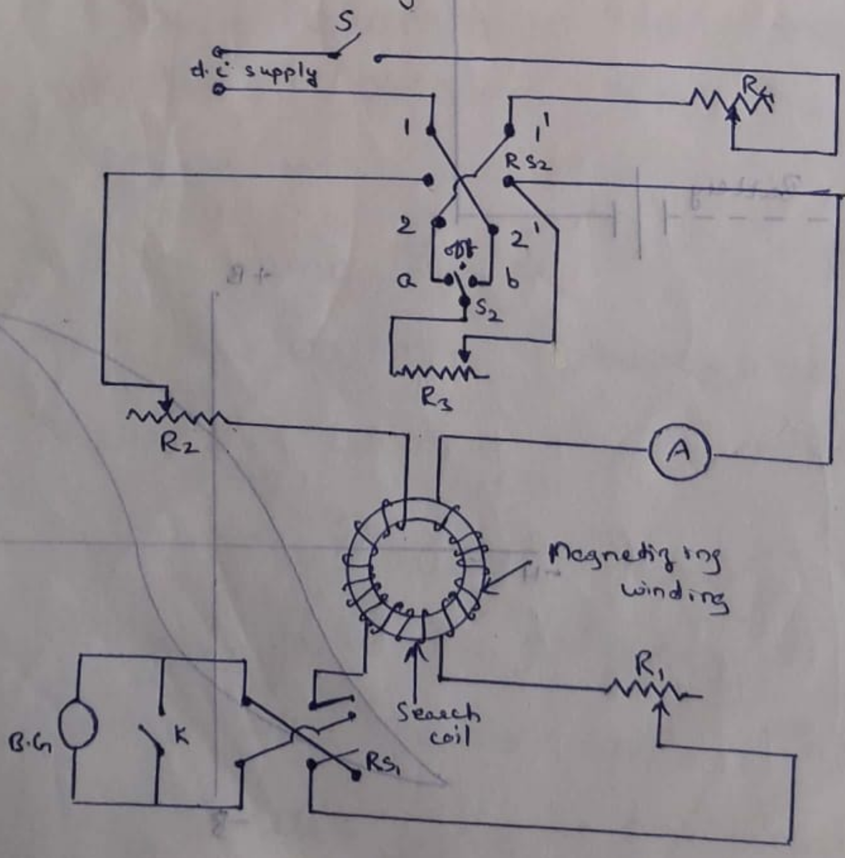
After reaching the point of maximum H ie, when switch S_2 is at tapping 10, the magnetising current is next reduced, in step to zero by moving switch S_2 down through the tapping point 9, 8, 7, . . . , 3, 2, 1. After reduction of magnetising force to zero, negative value of H are obtained by reversing the supply to potential divider and then moving the switch S_2 up again in order 1, 2, 3 . . . 8, 9, 10.


Search coil
K
B.G
Specimen
Calibrating coil
S2
1
2
3
4
5
6
7
8
9
10
A
Magnetizing winding
S1
Battery
+B
-H
+H
-B

(ii) Method of Reversal.

This test is done by means of a number of steps, but the change in flux density measured at each step is the change from the maximum value $+B_m$ down to some lower value. But befor the next step is conneced the iron specimen is passed through the remainder of the cycle of magnetisation back to the flux density $+B_m$. Thus the cyclic state of magnetisation is preseeved.

The connection for the method of reversals are shown in fig.



Procedure

→ The value of magnetising force H_{max} required to produce flux density B_{max} to be used during the test is obtained from the B-H curve of the specimen

→ The resistance R_2 & R_1 are adjusted so that the magnetising current is such that this value of H (ie H_m) is obtained when switch S_2 is in off position

→ The resistance R_1 is adjusted so that a convenient deflection of galvanometer is obtained when the maximum value of magnetising force is reversed.

→ Resistance R_3 is adjusted to such a value that a suitable reduction of the current in the magnetising winding is obtained when the resistance is brought into the circuit.

→ The reversing switch RS_2 is placed on contacts 1,1' and the ballistic galvanometer is connected to the circuit by opening short circuiting key K.

The value of B_{max} is determined corresponding to H_{max} from the deflection of galvanometer obseved on reversing switch RS_2 and point A' on the hysteresis loop is obtained the magnetising winding and galvanometer circuit. R_3 is a Variable shunting resistance, which is connected across the magnetising winding by means of switch thus reducing the magnetising current from its maximum value down to any desired value depending upon the value of R_4.

Now switch S_2 is quickly thrown over from off position to contact b, thus shunting the magnetising winding with resistance R_3.

~~The~~ The magnetising force is thus reduced to H_c'. The corresponding reduction is the value of flux density ΔB can be known from the galvanometer deflection and thus point c' is located on the hysteresis loop.

The galvanometer is then short circuited by closing key K and reversing switch RS_2 is reversed to 2, 2'. Switch S_2 is then opened and switch RS_2 moved back again to contact 1, 1'

This procedure passes the specimen through the cycle of magnetisation and back to point A.

The specimen is now reddy for the next step in the test. The part AD of the loop is obtained by adjusting the shunting resistance R_3 to give different reduced values of H and determining corresponding reduction in B.

To obtain part DEF of the loop switch RS_2 is paled on contact 1, 1' with K is closed and S_2 is off position. Now place switch S_2 on 'a' contact open the key K and rapidly revese RS_2 to contact 2, 2'.

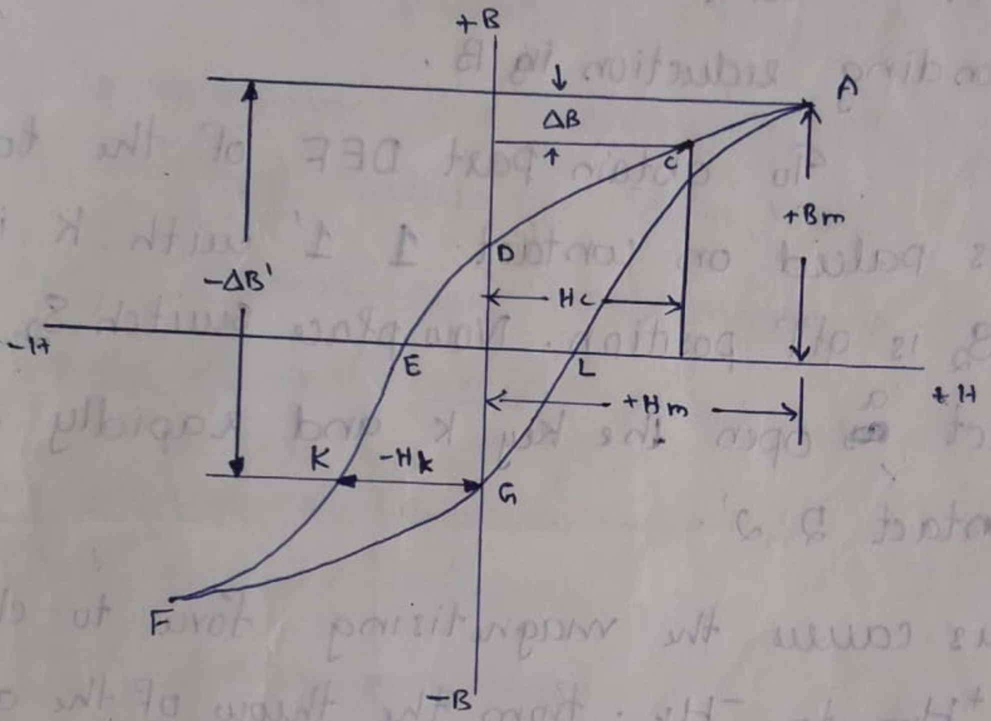
This causes the magnetising force to change from $+H_m$ to $-H_k$. from the throw of the galvanometer change in flux density $\Delta B'$ can be calculated.

Thus point K on the hysteresis loop can be located. The magnetisation of specimen is brought back to point A by reversing switch RS_2 on to contact 1, 1' with key K closed.

By continuing this procedure, other points on part DEF of the hysteresis loop are obtained. Thus part ADEF of the loop can be traced.

Scanned by CamScanner

The part FGLA of the loop may be obtained by drawing in the reverse of part ADEF as the two halves are idential.



Hystesis loop

2.
copy.

(15)

Measurement of Iron losses.

The AC magnetic testing is carried out for the following purpose.

(i) To determine the iron losses in magnetic material at different values of flux density and frequency.
(ii) To seperate two components of iron losses ie, eddy current losses and hysteris loses.

The following methods are need to measure iron losses in ferromagnetic materials.

(i) Wattmeter method
(ii) Bridge method
(iii) Potentiometer method

(i) Wattmeter method

This method is most commonly used for measurement of iron loss in strip (sheet) material. The strip material to be tested is assembled as a closed magnetic circuit in the form of a square. Therefore this arrangement is known as a magnetic square

There are two common forms of these magnetic square
(i) Epstein square
(ii) Lloyd - Fisher Square

Lloyd - Fisher Square.

This is the most commonly used magnetic square and therefore it is described in greater details. The strips used are usually 0.25m long and 50 to 60mm wide. These strips are built up into four stacks. Each stack is made up of two types of strips one cuts in the direction of rolling and the other cut perpendicular to the direction of rolling.

The stacks or strips are placed inside four similar magnetising coils of large cross-sectional area. These four coils are connected in series to form the primary winding.

Each magnetising coil has two similar single layer coils underneath it. They are called secondary coils.

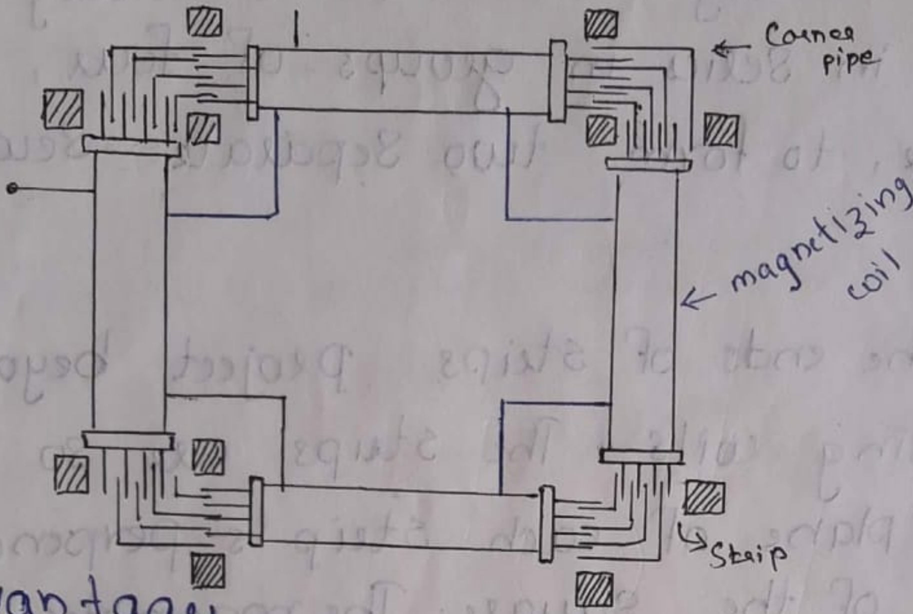
Thus in a magnetic square there are eight Secondary coils. These secondary coils are connected in series in groups of four, one from each core, to form two separate secondary winding

The ends of strips project beyond the magnetising coils. The strips are so arranged that the plane of each strip is perpendicular to the plane of the square. The magnetic circuit is completed by bringing the four stacks together in the form of a square and joining them at the corners.

The corner joints are made by a set of standard right angled corner piece as shown in fig

The corner pieces are of the same material as strips or at least a material having the same magnetic properties. There is an overlapping of corner piece and strips at the corners due to which cross-section of iron is doubled at the corners.

The measured loss has to be corrected for the loss in the corner pieces.



Advantages

(i) This square gives rather more reliable results than Epstin square, in case allowance for corner pieces is known with adequate accuracy.

(ii) The use of corner pieces in this type of square makes it superior for testing anistropic materials.

Set up for the test.

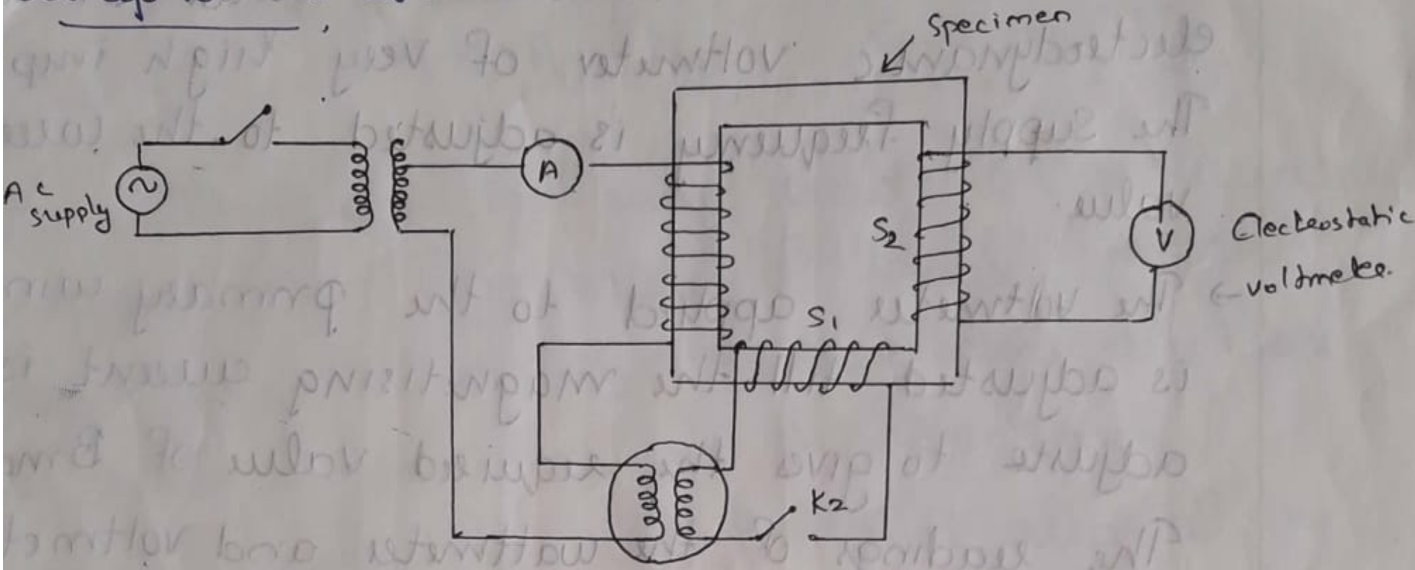


Figure shows the connection diagram for finding the total iron loss by wattmeter method.

→ The test specimen is weighted before assembly and its cross - sectional area is determined.

→ The primary winding is connected the current coil of the wattmeter. The pressure coil of the wattmeter is connected to the one of the secondary windings.

→ The test specimen has two secondary winding S_1 and S_2. S_1 is connected to the ~~prim~~ pressure coil of the wattmeter through switch K_2.

→ S_2 is to an electrostatic voltmeter or an electrodynamic voltmeter of very high impedance. The supply frequency is adjusted to the correct value.

→ The voltmeter applied to the primary winding is adjusted till the magnetising current is adjuste to gives the required value of Bmax. The readings of the wattmeter and voltmeter are observed.

Theory

The electrostatic voltmeter connected across secondary winding S_2 measures the rms value of induced voltage.

The value of induced voltage is

$$E = 4 K_f \phi_m f N_2.$$
$$= 4 K_f B_{max} A_s f N_2 = 4.44 B_{max} A_s f N_2.$$

where

ϕ_{max} → Maximum value of flux ; wb

B_{max} → Maximum flux density ; wb/m²

K_f → form factor [1.11 for sinusoidal wave]

A_s → Cross-section of specimen ; m²

f → frequency ; Hz

N_2 → Numbers of turns on the secondary winding.

$$\therefore B_{max} = \frac{E}{4 K_f A_s f N_2} = \frac{E}{4.44 A_s f N_2}$$

The expression may need to be corrected, especially is high values of B_{max}, for the fact that the coil S_2 encloses some air flux as well as the flux in the specimen / Sample, since the cross-sectional area of the coil must be greater than that of specimen itself.

Let

$A_c \rightarrow$ Cross-sectional area of coil

$A_s \rightarrow$ Cross-sectional area of specimen.

$H_{max} \rightarrow$ Maximum magnetising force.

$B_{max} \rightarrow$ Actual maximum flux density in the specimen.

Total flux within the coil is

$$B_{max} A_s = B'_{max} \cdot A_s + \mu_0 H_{max} [A_c - A_s]$$

$$B_{max} = B'_{max} - \mu_0 H_{max} \left[\frac{A_c}{A_s} - 1\right]$$

16

Power loss in iron :-

$P_i \rightarrow$ Total iron loss, W

$P \rightarrow$ wattmeter reading, W

$V \rightarrow$ Voltage applied to wattmeter voltage coil.

$E \rightarrow$ Voltage reading

$r_p \rightarrow$ resistance of wattmeter pressure coil, Ω

$r_c \rightarrow$ resistance of coil S_1, Ω

$I_p \rightarrow$ current in the pressure coil circuit, A.

then

$$E = I_p(r_p + r_c)$$

$$V = I_p r_p$$

$$P_i = P \cdot \frac{E}{V}$$

$$= P\left[\frac{I_p(r_p+r_c)}{I_p r_p}\right]$$

$$= P\left[\frac{r_p+r_c}{r_p}\right]$$

$$= P\left[1 + \frac{r_c}{r_p}\right]$$

~~The copper losses in r_p and r_c are =~~ $I^2 r = I_p^2(r_p+r_c)$

$$I_p^2[r_p+r_c] = \left[\frac{E}{r_p+r_c}\right]^2(r_p+r_c)$$

Total copper loss in secondary winding = $\frac{E^2}{r_p + r_c}$

Total iron loss in the specimen, $P_i = P\frac{E}{V} - \frac{E^2}{(r_p + r_c)}$

$$P_i = P\left[1 + \frac{r_c}{r_p}\right] - \frac{E^2}{r_p + r_c} \quad ; \text{watt}$$

→ Specific iron loss i.e, iron loss per kg can be calculated by dividing the total iron losses by the weight of the specimen.

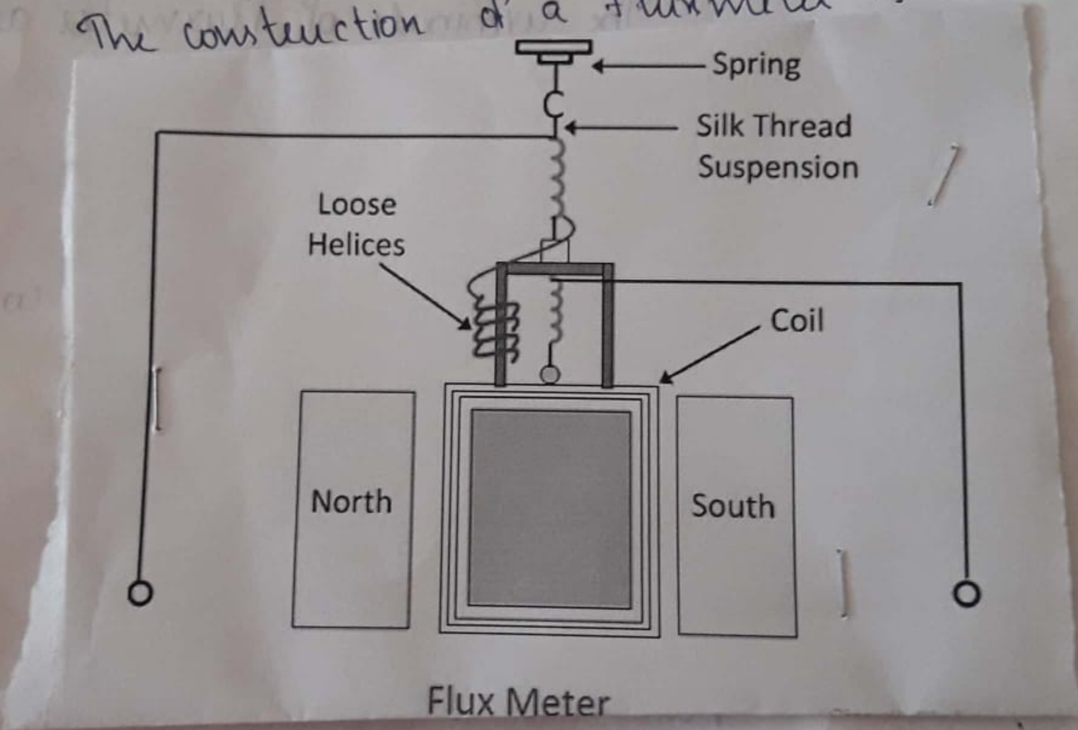
→ The hysteresis and eddy current component of the losses can be graphically determined from the results of power measurement such as the at different frequencies.

Flux meter

The flux meter is a Special type of Ballistic Galvanometer in which the controlling torque is very small and electromagnetic damping is high.

construction of fluxmeter

The construction of a fluxmeter is shown in figure.



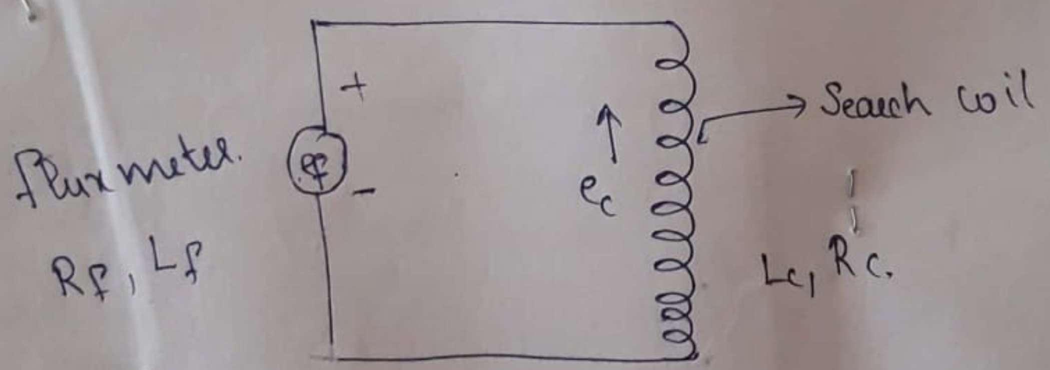
Flux Meter

A coil of small cross-section is Suspended from a Spring support by means of a Single silk thread. The coil moves in the narrow gap of a permanent magnet. There are no control springs.

The current is led into the coil with the help of a very loose helices of very thin annealed silver strips. The controlling is thus reduced to minimum. The coil is formerless and the air friction damping is negligible.

Operation of Fluxmeter:

The terminals of fluxmeter are connected to a search coil as shown in figure.



Flux meter with search coil

The flux linking with the search coil is changed either by removing the coil from the magnetic field or by reversing the field. Due to the change in the value of flux linking with the search coil an emf is induced in it.

This emf sends a current through the flux meter which deflects through an angle depending upon the change in the value of flux linkages.

The instrument coil deflects during the period the flux linkages change but as soon as the change occurs the coil stops, due to the high electromagnetic damping in the circuit. This high electromagnetic damping is obtained by having a low resistance of the circuit comprising the flux meter and search coil.

Theory of flux meter

Let

N → Number of turns on the search coil.

R_c, L_c → Resistance and Inductance of the search coil

R_f, L_f → Resistance and Inductance of flux meter.

ϕ → flux linking with the search coil

i → current is the circuit at any instant.

θ → deflection of the instrument at any instrument

Equation of motion is

$$T_j + T_D + T_c = T_d.$$

$T_j \rightarrow$ Torque due to inertia

$T_D \rightarrow$ Torque due to damping [damping torque]

$T_d \rightarrow$ deflection torque.

$T_c \rightarrow$ controlling torque.

$$T_j = J\frac{d^2\theta}{dt^2}$$

$$T_D = D\frac{d\theta}{dt}$$

$$T_c = K\theta$$

$$T_d = Gi$$

$$J\frac{d^2\theta}{dt^2} + D\frac{d\theta}{dt} + K\theta = Gi \longrightarrow (1)$$

It is assumed that the control torque is negligibly small and also the air friction damping is small.

$\therefore$ the equation of motion reduces to

$$J\frac{d^2\theta}{dt^2} = Gi \longrightarrow (2)$$

D & K are zero.

The emf due to any change of flux linked with Search coil is

$$e_c = N\frac{d\phi}{dt} \longrightarrow (3)$$

At the same time, the movement of the flux meter coil is the field of the magnet, emf is induced in the coil

$$e_f = G\frac{d\theta}{dt} \longrightarrow (4)$$

Also there are voltage drop in the resistance and inductance of the circuit.

$$e_c = e_f + (L_f + L_c)\frac{di}{dt} + (R_f + R_c)\, i \longrightarrow (5)$$

$$N\frac{d\phi}{dt} = G\frac{d\theta}{dt} + [L_f + L_c]\frac{di}{dt} + [R_f + R_c]\, i$$

$$N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - [L_f + L_c]\frac{di}{dt} = [R_f + R_c]\, i$$

$$i = \frac{N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - [L_f + L_c]\frac{di}{dt}}{[R_f + R_c]} \longrightarrow (6)$$

Sub (6) in (2) $\quad J\frac{d^2\theta}{dt^2} = Gi$

$$J\frac{d^2\theta}{dt^2} = G\left[\frac{N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - [L_f + L_c]\frac{di}{dt}}{[R_f + R_c]}\right]$$

$$J\frac{d^2\theta}{dt^2} = \frac{G}{R_f+R_c}\left[N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - (L_f+L_c)\frac{di}{dt}\right]$$

$$J\frac{d^2\theta}{dt^2} \times \frac{(R_f+R_c)}{G} = N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - [L_f+L_c]\frac{di}{dt}.$$

$$\frac{J[R_f+R_c]}{G}\frac{d^2\theta}{dt^2} = N\frac{d\phi}{dt} - G\frac{d\theta}{dt} - [L_f+L_c]\frac{di}{dt}.$$

$$\frac{J[R_f+R_c]}{G}\frac{d^2\theta}{dt^2} + G\frac{d\theta}{dt} + [L_f+L_c]\frac{di}{dt} = N\frac{d\phi}{dt}$$

$$N\frac{d\phi}{dt} = \frac{J(R_f+R_c)}{G}\frac{d^2\theta}{dt^2} + G\frac{d\theta}{dt} + [L_f+L_c]\frac{di}{dt}.$$

Sub $\frac{d^2\theta}{dt^2} = \frac{d\omega}{dt}$, $\because$ $\omega \rightarrow$ angular velocity of moving coil at any instant 't'

$$N\frac{d\phi}{dt} = \frac{J[R_f+R_c]}{G}\frac{d^2\omega}{dt^2} + G\frac{d\theta}{dt} + [L_f+L_c]\frac{di}{dt}. \rightarrow (7)$$

Now if the time taken by change in flux is T.

$$\int_0^T N\frac{d\phi}{dt} = \int_0^T \frac{J[R_f+R_c]}{G}\frac{d^2\omega}{dt} + \int_0^T G\frac{d\theta}{dt} + \int_0$$

limit from 0 to T

equ (7)

$$\int_0^T N\frac{d\phi}{dt}.dt = \int_0^T \frac{J[R_f+R_c]}{G}\frac{d\omega}{dt}.dt + \int_0^T G\frac{d\theta}{dt}.dt + \int_0^T (L_f+L_c)\frac{di}{dt}.dt$$

$$N d\phi = \frac{J[R_f+R_c]}{G}d\omega + G\,d\theta + [L_f+L_c]\,di \longrightarrow (8)$$

flux $\phi \rightarrow \phi_1$ to ϕ_2. are the interlinking flux.

$\omega \rightarrow \omega_1$ to ω_2 are the angular velocities

$\theta \rightarrow \theta_1$ to θ_2 are deflection

$i \rightarrow i_1$ to i_2 are currents

equ (8)

$$\int_{\phi_1}^{\phi_2} N\,d\phi = \int_{\omega_1}^{\omega_2} \frac{J[R_f+R_c]}{G}d\omega + \int_{\theta_1}^{\theta_2} G\,d\theta + \int_{i_1}^{i_2} (L_f+L_c)\,di$$

$$N(\phi_2-\phi_1) = \frac{J(R_f+R_c)}{G}[\omega_2-\omega_1] + G[\theta_2-\theta_1] + (L_f+L_c)[i_2-i_1] \longrightarrow (9)$$

Suffixes 1 & 2 indicate respectively values at the begining and at the end of the fluxes. But the angular velocities and current are zero at both the begining and end of the changes.

ie $\omega_1 = \omega_2 = 0$; $i_1 = i_2 = 0$

Putting in equ (9)

$$N(\phi_2 - \phi_1) = G(\theta_2 - \theta_1)$$

$\phi \rightarrow$ change in flux.

$\theta \rightarrow$ change in flux meter deflection

$$N\phi = G\theta$$

$$\boxed{\phi = \frac{G}{N}\theta}$$

If the flux meter permanent magnet field is uniform for all positions of moving coil G, is a constant.

Thus change in the value of flux is directly proportional to change in the deflection and hence the instrument will have a uniform scale.