1.8 Moving Iron (MI) instruments

One of the most accurate instrument used for both AC and DC measurement is moving iron instrument. There are two types of moving iron instrument.
• Attraction type
• Repulsion type

1.8.1 Attraction type M.I. instrument

Construction: The moving iron fixed to the spindle is kept near the hollow fixed coil (Fig. 1.10). The pointer and balance weight are attached to the spindle, which is supported with jeweled bearing. Here air friction damping is used.

Principle of operation

The current to be measured is passed through the fixed coil. As the current is flow through the fixed coil, a magnetic field is produced. By magnetic induction the moving iron gets magnetized. The north pole of moving coil is attracted by the south pole of fixed coil. Thus the deflecting force is produced due to force of attraction. Since the moving iron is attached with the spindle, the spindle rotates and the pointer moves over the calibrated scale. But the force of attraction depends on the current flowing through the coil.

Torque developed by M.I

Let 'θ' be the deflection corresponding to a current of 'i' amp

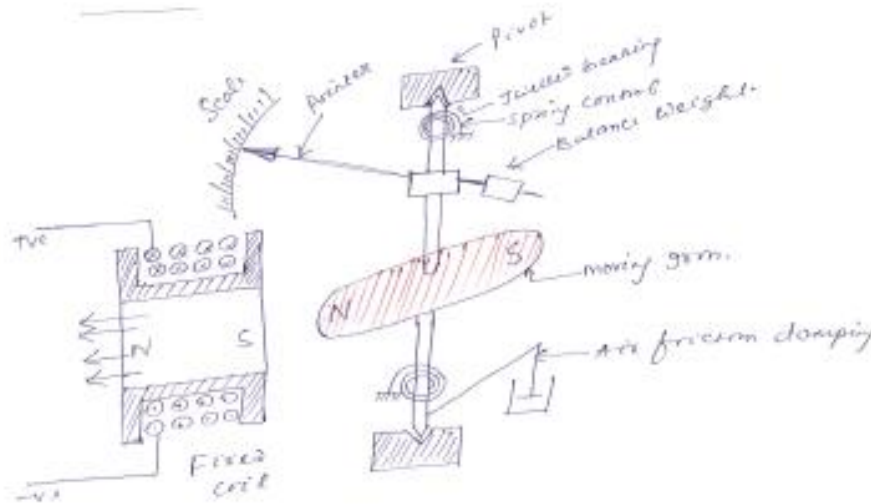Let the current increases by di, the corresponding deflection is '$\theta + d\theta$'

Fig. 1.10

There is change in inductance since the position of moving iron change w.r.t the fixed electromagnets.

Let the new inductance value be 'L+dL'. The current change by 'di' is dt seconds.

Let the emf induced in the coil be 'e' volt.

$$e = \frac{d}{dt}(Li) = L\frac{di}{dt} + i\frac{dL}{dt} \tag{1.22}$$

Multiplying by 'idt' in equation (1.22)

$$e \times idt = L\frac{di}{dt} \times idt + i\frac{dL}{dt} \times idt \tag{1.23}$$

$$e \times idt = Lidi + i^2 dL \tag{1.24}$$

Eq^n (1.24) gives the energy is used in to two forms. Part of energy is stored in the inductance. Remaining energy is converted in to mechanical energy which produces deflection.
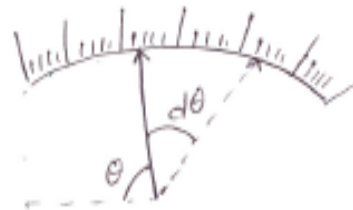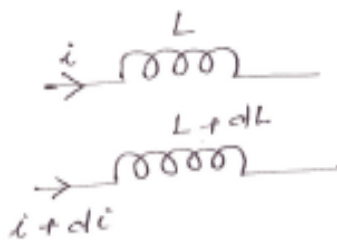

Fig. 1.11

Change in energy stored=Final energy-initial energy stored

$$= \frac{1}{2}(L+dL)(i+di)^2 - \frac{1}{2}Li^2$$

$$= \frac{1}{2}\{(L+dL)(i^2+di^2+2idi) - Li^2\}$$

$$= \frac{1}{2}\{(L+dL)(i^2+2idi) - Li^2\}$$

$$= \frac{1}{2}\{Li^2+2Lidi+i^2dL+2ididL - Li^2\}$$

$$= \frac{1}{2}\{2Lidi+i^2dL\}$$

$$= Lidi + \frac{1}{2}i^2dL \qquad (1.25)$$

Mechanical work to move the pointer by $d\theta$
$$= T_d d\theta \qquad (1.26)$$

By law of conservation of energy,
Electrical energy supplied=Increase in stored energy+ mechanical work done.

Input energy= Energy stored + Mechanical energy

$$Lidi + i^2dL = Lidi + \frac{1}{2}i^2dL + T_d d\theta \qquad (1.27)$$

$$\frac{1}{2}i^2dL = T_d d\theta \qquad (1.28)$$

$$T_d = \frac{1}{2}i^2\frac{dL}{d\theta} \qquad (1.29)$$

At steady state condition $T_d = T_C$

$$\frac{1}{2}i^2\frac{dL}{d\theta} = K\theta \qquad (1.30)$$

$$\theta = \frac{1}{2K}i^2\frac{dL}{d\theta} \qquad (1.31)$$

$$\theta \propto i^2 \qquad (1.32)$$

When the instruments measure AC, $\theta \propto i^2_{rms}$

Scale of the instrument is non uniform.

Advantages
- ✓ MI can be used in AC and DC
- ✓ It is cheap
- ✓ Supply is given to a fixed coil, not in moving coil
- ✓ Simple construction
- ✓ Less friction error.

Disadvantages
- ✓ It suffers from eddy current and hysteresis error
- ✓ Scale is not uniform
- ✓ It consumed more power
- ✓ Calibration is different for AC and DC operation

1.8.2 Repulsion type moving iron instrument

Construction: The repulsion type instrument has a hollow fixed iron attached to it (Fig. 1.12). The moving iron is connected to the spindle. The pointer is also attached to the spindle in supported with jeweled bearing.

Principle of operation: When the current flows through the coil, a magnetic field is produced by it. So both fixed iron and moving iron are magnetized with the same polarity, since they are kept in the same magnetic field. Similar poles of fixed and moving iron get repelled. Thus the deflecting torque is produced due to magnetic repulsion. Since moving iron is attached to spindle, the spindle will move. So that pointer moves over the calibrated scale. Damping: Air friction damping is used to reduce the oscillation. Control: Spring control is used
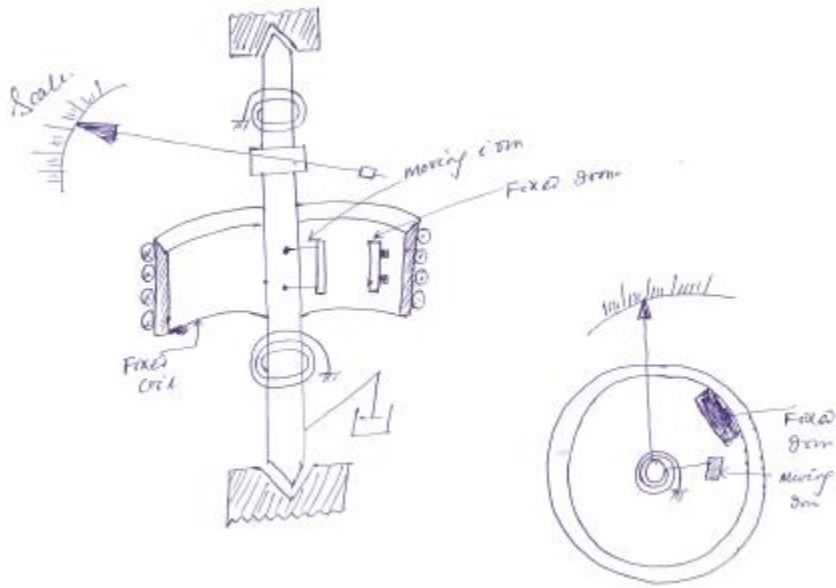
Fig. 1.12

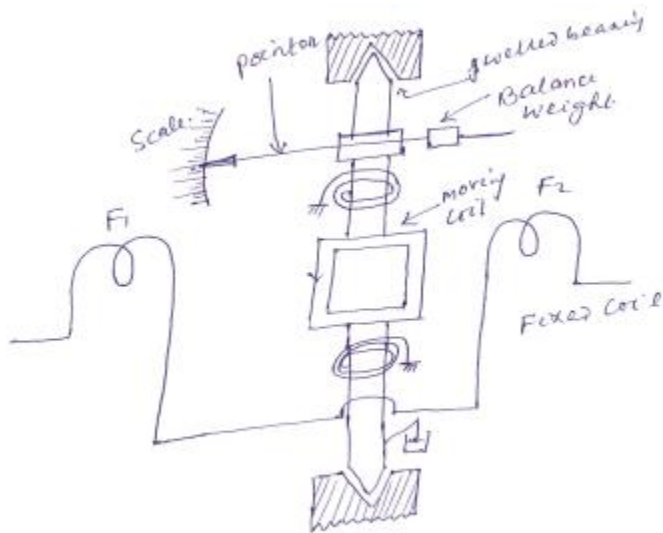## 1.9 Dynamometer (or) Electromagnetic moving coil instrument (EMMC)

Fig. 1.13

This instrument can be used for the measurement of voltage, current and power. The difference between the PMMC and dynamometer type instrument is that the permanent magnet is replaced by an electromagnet.

Construction: A fixed coil is divided in to two equal half. The moving coil is placed between the two half of the fixed coil. Both the fixed and moving coils are air cored. So that the hysteresis effect will be zero. The pointer is attached with the spindle. In a non metallic former the moving coil is wounded.

Control: Spring control is used.

Damping: Air friction damping is used.

Principle of operation:
When the current flows through the fixed coil, it produced a magnetic field, whose flux density is proportional to the current through the fixed coil. The moving coil is kept in between the fixed coil. When the current passes through the moving coil, a magnetic field is produced by this coil. The magnetic poles are produced in such a way that the torque produced on the moving coil deflects the pointer over the calibrated scale. This instrument works on AC and DC. When AC voltage is applied, alternating current flows through the fixed coil and moving coil. When the current in the fixed coil reverses, the current in the moving coil also reverses. Torque remains in the same direction. Since the current i1 and i2 reverse simultaneously. This is because the fixed and moving coils are either connected in series or parallel.
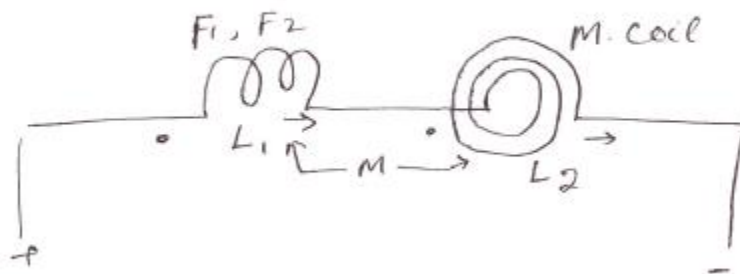
Torque developed by EMMC

Fig. 1.14

Let

L_1=Self inductance of fixed coil

L_2= Self inductance of moving coil

M=mutual inductance between fixed coil and moving coil

i_1=current through fixed coil

i_2=current through moving coil

Total inductance of system,

$$L_{total} = L_1 + L_2 + 2M \tag{1.33}$$

But we know that in case of M.I

$$T_d = \frac{1}{2}i^2\frac{d(L)}{d\theta} \tag{1.34}$$

$$T_d = \frac{1}{2}i^2\frac{d}{d\theta}(L_1 + L_2 + 2M) \tag{1.35}$$

The value of L_1 and L_2 are independent of 'θ' but 'M' varies with θ

$$T_d = \frac{1}{2}i^2 \times 2\frac{dM}{d\theta} \tag{1.36}$$

$$T_d = i^2\frac{dM}{d\theta} \tag{1.37}$$

If the coils are not connected in series $i_1 \neq i_2$

$$\therefore T_d = i_1 i_2\frac{dM}{d\theta} \tag{1.38}$$

$$T_C = T_d \tag{1.39}$$

$$\therefore \theta = \frac{i_1 i_2}{K}\frac{dM}{d\theta} \tag{1.40}$$

Hence the deflection of pointer is proportional to the current passing through fixed coil and moving coil.

1.9.1 Extension of EMMC instrument

Case-I Ammeter connection
Fixed coil and moving coil are connected in parallel for ammeter connection. The coils are designed such that the resistance of each branch is same.
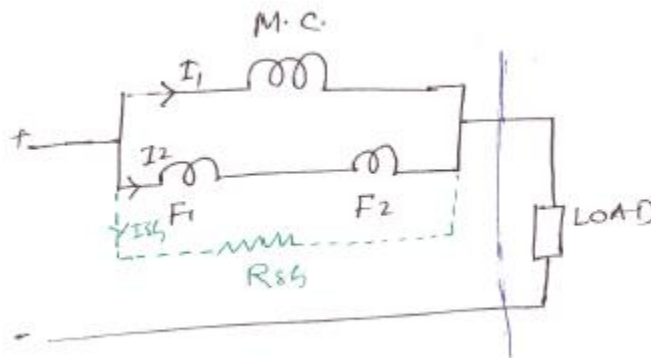Therefore

$$I_1 = I_2 = I$$

Fig. 1.15

To extend the range of current a shunt may be connected in parallel with the meter. The value R_{sh} is designed such that equal current flows through moving coil and fixed coil.

$$\therefore T_d = I_1 I_2 \frac{dM}{d\theta} \tag{1.41}$$

$$\text{Or} \therefore T_d = I^2 \frac{dM}{d\theta} \tag{1.42}$$

$$T_C = K\theta \tag{1.43}$$

$$\theta = \frac{I^2}{K} \frac{dM}{d\theta} \tag{1.44}$$

$$\therefore \theta \propto I^2 \text{ (Scale is not uniform)} \tag{1.45}$$

Case-II Voltmeter connection

Fixed coil and moving coil are connected in series for voltmeter connection. A multiplier may be connected in series to extent the range of voltmeter.
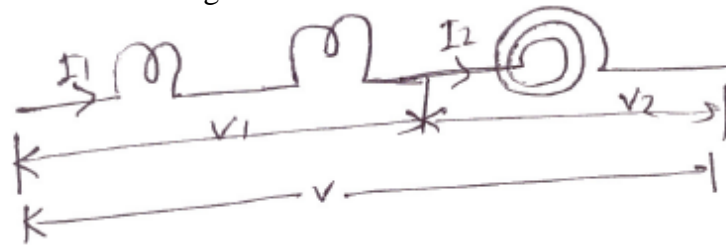

Fig. 1.16

$$I_1 = \frac{V_1}{Z_1}, I_2 = \frac{V_2}{Z_2} \tag{1.46}$$

$$T_d = \frac{V_1}{Z_1} \times \frac{V_2}{Z_2} \times \frac{dM}{d\theta} \tag{1.47}$$

$$T_d = \frac{K_1 V}{Z_1} \times \frac{K_2 V}{Z_2} \times \frac{dM}{d\theta} \tag{1.48}$$

$$T_d = \frac{K V^2}{Z_1 Z_2} \times \frac{dM}{d\theta} \tag{1.49}$$

$$T_d \propto V^2 \tag{1.50}$$

$$\therefore \theta \propto V^2 \quad \text{(Scale in not uniform)} \tag{1.51}$$

Case-III As wattmeter

When the two coils are connected to parallel, the instrument can be used as a wattmeter. Fixed coil is connected in series with the load. Moving coil is connected in parallel with the load. The moving coil is known as voltage coil or pressure coil and fixed coil is known as current coil.
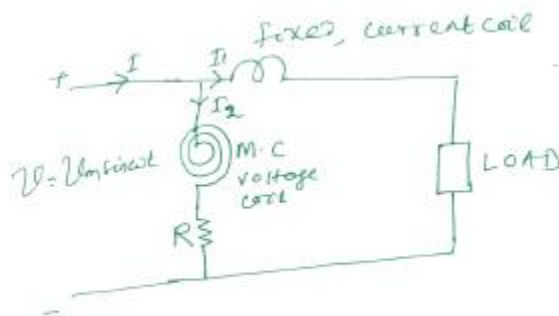

Fig. 1.17

Assume that the supply voltage is sinusoidal. If the impedance of the coil is neglected in comparison with the resistance 'R'. The current,

$$I_2 = \frac{V_m \sin wt}{R} \tag{1.52}$$

Let the phase difference between the currents I_1 and I_2 is ϕ

$$I_1 = I_m \sin(wt - \phi) \tag{1.53}$$

$$T_d = I_1 I_2 \frac{dM}{d\theta} \tag{1.54}$$

$$T_d = I_m \sin(wt - \phi) \times \frac{V_m \sin wt}{R} \frac{dM}{d\theta} \tag{1.55}$$

$$T_d = \frac{1}{R}(I_m V_m \sin wt \sin(wt - \phi)) \frac{dM}{d\theta} \tag{1.56}$$

$$T_d = \frac{1}{R} I_m V_m \sin wt . \sin(wt - \phi) \frac{dM}{d\theta} \tag{1.57}$$

The average deflecting torque

$$(T_d)_{avg} = \frac{1}{2\Pi} \int_0^{2\Pi} T_d \times d(wt) \tag{1.58}$$

$$(T_d)_{avg} = \frac{1}{2\Pi} \int_0^{2\Pi} \frac{1}{R} \times I_m V_m \sin wt . \sin(wt - \phi) \frac{dM}{d\theta} \times d(wt) \tag{1.59}$$

$$(T_d)_{avg} = \frac{V_m I_m}{2 \times 2\Pi} \times \frac{1}{R} \times \frac{dM}{d\theta} \left[\int \{\cos\phi - \cos(2wt - \phi)\} dwt \right] \tag{1.60}$$

$$(T_d)_{avg} = \frac{V_m I_m}{4\Pi R} \times \frac{dM}{d\theta} \left[\int_0^{2\Pi} \cos\phi . dwt - \int_0^{2\Pi} \cos(2wt - \phi) . dwt \right] \tag{1.61}$$

$$(T_d)_{avg} = \frac{V_m I_m}{4\Pi R} \times \frac{dM}{d\theta} \left[\cos\phi[wt \, _0^{2\Pi}] \right] \tag{1.62}$$

$$(T_d)_{avg} = \frac{V_m I_m}{4\Pi R} \times \frac{dM}{d\theta} \left[\cos\phi(2\Pi - 0) \right] \tag{1.63}$$

$$(T_d)_{avg} = \frac{V_m I_m}{2} \times \frac{1}{R} \times \frac{dM}{d\theta} \times \cos\phi \tag{1.64}$$

$$(T_d)_{avg} = V_{rms} \times I_{rms} \times \cos\phi \times \frac{1}{R} \times \frac{dM}{d\theta} \tag{1.65}$$

$$(T_d)_{avg} \propto KVI \cos\phi \tag{1.66}$$

$$T_C \propto \theta \tag{1.67}$$

$$\theta \propto KVI \cos\phi \tag{1.68}$$

$$\theta \propto VI \cos\phi \tag{1.69}$$

Advantages

- ✓ It can be used for voltmeter, ammeter and wattmeter
- ✓ Hysteresis error is nill
- ✓ Eddy current error is nill
- ✓ Damping is effective
- ✓ It can be measure correctively and accurately the rms value of the voltage

Disadvantages

- ✓ Scale is not uniform
- ✓ Power consumption is high(because of high resistance)
- ✓ Cost is more
- ✓ Error is produced due to frequency, temperature and stray field.
- ✓ Torque/weight is low.(Because field strength is very low)

Errors in PMMC

- ✓ The permanent magnet produced error due to ageing effect. By heat treatment, this error can be eliminated.
- ✓ The spring produces error due to ageing effect. By heat treating the spring the error can be eliminated.
- ✓ When the temperature changes, the resistance of the coil vary and the spring also produces error in deflection. This error can be minimized by using a spring whose temperature co-efficient is very low.

1.10 Difference between attraction and repulsion type instrument:

An attraction type instrument will usually have a lower inductance, compare to repulsion type instrument. But in other hand, repulsion type instruments are more suitable for economical production in manufacture and nearly uniform scale is more easily obtained. They are therefore much more common than attraction type.