3. Measurement of Displacement & Velocity.

3.1 Potentiometers / Potentiometric Resistance type Transducers:

A potentiometer (POT) is very simple & cheap form of transducer. It converts linear or rotational displacements into voltage.

Linear POTs for the measurement of position & displacement takes numerous forms dependent on intended applications. The simplest & cheapest form is a single length of wire along which a slider contacts the wire. The position of the slider determines the effective length of the conductor. Hence a change in electrical resistance or voltage drop is related to the position/displacement of the slider. The simple device is useful for laboratory demonstration but seldom is employed in industrial applications.

In a wire wound resistive potentiometer a very thin (0.01 mm diameter) wire of Pt/Ni alloy is wound uniformly throughout its length with a slider contact called the wiper. Potentiometer having translatory motion of wiper is called translatory potentiometers & the devices having rotatry motion are called rotary potentiometers. When the motion of wiper are both ways, i.e., translational as well as rotational, the potentiometer is called the helipot.

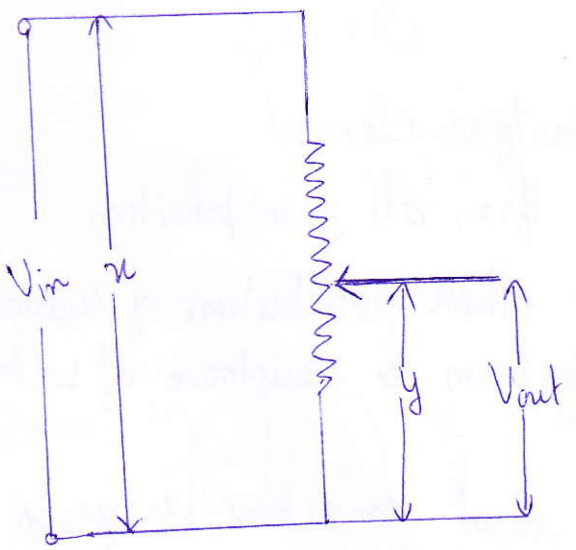

Fig. 3.1 Translatory Potentiometer

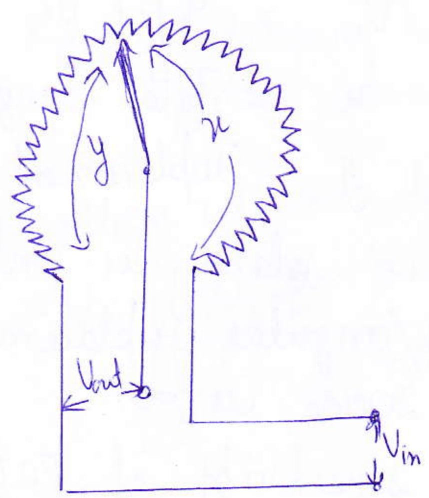

Fig. 3.2 Rotary Potentiometer

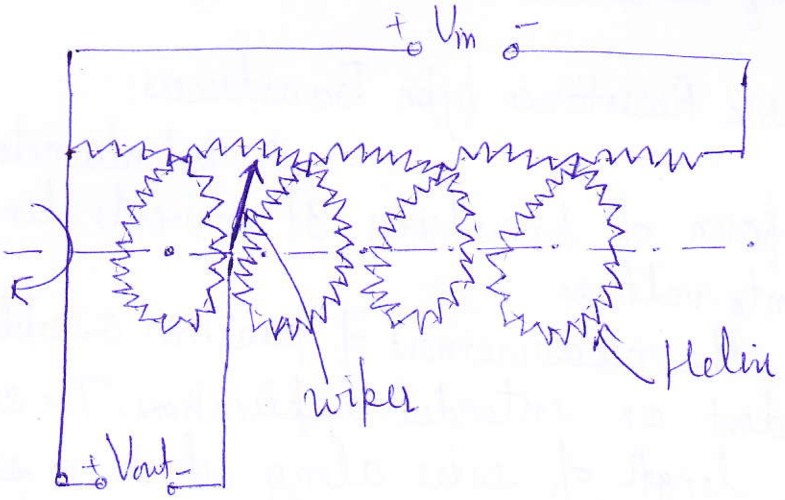

Fig. 3.3 Helipot

The POT is a passive transducer sinse it requires a external power source for its operation. It is supplied power either from a dc or ac voltage source & its output voltage is a linear function of input displacement in ideal conditions.

The POTs are designed on the basis of power rating which is related directly to their heat dissipiating capacity. The maximum input excitation voltage is limited on account of POT heat dissipiating capacity & is given by =n:

$$V_{inmax} = \sqrt{P R_t} \quad \text{---(3.1)}$$

O/P voltage, $V_{out} = \frac{y}{x} V_{in}$ --- (3.2)

Where V_{in} = Input dc voltage

x = Total length of resitance element

y = Displacement of wiper from its zero position

The above relation is only true when distribution of resistance wrt. linear/angular displacement is uniform & resistance of voltage measuring device is ∞.

The sensitivity of POT under ideal conditions is given by $\frac{V_{out}}{y}$ or $\frac{V_{in}}{x}$ volts/meter.

Loading Effect:

The loading effect due to input resistance R_l of the device. The resistance of the ‖ combination of the load resistance R_l & the portion of the resistance of the POT, $\frac{y}{x}R_t$ is

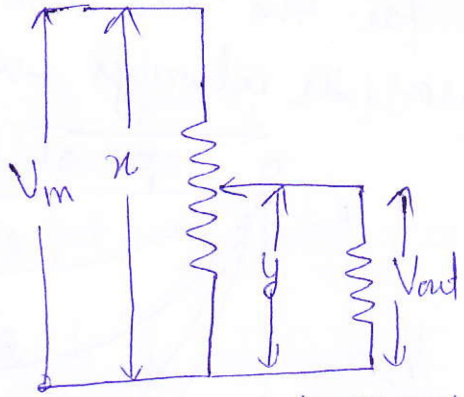

Fig. 3.4 Simple Translatory POT

$$= \frac{\frac{y}{x} R_t R_l}{\frac{y}{x} R_t + R_l}$$. The total resistance

is

$$= \frac{y/x \, R_t R_l}{y/x \, R_t + R_l} + \left(1 - \frac{y}{x}\right) R_t$$

$$= \frac{y/x (R_t)^2 \left(1 - \frac{y}{x}\right) + R_t R_l}{\frac{y}{x} R_t + R_l}$$

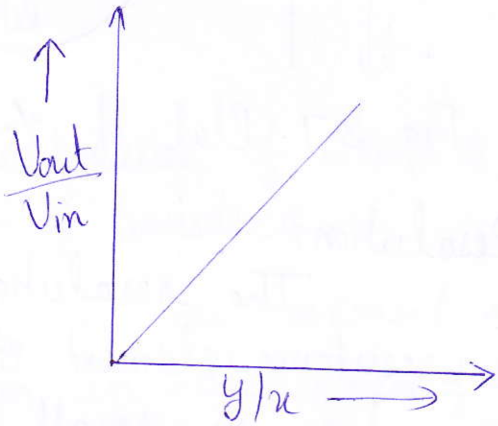

Fig. 3.5 Plot of $\frac{V_{out}}{V_{in}}$ vs. y/x

The ratio of o/p voltage & i/p voltage is given by the eqn:

$$\frac{V_{out}}{V_{in}} = \frac{y/x \, R_t R_l / \frac{y}{x} R_t + R_l}{\frac{\frac{y}{x}(R_t)^2 \left(1 - \frac{y}{x}\right) + R_t R_l}{\frac{y}{x} R_t + R_l}}$$

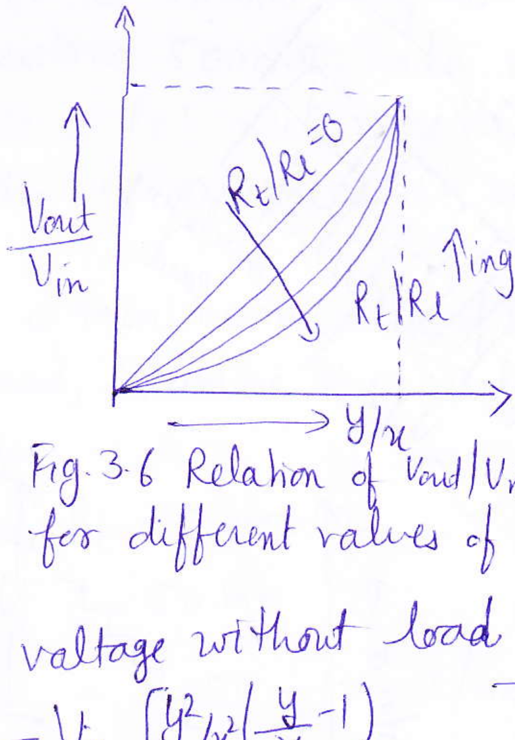

Fig. 3.6 Relation of V_{out}/V_{in} & y/x for different values of R_t/R_l

$$\frac{V_{out}}{V_{in}} = \frac{1}{R_t/R_l \left[1 - y/x\right] + x/y} \quad \text{--- (3.3)}$$

Error = O/p voltage with load − o/p voltage without load

$$\text{Error} = \frac{V_{in}}{\frac{R_t}{R_l}\left(1 - \frac{y}{x}\right) + \frac{x}{y}} - \frac{V_{in}}{x/y} = -V_{in}\left[\frac{y^2/x^2 \left(\frac{y}{x} - 1\right)}{\frac{y}{x}\left(1 - \frac{y}{x}\right) + R_l/R_t}\right]$$

$$\% \text{ Error} = -\left[\frac{V_{in}\left(\frac{y^2}{x^2}\left(\frac{y}{x} - 1\right)\right)}{\frac{y}{x}\left(1 - \frac{y}{x}\right) + R_l/R_t}\right] \times 100$$

Except for the end two points, i.e., when $y/x = 0$ & $y/x = 1$, the error is always -ve.

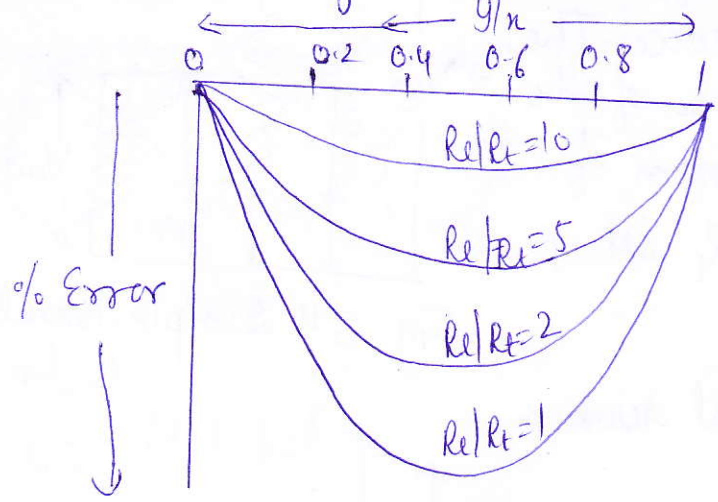

Fig. 3.7 Plot of % Error vs. y/x

POT Resolution:

The resolution of the POT depends on the construction of the resistance element & for achieving sufficiently high resistance values in small space the wire wound element is extensively used.

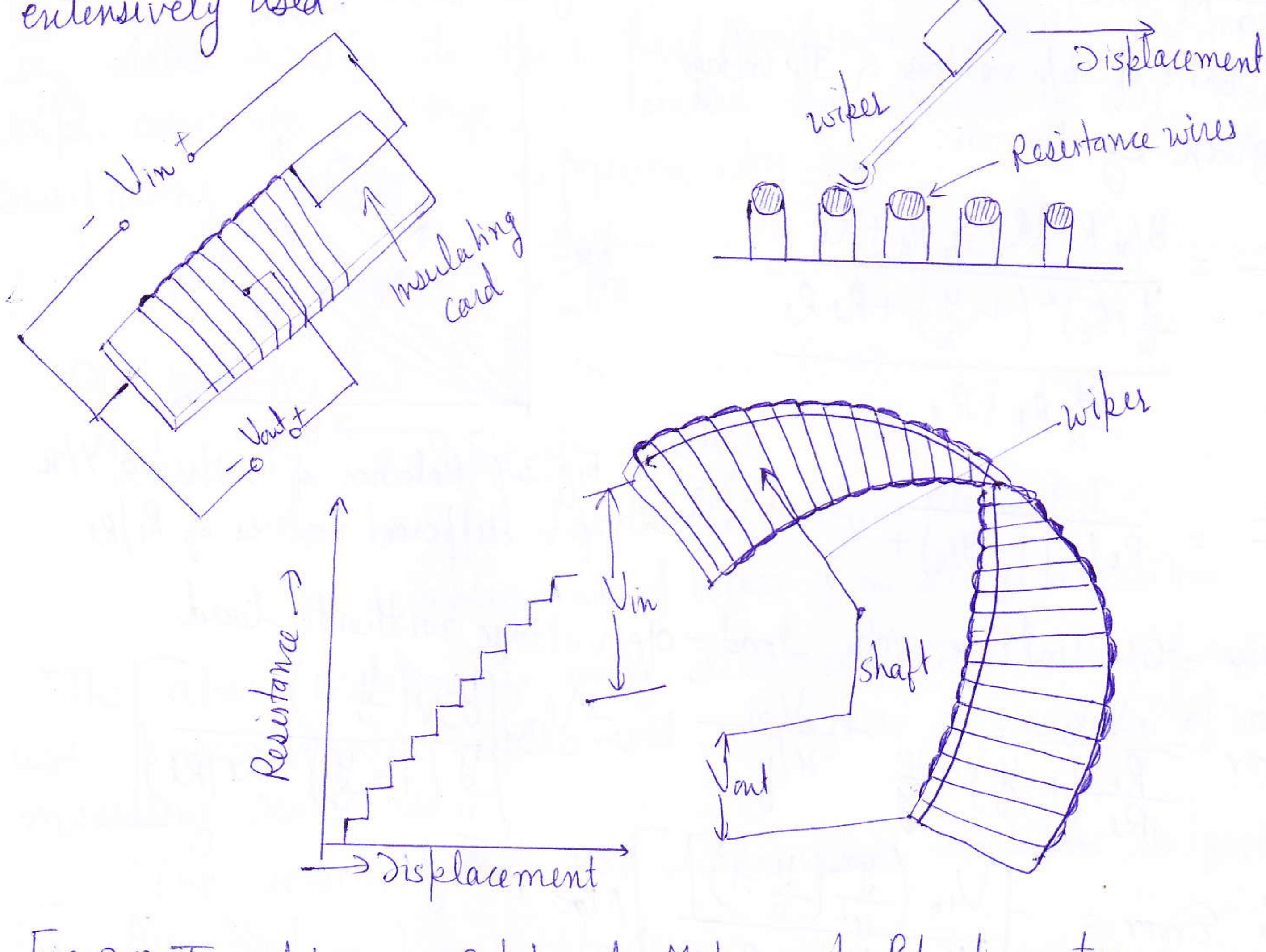

Fig. 3.8 Translatory & Rotational Motion of Potentiometer

Merits of Potentiometers:

1. The POTs are very cheap, easy to operate, simple in construction & very useful for simple applications.
2. The POTs, except wire wound, have got very good freq. response & infinite resolution.
3. The POT can measure large amplitude of displacement.
4. The POTs give very high electrical efficiency enough output to centre circuit for operation.

Drawbacks/Demerits:

1. The main drawback with POTs is because of wear & tear of wiper & it effects on the life of transducer.
2. The potentiometers require large force for movement of wiper.
3. The o/p is unsensitive to variation in displacement of movable contact or wiper between two consecutive turns of the POT.

Problem 3.1: A linear resistance POT is 50 mm long & is uniformly wound with a wire of total resistance 5000 Ω. Under normal conditions, the slider is at the centre of POT. Determine the linear displacement when the resistance of the POT as measured by Wheat Stone bridge is 1850 Ω.

If it is possible to measure a minimum value of 5 Ω resistance with the above arrangement, determine the resolution of POT in mm.

Solⁿ: Total resistance of POT wire, $R_t = 5,000\ \Omega$

Total length " " ", $L = 50$ mm

Resistance/length of POT wire $= \frac{5000}{50} = 100\ \Omega/mm$.

Resistance of POT at normal position $= \frac{5000}{2} = 2500\ \Omega$

Change in resistance of POT from its normal position $= 2500 - 1850 = 650\ \Omega$.

$$y = \frac{650}{100} = 6.5\ mm.$$

Minimum measurable resistance = 5 Ω.

$$\text{Resolution} = \frac{\text{Minimum measurable resistance}}{\text{Resistance per mm Length}}$$

$$= \frac{5}{100} = 0.05 \text{ mm.}$$

3.2 Linear Variable Differential Transformer (LVDT)

This is the most widely used inductive transducer for translating linear motion into an electrical signal.

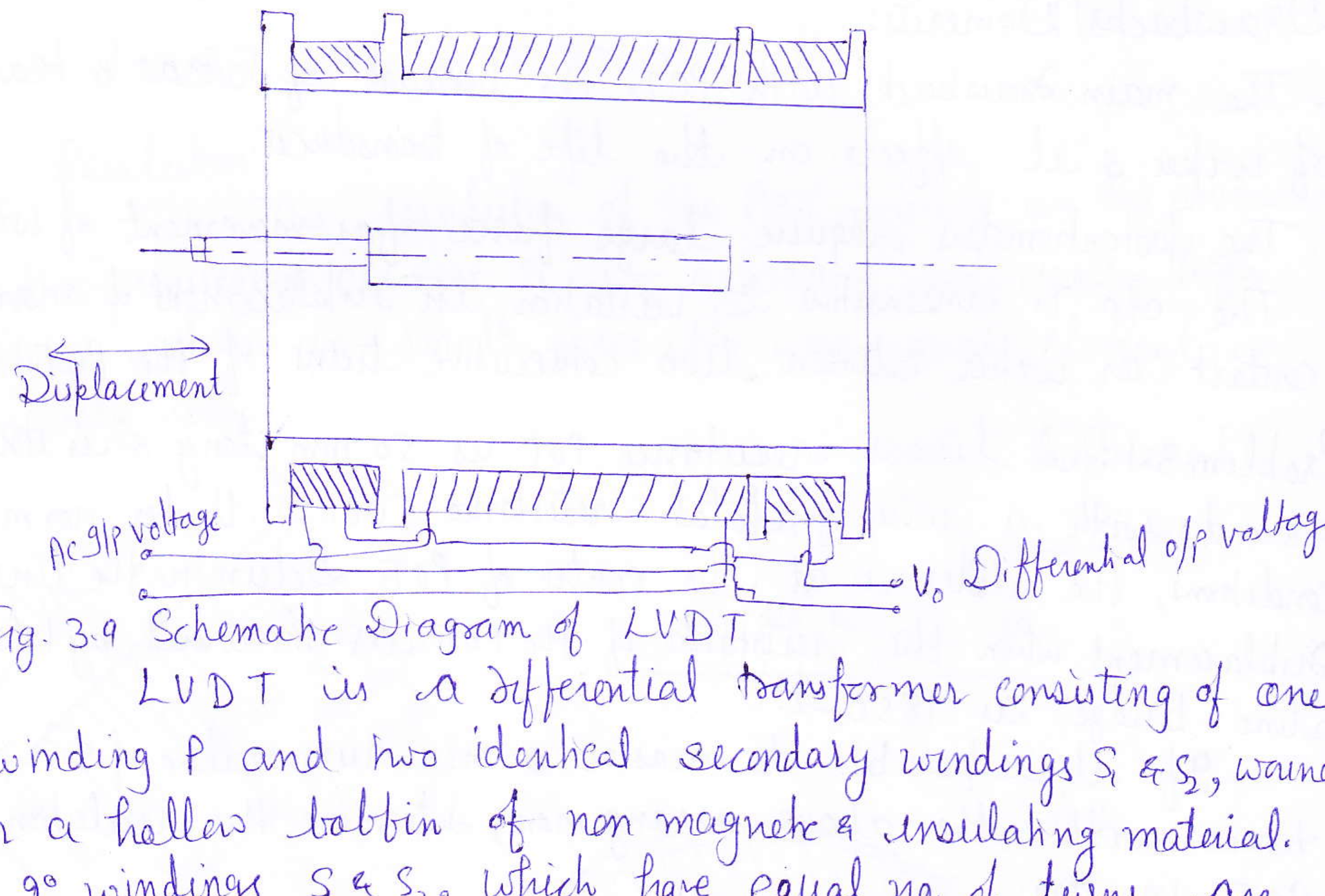

Fig. 3.9 Schematic Diagram of LVDT

LVDT is a differential transformer consisting of one 1° winding P and two identical secondary windings S_1 & S_2, wound over a hollow bobbin of non magnetic & insulating material. The 2° windings S_1 & S_2, which have equal no. of turns, are arranged concentrically & placed either side of the 1° winding. A soft iron core attached to the sensing element of which displacement is to be measured, in the shape rod slides freely in the hollow portion of the bobbin. 1° winding is connected to an a.c. source of voltage varying from 5 to 25V & of frequency ranging from 50 Hz to 20 kHz. In null position of the core, i.e., in central position, coupling of 1° winding to both 2° windings S_1 & S_2 are equal & so o/p voltages induced in 2° windings are range.

3. LVDT has high sensitivity.
4. Its o/p is very high which, even in same cases, eliminates the need for amplification devices.
5. These devices consume very less powers.
6. LVDT has good repeatability.

Demerits:

1. These devices are sensitive to stray magnetic fields.
2. Relatively large displacement is required for appreciable differential output.
3. Sometimes transducers performance is affected by vibrations.
4. Temprature affects the performance of transducer.

Applications:

1) LVDTs are suitable for use in applications where the displacements are too large for strain gauges to handle.
2) Sinse LVDTs can also be connected to other transducers, whose outputs are mechanical displacements. These are often employed together with other transducers for measurement of pressure, force, weight etc.

Problem 3.3 A LVDT produces an rms o/p voltage of 2.6V for displacement of 0.4 μm. Calculate sensitivity of LVDT.

Solⁿ:
$$S = \frac{\text{Rms value of o/p voltage}}{\text{Displacement in } \mu m} = \frac{2.6}{0.4} = 6.5\ V/\mu m$$

Problem 3.4 The o/p of an LVDT is 1.25 V at maximum displacement. At a load of 0.75 Mn the deviation from the linearity is maximum & it is 0.0025V from a straight line through origin. Determine linearity at a given load.

Solⁿ: Max. deviation from o/p, $D_{max} = 0.0025\ V$

o/p voltage, $V_{out} = 1.25\ V$

Let under strain conditions resistance of conductor be changed by ΔR ∵ of change in length by Δl, X-section area by ΔA & resistivity by $\Delta \rho$.

Differentiate eqn (3.4)

$$\frac{dR}{dP} = \frac{d}{dP}\left(\frac{\rho l}{A}\right)$$

$$= \frac{\rho}{A}\frac{dl}{dP} - \frac{\rho l}{A^2}\frac{dA}{dP} + \frac{l}{A}\frac{d\rho}{dP} \quad \text{--- (3.5)}$$

Dividing both sides by R

$$\frac{dR}{dP} = \frac{1}{l}\frac{dl}{dP} - \frac{1}{A}\frac{dA}{dP} + \frac{1}{\rho}\frac{d\rho}{dP} \quad \text{--- (3.6)}$$

For small variations

$$\frac{\Delta R}{R} = \frac{\Delta l}{l} - \frac{\Delta A}{A} + \frac{\Delta \rho}{\rho} \quad \text{--- (3.7)}$$

Under strained conditions, X-sectional area of the conductor changes, so the diameter of the conductor is also changed.

$$A = \frac{\pi}{4}D^2 \quad \text{---- (3.8)}$$

$$\frac{\delta A}{\delta S} = 2\frac{\pi}{4}D\frac{\delta D}{\delta S}$$

Dividing both sides by A

$$\frac{1}{A}\frac{\delta A}{\delta S} = \frac{2\pi/4\, D}{\frac{\pi}{4}D^2}\frac{\delta D}{\delta S} \quad \text{--- (3.9)}$$

For small variations

$$\frac{\Delta A}{A} = 2\frac{\Delta D}{D}$$

Now change in diameter of wire can be related with change in length of wire by Poisson's Ratio μ of the wire

$$\frac{\Delta D}{D} = -\mu\frac{\Delta l}{l} \qquad \because \mu = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

Value of μ is app. 0.3 for most of materials

$$\frac{\Delta A}{A} = -2\mu\frac{\Delta l}{l}$$

$$\text{Linearity at a given load} = \frac{D_{max}}{V_{out}} \times 100$$

$$= \frac{0.0025 \times 100}{1.25}$$

$$= 0.2\%$$

3.3 Strain Gauges:

The strain gauge is basically a device used for measuring mechanical surface strain & is one of the most extensively used electrical transducer. Its popularity stems from the fact that it can detect & convert force or small mechanical displacements into electrical signals.

Operating Principle of Resistance Strain Gauge:

The working of strain gauge is based on the fact that when stress is applied to the metal conductor its resistance changes owing to change in length & X-sectional area of conductor. Resistance of conductor under the stress is also changed due to change in resistivity of the conductor, this property is known as piezoresistive effect. That's why strain gauges are also called piezoresistive strain gauges.

$$R = \frac{\rho l}{A} \quad \ldots\ldots (3.4)$$

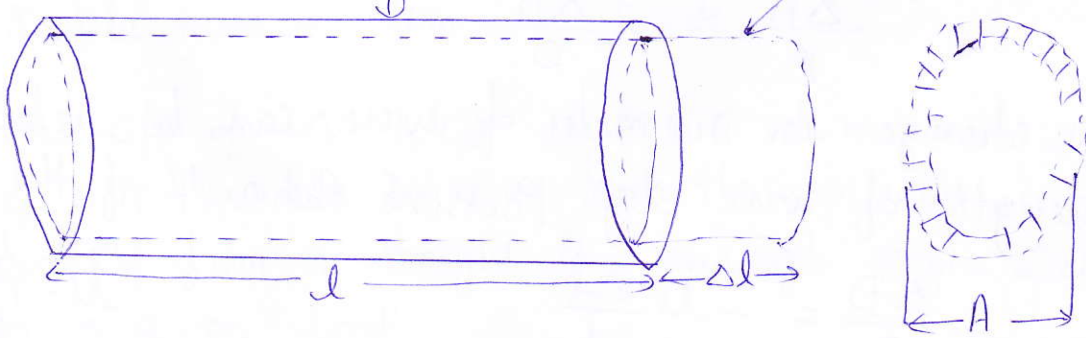

Fig. 3.12 Piezo Resistive Strain Gauge

Substituting these relations in eqn (3-7)

$$\frac{\Delta R}{R} = \frac{\Delta l}{l} + 2\mu\frac{\Delta l}{l} + \frac{\Delta \rho}{\rho}$$

$$\Delta R/R / \Delta l/l = 1 + 2\mu + \frac{\Delta \rho}{\rho} \Big/ \frac{\Delta l}{l} = G = \text{Gauss factor}$$

$$G = \frac{\Delta R}{R} \Big/ \Delta l/l = 1 + 2\mu + \frac{\Delta \rho}{\rho} \Big/ \frac{\Delta l}{l}$$

- 1 → Change in resistance due to change in length
- 2μ → Change in resistance due to change in area
- $\frac{\Delta \rho}{\rho} / \frac{\Delta l}{l}$ → Change in resistance due to piezo-resistive effect

$$\boxed{G = 1 + 2\mu + \frac{\Delta \rho}{\rho} \Big/ \frac{\Delta l}{l}}$$

$\frac{\Delta l}{l} = \epsilon$ (is usually measured in microstrain)

The term $\frac{\Delta \rho}{\rho} / \frac{\Delta l}{l}$ can be expressed as πE. Where π is called longitudinal piezoresistance constant & E is Young's modulus of Elasticity. The material property π may be +ve or -ve. Poissions ratio for mast of metals lies in range of 0 & 0.5.

Merits of Strain Gauge:

1. They are chemically inert & have low X- sensitivity.
2. They have gd freq. response upto 10^{12} Hz.
3. They are almast free from hysteresis & creep effects
4. Their fatique life is much higher than that of wire & fail gauges due to perfect elastic deformation of silicon filament.

Demerits of Strain Gauge:

They are expensive, brittle, highly sensitive to temp. variations & have poor linearity.

Applications of Strain Gauges:

1. Strain gauge transducers are extensively used for analyzing the dynamic strains in complex structures, such as stress & strain in bridges, automobiles, roads etc. where the output of bridge can be recorded with the help of oscillograph.
2. Strain gauge transducers are used for measuring tension, forces stresses in structures.
3. Strain gauges are used for measurement of force by the strain produced in load cells.

Problem 3.5: A thin circular wire of soft iron has a gauge factor of 3.8 Determine the Poisson's ratio of soft iron.

Soln: Gauss factor, $G = 3.8$

$$\mu = \frac{G-1}{2} = \frac{3.8-1}{2} = 1.4$$

3.4 Capacitive Transducer:

Consider the capacitance of two ‖ plate capacitor

$$C = \frac{\epsilon A}{d} = \frac{\epsilon_0 \epsilon_r A}{d} \quad \text{- - - -} \quad (3.10)$$

Where, C = Capacitance of the Capacitor

ϵ_0 = Absolute permittivity of free space

ϵ_r = Relative " " "

A = Overlapping area of plates

d = Distance between two plates

The capacitance of capacitive type transducer is

1. Change in overlapping area, A.
2. Change in the distance between two plates
3. Change in dielectric Constant

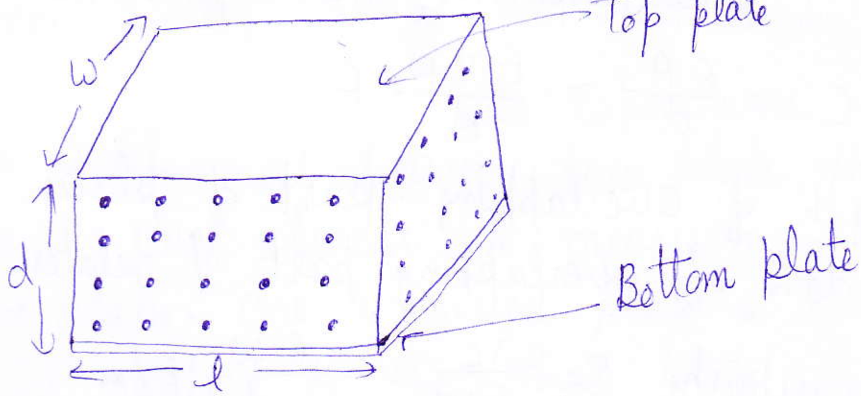

Fig. 3.13 Schematic diagram of Capacitive Transducer

The capacitance may be measured with bridge circuits. The output impedence of a capacitor Transducer is $X_c = \frac{1}{2\pi f c}$

The o/p impedence of capacitive transducer is high. So, we must take care to design a capacitive transducer.

Transducers Using change in area of Plates:

As capacitance of capacitor is directly proportional to the area of X-section of the plates. Capacitor transducer can measure the displacement between 1mm to several cm.

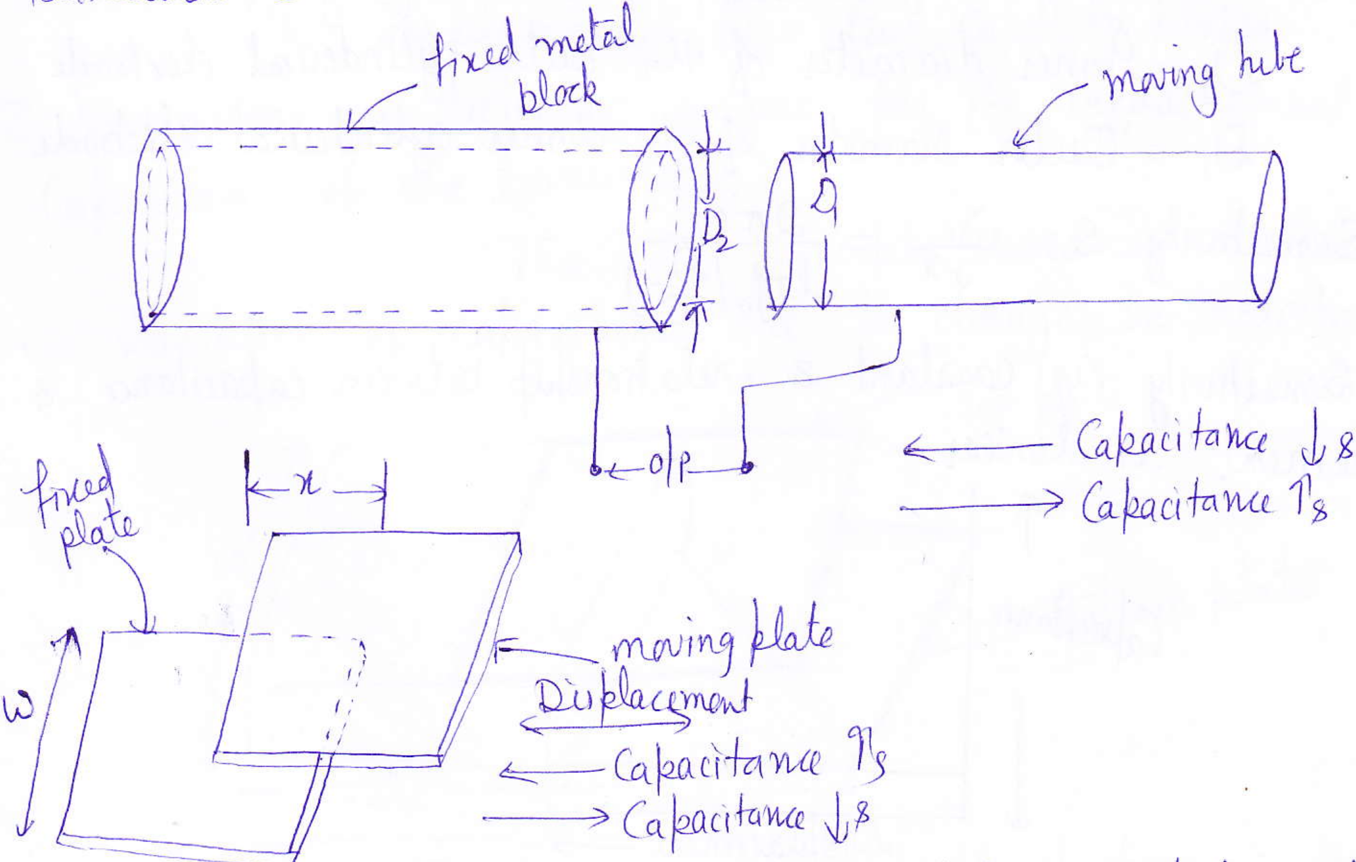

Fig. 3.14 Capacitive Transducer working of principle of change of capacitance with change of area

For a ∥ plate capacitor, the capacitance is

$$C = \frac{\epsilon A}{d} = \frac{\epsilon x w}{d} \, F$$

x = length of overlapping part of plates
w = Width of overlapping part of plates

As sensitivity $S = \frac{\partial C}{\partial x} = \frac{\epsilon w}{d}$ F/m

The sensitivity is constant & ∴ there is a linear relationship between capacitor & displacement.

So, sensitivity for a fractional change in capacitor

$$S' = \frac{\partial C}{C \, \partial x} = \frac{1}{x}$$

This type of capacitive transducer is suitable for measurement of linear displacements ranging from 1 mm. to 10 mm.

For a cylinderical capacitor, the capacitance is

$$C = \frac{2\pi \epsilon x}{\log_e (D_2/D_1)}$$

where x = Length of overlapping parts of cylinder.
D_2 = Inner diameter of the outer cylinderical electrode
D_1 = Outer diameter of the inner cylinderical electrode

Sensitivity $S = \frac{\partial C}{\partial x} = \frac{2\pi \epsilon}{\log_e \left(\frac{D_2}{D_1}\right)}$

∴ Sensitivity is constant & relationship between capacitance & displacement is linear.

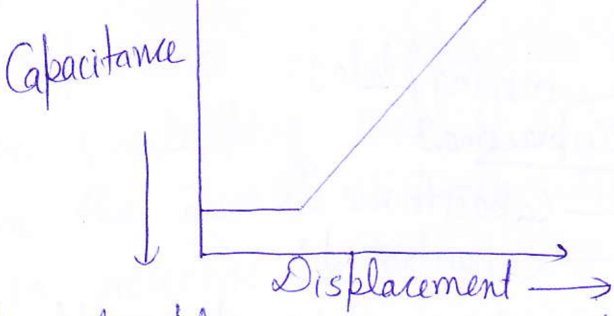

Fig3.15 Capacitive Displacement curve for Capacitive Transducer

2. Transducers Using Change in Distance between plates:

As Capacitance is inversly proportional to Displacement between two plates, the response of this transducer is not linear. For measurement of capacitance, we take two plates - one is fixed plate & the displacement to be measured is applied to the other plate which is movable.

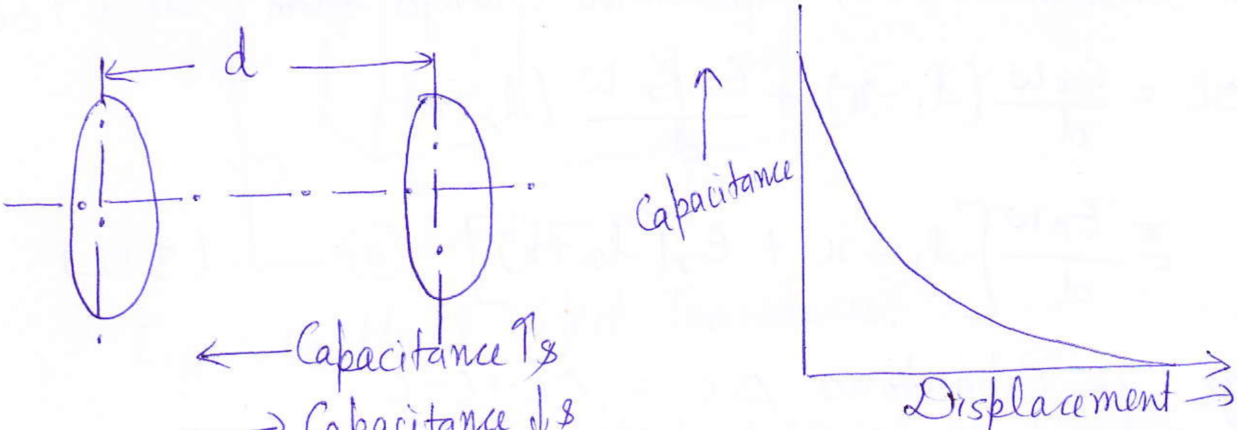

Fig. 3.16 Capacitive Transducer using the Principle of change in Displacement between the capacitor plates.

Sensitivity $\Rightarrow S = \frac{\partial C}{\partial x} = -\frac{\epsilon A}{x^2}$

x = Displacement b/w two capacitor plates

3 Variation in dielectric Constant for the measurement of Capacitance of the transducer:

The 3rd principle used in capacitive transducer is variation of capacitance due to change in dielectric constant.

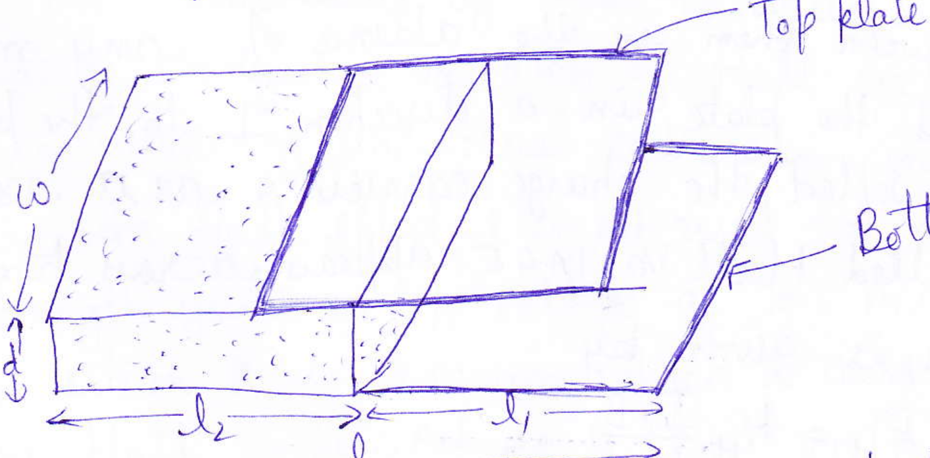

Fig. 3.17 Capacitive Transducer using the principle of change in dielectric constant for the measurement of displacement

Initial Capacitance of transducer $= \epsilon_0 \frac{W l_1}{d} + \frac{\epsilon_0 \epsilon_r W l_2}{d}$

$$= \frac{\epsilon_0 W}{d}(l_1 + \epsilon_r l_2) \quad \text{---- (3.11)}$$

Let the dielectric be moved through a distance x in the direction indicated. So, capacitance changes from C to $C+\Delta C$

$$C + \Delta C = \frac{\epsilon_0 W}{d}(l_1 - x) + \frac{\epsilon_0 \epsilon_r W}{d}(l_2 + x)$$

$$= \frac{\epsilon_0 W}{d}\left[l_1 - x + \epsilon_r(l_2 + x)\right] \quad \text{---- (3.12)}$$

Change in Capacitance $\Delta C = \Delta C + C - C$

$$= \frac{\epsilon_0 x W}{d}(\epsilon_r - 1) \quad \text{--- (3.13)}$$

Hence the change in capacitance is directly proportional to displacement.

3.5 Hall Effect Transducer:

A Hall Effect transducer is based on the effects of magnetic fields on moving charges. Refer to Fig. 3.. a current (I) passing lengthwise as shown through a plate made from semiconducting material like Indium antimonide, Germanium or Indium arsenide. Two conductive contacts are so adjusted the voltage between them in the absence of any magnetic field (B) traverses the plate in a direction ⊥ to the plate, it would tend to deflect the charge carriers & as a result, a voltage (E_H) called Hall VOLTAGE appears across two contacts

The voltage is given by

$$E_H = K_H \frac{I \cdot B}{t}$$

where, t = Plate thickness

K_H = Hall coefficient whose value depends upon the semiconductor material used.

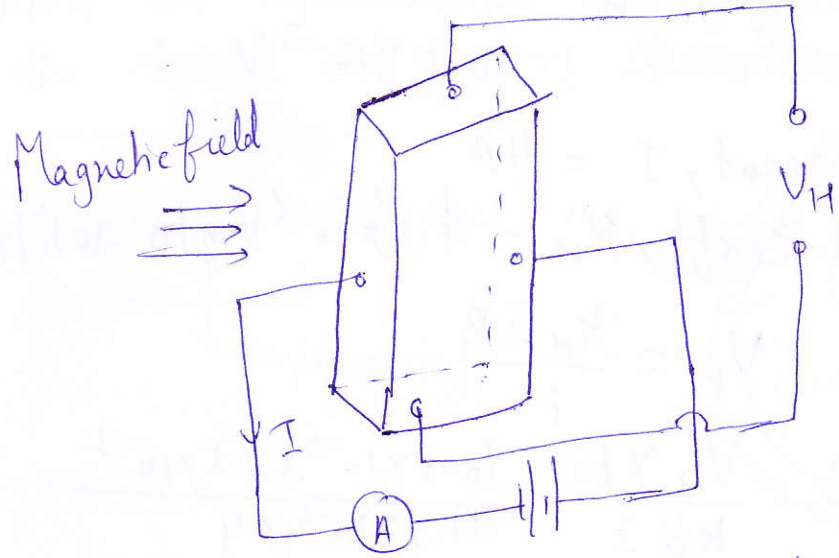

Fig. 3.18 Hall Effect Transducer.

The Hall effect element is rigidly suspended between the poles of a permanent magnet fixed to the shaft. The element remains stationary when the shaft rotates. With a constant current I supplied to the element, the voltage output across the element in directly proportional to the sine of angular displacement of the shaft & for smaller angular displacements ~~of the shaft & for~~ the o/p will be directly proportional to the angular displacement, thereby giving linear scale.

The main advantage of Hall Effect transducers is that they are non contact devices with small size & high resolution.

The main drawbacks of these transducers are high sensitivity to temprature changes & variation of Hall coefficient from plate to plate, ∴ requiring individual calibration in each cases.

Problem 3. An Hall effect element used for measuring a magnetic field strength gives an o/p voltage of 10.5 mV. The element is made of silicon & is 2.5 mm thick & carries a current of 4 A. The Hall coefficient is 4.1×10^{-6} Vm/A-wb/m²

Solution: Hall effect element thickness, $t = 2.5\ mm$
$= 2.5 \times 10^{-3}\ m$

O/P voltage, $V_H = 10.5\ mV$
$= 10.5 \times 10^{-3}\ V$

Current, $I = 4A$

Hall coeff, $K_H = 4.1 \times 10^{-6}\ Vm/A\text{-}Wb/m^2$

$$V_H = \frac{K_H I B}{t}$$

$$B = \frac{V_H \times t}{K_H I} = \frac{10.5 \times 10^{-3} \times 2.5 \times 10^{-3}}{4.1 \times 10^{-6} \times 4}$$

$$= 1.6\ Wb/m^2$$

3.6 Inductive Transducers:

Inductive transducers are analog passive transducers. These transducers operate on:

1. Variation of self inductance of the coil
2. Variation of mutual Inductance of the coil
3. Production of Eddy currents

1. Transducers Operating on the principle of Variation of Self Inductance:

The self inductance of coil is, $L = \frac{N^2}{l/\mu A} = \frac{N^2 \mu A}{l} = N^2 \mu G$ --- (3.14)

G = Geometric form factor

From the eqn (3.14) it is obvious that self inductance of a coil can be varied by varying the no. of turns on the coil, the permeability of magnetic material or by changing the geometrical configuration of the magnetic circuit.

1) By Variation of No. of turns of coil:

These types of Inductive transducer working on the principle that self inductance is varied due to the change in no. of turns on the coil.

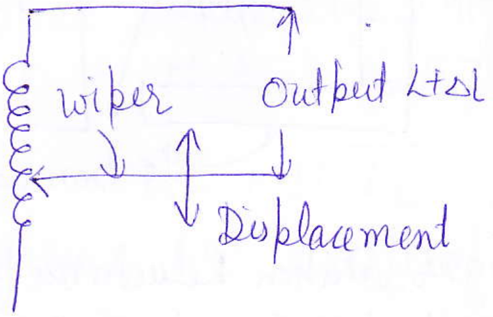

Fig. 3.19 Inductive Transducer for measurement of Linear Displacement

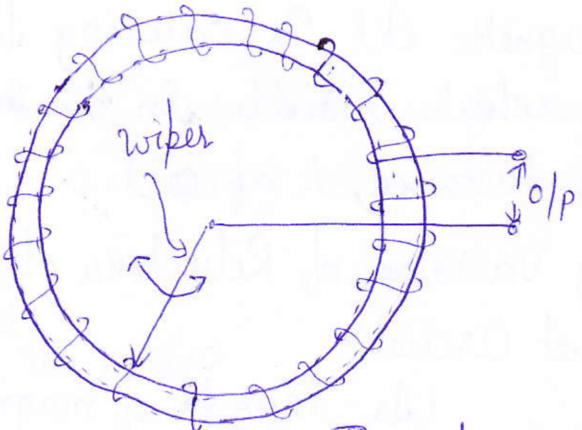

Fig. 3.20 Inductive Transducer for Measurement of angular displacement

Air or iron cored coil can be used in these transducers, depending mainly on working frequency or other requirements. Air-cored coils can be operate at high frequencies because of absence of eddy current losses in the air cores. The inductance of air-cored coils is independent of coil current as the permeability of air is constant. But changes in air cored coils are small ∵ of low permeability of air. Iron cored coils produce large inductance variations with better defined magnetic ckts. due to high permeability of iron cores.

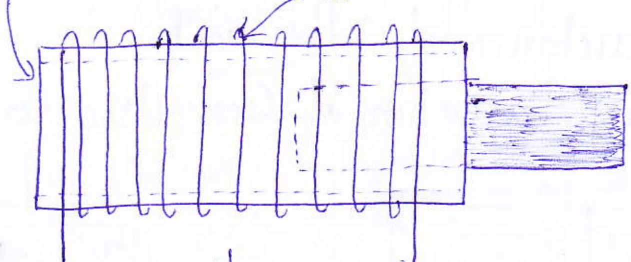

Fig. 3.21 Inductive Transducer for Measurement of Linear Displacement

(b) By Variation of Permeability of The Magnetic Ckt:-

Such a transducer has a coil wound on a former (non-conductive tube) & an iron the coil. When the iron core is completely inside the coil, self inductance of coil is max. ∵ of ↑ed value of flux. As the iron core moves out, reluctance of the magnetic ckt. ↑s causing ↓ in flux which results in ↓ in self inductance, L of coil.

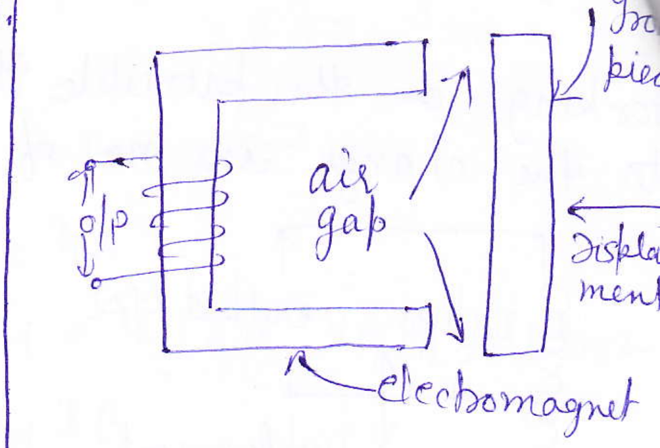

Fig 3.32 Variation Reluctance type Inductive transducer for measurement of linear Displacement

(C) By Variation of Reluctance of the Magnet Circuit:

As length of magnetic path varies with the displacement so reluctance of the magnetic ckt. changes causing change in self inductance of the coil.

$$S = S_1 + S_g$$

where S_1 = Reluctance of iron path

S_g = Reluctance of air gap.

& Self inductance of coil, $L = \frac{N^2}{S_g}$

So, self inductance of coil is inversely proportional to reluctance of the coil.

(d) By Variation of Geometric Configuration of the Magnetic Circuit:

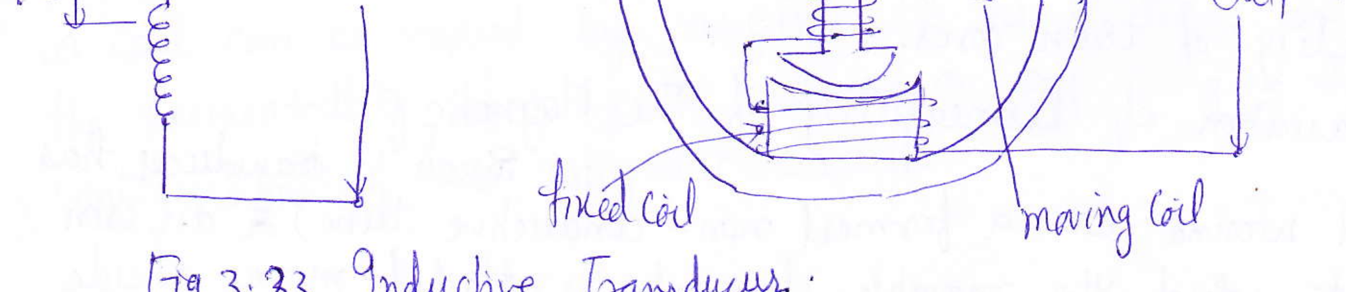

Fig 3.33 Inductive Transducers.

The displacement makes one part of the coil to move w.r.t. another part & so change the geometric configuration of the coil. Thus the self inductance of the coil is changed.

2. Transducers Operating on the Principle of Variation of Mutual Inductance:

Mutual Inductance between two coils is given by

$$M = K\sqrt{L_1 L_2} \quad --- (3.15)$$

Where K = Coeff. of coupling

L_1, L_2 = Self inductances of the coils

In such transducers two or more coils are used & mutual Inductance between the coils is varied as per measurand. A simple application of inductive transducer using this principle of measurement of linear displacement. In such a transducer, both the coils are in series so have inductance of both coils & mutual inductance b/w the coils. The inductance of such an arrangement varies from L_1+L_2-2M to L_1+L_2+2M.

With displacement, moving iron piece causes change in air gap of the magnetic circuit, so change in magnetic flux linking with the coils resulting change in mutual inductance b/w the coils. This change in mutual inductance is sensed by the bridge circuit.

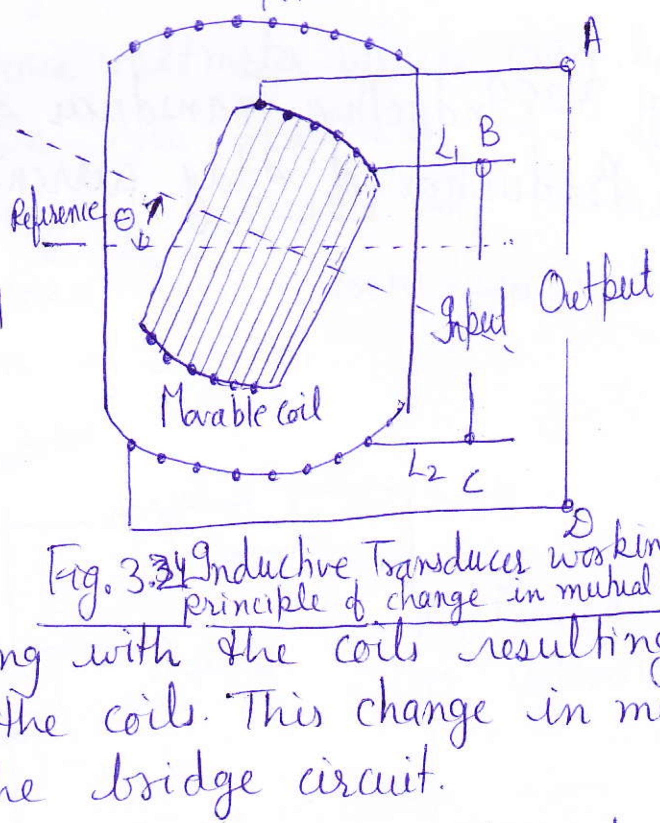

Fig. 3.34 Inductive Transducer working on principle of change in mutual Inductance

3. Transducers Working on Principle of Production of Eddy Currents: These transducers operate on the principle that when a conducting plate is kept near a coil carrying alternating current, eddy currents are induced in conducting plate, producing ... field in opposition to the main field

created by the coil. Thus eddy currents induced in the conducting plate reduce the net flux linking with the coil & so the inductance of the coil is reduced. The nearer is the plate to the coil, the higher are the induced eddy currents & so higher is the reduction in inductance of the coil. Thus, the inductance of the coil changes with the movement of the plate.

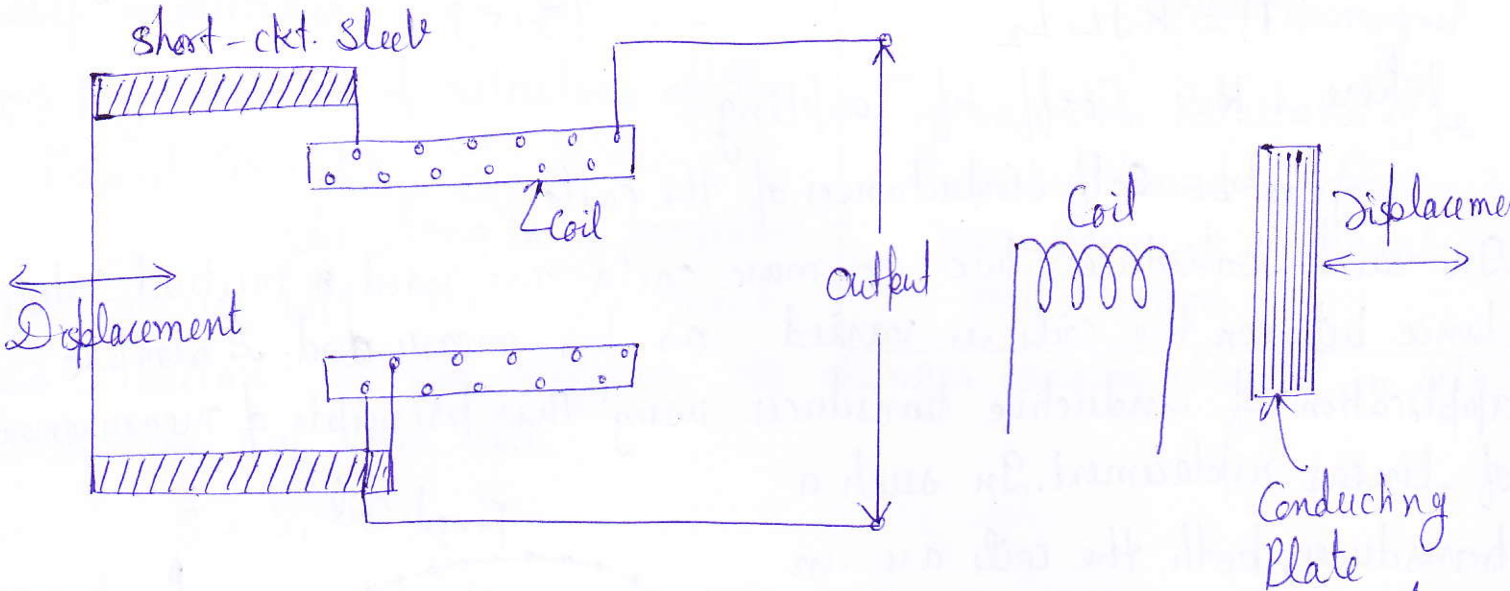

Fig. 3.25 Inductive Transducer working on the principle of Production of eddy currents for measurement of linear Displacement

3.7 Electromagnetic Tachometers:

There are two types of electromagnetic tachometers.

1. Dc generator Tachometer
2. Ac generator Tachometer

1. Dc generator Tachometer:

It is an ordinary miniature dc generator consisting of a small aperture rotating in a constant magnetic field. The magnetic field is created either by magnetic field mounted on a stator or by separately excited electromagnet on the stator. The armature is coupled to the shaft of the m/c whose speed is to be measured. The emf generated by this transducer is proportional to the speed of rotation of armature called coupled mechanically to the shaft of the test m/c. The emf is measured with a high resistance voltmeter which may be calibrated in terms of rpm. One nice feature of this type of transducer is that propert palarity of generated emf reverses when direction of rotation reverses. Hence such a transducer indicates the speed as well as direction of rotation.

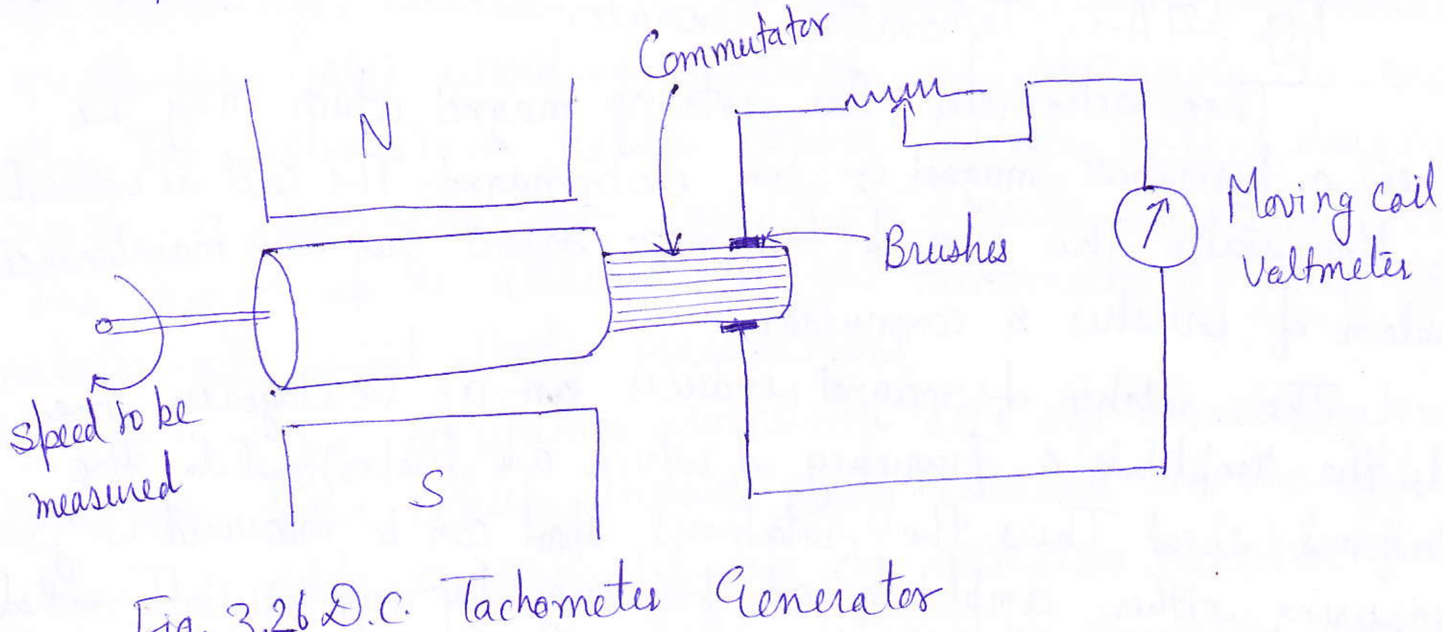

Fig. 3.26 D.C. Tachometer Generator

Advantages:

⊗ The direction of rotation is directly indicated by the polarity of o/p.

⊕ The o/p voltage is typically 10mv/rpm & can be measured with conventional type d.c. generator.

Disadvantages:

A d.c. generator tachometer has a maintenance problem of commutator & brushes whose resistances may vary & cause error.

The main magnetic field becomes distorted & gives rise to non-linear relation between the o/p voltage & rotational speed in case the armature current becomes high.

2. AC Generator Tachometer:

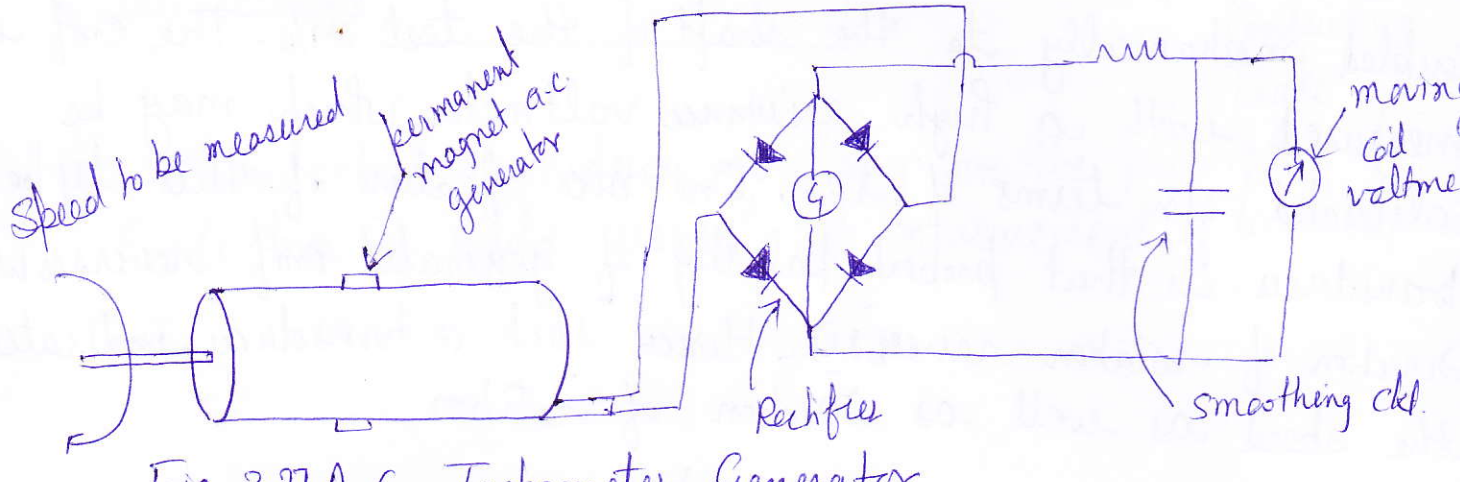

Fig. 3.27 A.C. Tachometer Generator

The ac tachometer has rotating magnet which may be either a permanent magnet or an electromagnet. The coil is wound on the stator. This type of tachometer doesn't give any maintenance problem of brushes & commutator.

The rotation of magnet induces an ac voltage in the coil, the amplitude & frequency of which are proportional to the rotational speed. Thus the rotational speed can be measured by measuring either amplitude or frequency by any suitable method. The o/p voltage of a.c. tachometer generator is rectified & measu with a permanent magnet moving coil instrument.

* Limitations:

At low speed, frequency is low so it is very difficult to smooth out the ripples in the O/P voltage waveshape & hence a-c tachometer generators are designed to have a large no. of poles so that freq. of o/p voltage is high even at low speeds.

(II). In a-c tachometer generator, high speed also creat problem

3. Drag Cup Rotor A-C Tachometer:

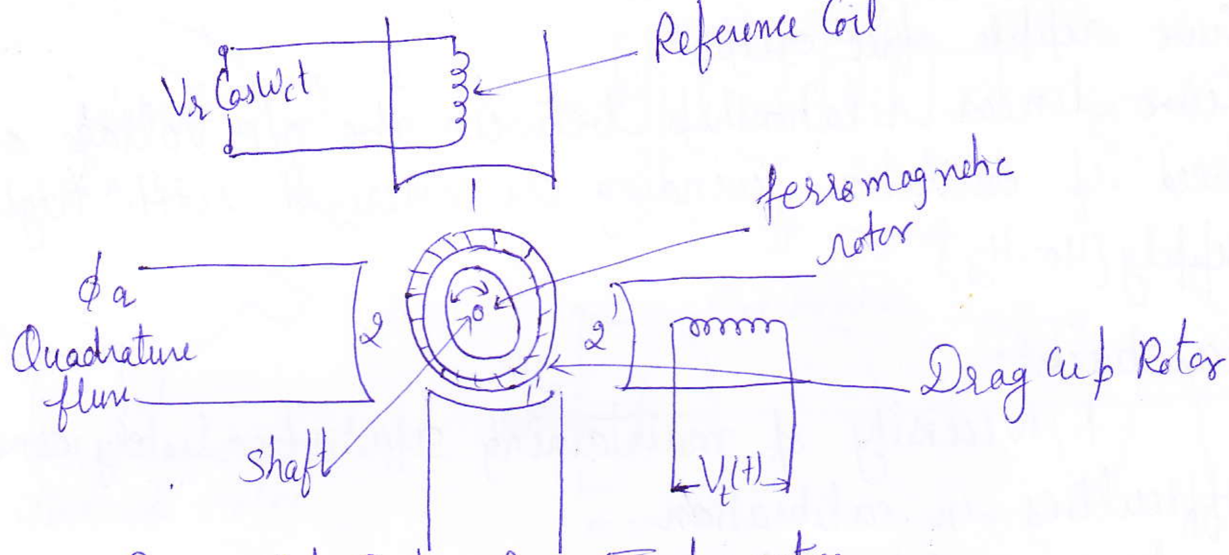

Fig. 3.28 Drag Cup Rotor A.C. Tachometer

In drag cup rotor, the stator has two sets of windings, called the reference (excitation) winding & quadrature (O/P) winding, mounted at rt. angle to each other. The rotor is a hallow copper cylinder, called drag cup, with a laminated iron core which doesn't contact the cup. The drag cup is attached to the tachometer I/P shaft & rotates at speed under measurement.

The excitation winding sets up an alternating magnetic field which induces eddy currents in the copper cup. The eddy currents set up an armature reaction field at right angles to the field set up by excitation winding. The rt. angle field then induces an ac output voltage in output winding. With the rotor stationary the output voltage is essentially zero. Rotation of rotor in one direction induces a a.c. o/p of the same freq. as that of input & amplitude proportional to the instantaneous speed & in phase with voltage.

Merits of Drag Cup A-C Tachometers:

1. Rugged in construction
2. Cheaper in cost
3. Require little maintenance
4. Give ripple free output
5. Give linear relationship between the o/p voltage & rotational speed if excitation winding is enerized with high frequency supply (400 Hz).

Drawbacks:

I. Necessity of maintaining I/P absolutely constant.
II. Difficulties in calibration
III. Non linear relationship between output voltage & rotational speed at very high speed.

3.8 Variable Reluctance Pick Up/ Toothed Rotor Tachometer:

It consists of a metallic toothed rotor mounted on the shaft of the m/c whose speed is to be measured & a permanent magnet with a coil of wire wrapped around it.

Usually rotor is made with 60 teeth. The magnet is placed near the toothed rotor with an air gap of the order of 0.3 mm. When the rotor rotates, the teeth come into close proximity with the magnet, the air-gap reluctance is low and when there is no tooth near the magnet the air gap reluctance is high. Variation in reluctance causes variation in flux, which in turn induces an em emf in the coil wrapped on the permanent magnet. This induced emf / o/p voltage is in form of pulses with a variety of waveshapes. The freq. of the o/p pulses depend on the no. of teeth on the rotor & the rotor speed.

$$f\,(\text{pulses/sec}) = \text{Speed of rotation in rps} \times \text{no of teeth on rotor}$$

$$\text{Rotational speed in rpm} = \frac{60f}{\text{No. of teeth on rotor}}$$

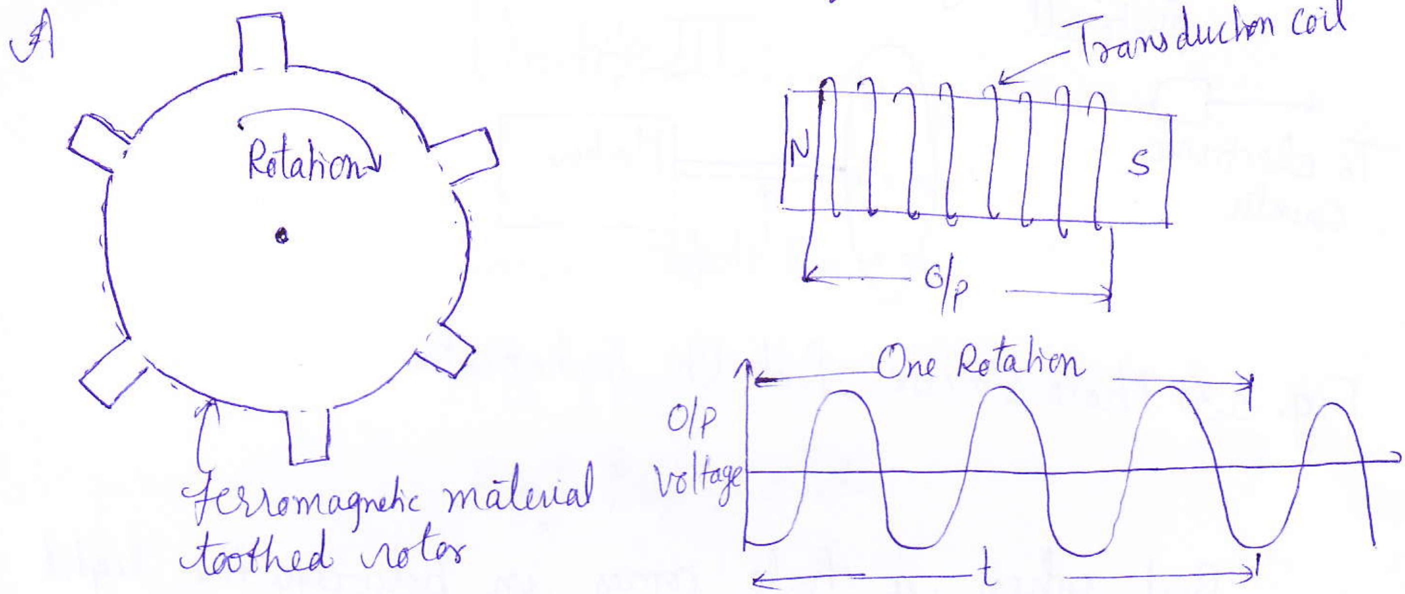

Fig. 3.29 Toothed Rotor Tachometer

Advantages of Toothed Rotor Tachometer:

* These are simple & rugged in construction.
* Easy to calibrate
* Don't need any maintenance
* Give the information that can be easily transmitted

The main drawback of such tachometers is that these can't measure small speeds because at low speed the magnitude of induced voltage pulses may not be sufficient to trigger the counter.

3.9 Photo electric Tachometer:

Such a tachometer essentially consists of light source, a photocell & a rotating disc placed between the light source & the photocell. The disc has a no. of equidistant holes on its periphery & is mechanically coupled to the shaft of the machine whose speed is to be measured. When the opaque portion of the disc is between the light source & the photocell, the latter doesn't get illuminated & so doesn't give any output.

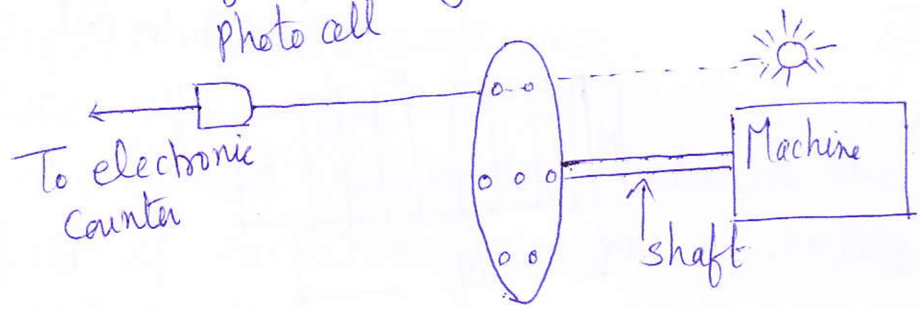

Fig. 3.30 Photo Electric Pick Up Tachometer

But when a hole comes in between the light source & photocell, the light falling upon the cell gives an output pulse. Thus the photovoltaic cell is constantly turned on & off, at a freq. which depends on the no. of holes on the disc & speed of rotation.

$$f = \text{Speed in rps} \times \text{no. of holes on disc}$$

$$\text{Rotational speed in rpm} = \frac{60 f}{\text{No. of holes on disc}}$$

As the no. of holes in disc is fixed & known so the rotational speed can be determined simply by measuring the pulse rate with an electronic counter, which can be calibrated to indicate directly the speed of rotation in rpm.