UNIT 8

1. Illustrate the principle of force summing devices using suitable examples and sketches?

Ans: Force summing devices serve as primary transducers and convert the pressure applied at the input into displacement, which then can be measured by means of secondary transducer. The lists of most widely used force summing devices are

1. Diaphragms
2. Bellows
3. Bourdon tubes

1. Diaphragms

Any thin metal whose ends are fixed between two parallel plates is referred to as diaphragm. It is one of the pressure measuring elements. The operating principle is the applied pressure is converted into proportional displacement. The materials used to make diaphragms are phosphor bronze, nickel, beryllium copper, stainless steel, etc. These can be available in flat or corrugated shapes.

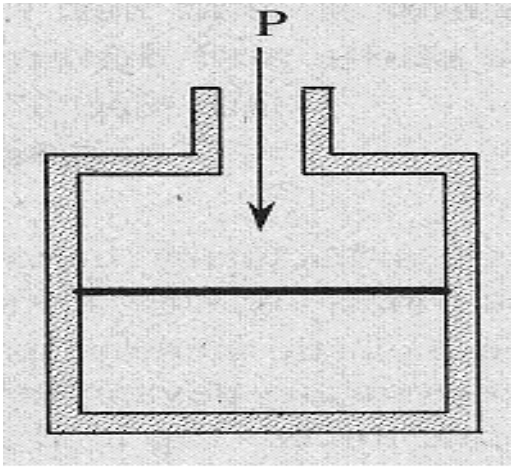

fig 1.1. Flat diaphragm for absolute pressure measurement

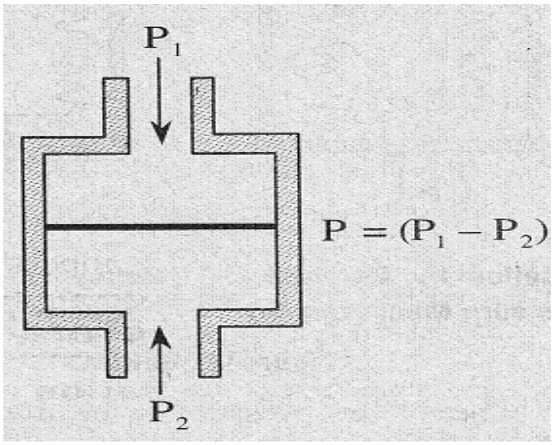

fig 1.2 Flat diaphragm for differential pressure measurement

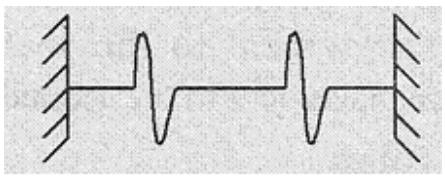

fig 1.3 corrugated diaphragm

When two corrugated diaphragms are joined together at their ends a capsule is formed. When compared to flat diaphragms corrugated diaphragms produce greater displacements. Since the capsule is a combination of two diaphragms it generates more displacement which is twice that of the single corrugated diaphragm. This generated displacement is proportional to the applied pressure.

2. Bellows

Bellows, the pressure measuring elements are formed by the series combination of capsules. The working principle of bellows is same as that of diaphragms i.e., the applied displacement is converted into proportionate mechanical displacement. The materials used to construct bellows are beryllium copper, brass, monel, stainless steel and nickel.

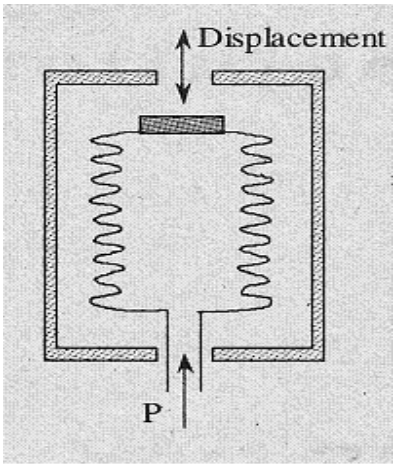

fig 1.4. Bellow for absolute pressure measurement

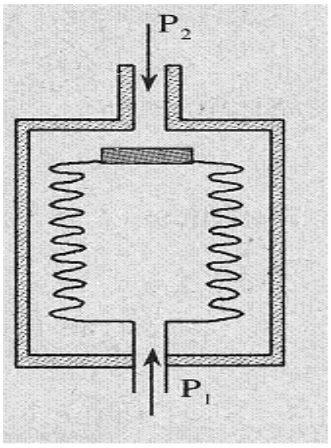

fig 1.5. Bellow for differential pressure measurement

Whenever the pressure to be measured is applied the sealed end of bellow suffers displacement. The generated displacement can be known by attaching a pointer scale arrangement to the sealed end or by transmitting the displacement to the secondary transducer.

3. Bourdon Tubes

The bourdon tubes are available in different shapes such as spiral, helical, twisted and C shaped. However all the tubes have non-circular cross-section. Also the materials used and working of all these types are same. The materials used in the construction of bourdon tubes are brass, steel and rubber.

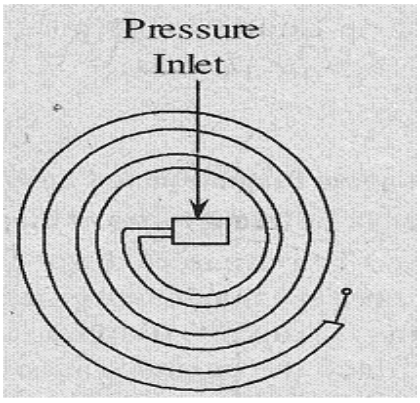

fig 1.6. Spiral type Bourdon Tube

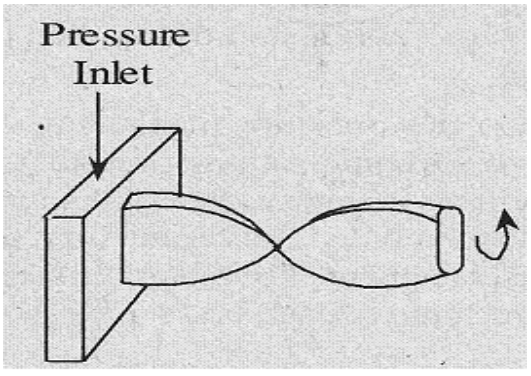

fig 1.7 Twisted Tube Bourdon Tube

The working principle of bourdon tube is same as that of diaphragms and bellows i.e., the applied pressure is converted into mechanical displacement.

The displacement generated by the above force summing devices can be converted into electrical form by transmitting it to LVDT. The output voltage generated by LVDT is proportional to displacement and hence applied pressure.

2. Explain general Data Acquisition System (DAS) with a neat block diagram?

Ans:

The block diagram of a general Data Acquisition System (DAS) is shown in the figure below. It consists of the following elements.

1. Transducer
2. Signal conditioner
3. Multiplexer
4. Analog to Digital Converter
5. Recorders and Display devices

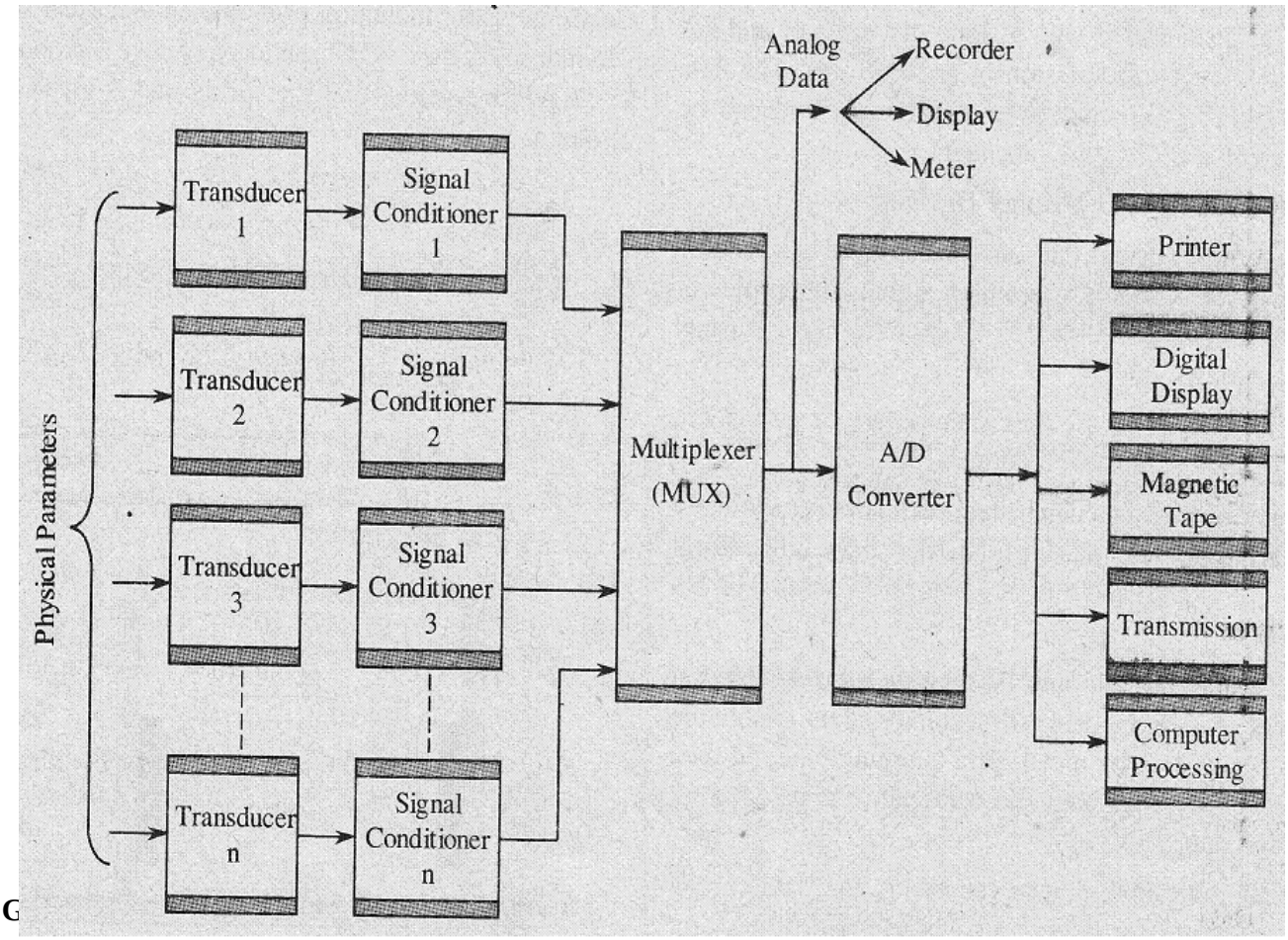

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fig 2.1 Genralized Data Acquisition System

1. Transducer

A transducer is used to convert the physical parameters corning from the field into electrical signals or it is used to measure directly the electrical quantities such as resistance, voltage, frequency, etc.

2. Signal Conditioner

Usually the output signals of the transducer will be of very low level (weak) signals which cannot be used for further processing. In order to make the signals strong enough to drive the other elements signal conditioners such as amplifiers, modifiers, filters etc., are used.

3. Multiplexer

The function of the multiplexer is to accept multiple analog inputs (after signal conditioning) and provide a single output sequentially according to the requirements.

4. A/D Converter

The analog-to-digital (A/D) converter is generally used to convert the analog data into digital form. The digital data is used for the purpose of easy processing, transmission, digital display and storage.

Processing involves various operations on data such as comparison, mathematical manipulations, data is collected, converted into useful form and utilized for various purposes like for control operation and display etc.

The transmission of data in digital form is possible over short distances as well as long distances of and has advantages over transmission in analog form. The data can be stored permanently or temporarily and can be displayed on a CRT or digital panel.

5. Recorders and Display Devices

In display devices the data is displayed in a suitable form in order to monitor the input signals. Examples of display devices are oscilloscopes, numerical displays, panel meters, etc.

In order to have either a temporary or permanent record of the useful data recorders are used. The analog data can be recorded either graphically or on a magnetic tape. Optical recorders, ultraviolet recorders, styles-and-ink recorders are some of its examples.

The digital data can be recorded through digital recorders. The digital data is first converted into a suitable form for recording by means of a coupling unit and then recorded on a magnetic tape, punched cards or a perforated paper tape.

3. Show and explain the capacitive transducer arrangement to measure angular velocity and what are its limitations?

Ans:

The arrangement of capacitive transducer in the arrangement of angular velocity is shown figure 3.1

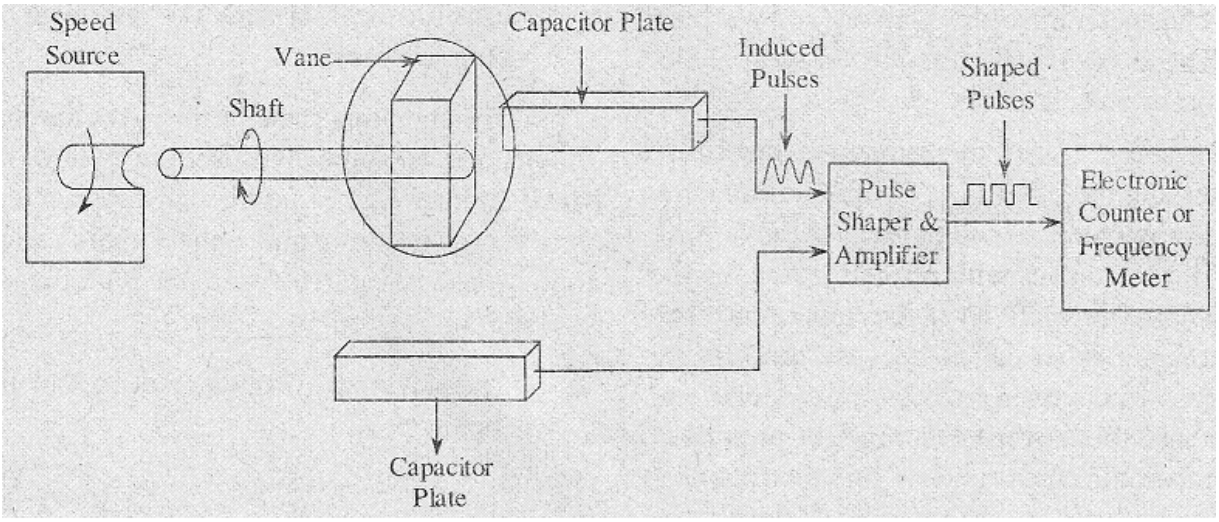

fig 3.1 Capacitive Tachometer Arrangement

The main components of a capacitive tachometer arrangement are given as follows,

1. Fixed capacitor plates
2. A vane attached to one of the two ends of a shaft
3. A pulse shaper and amplifier circuit
4. An electronic counter or frequency meter.

The vane is placed between the two fixed plates of capacitor and the free end of the shaft is connected to the source whose angular velocity is to be determined. Therefore the shaft rotates along with the source, which in turn rotates the vane between the plates. Due to this the capacitance of the capacitor changes. For every rotation of the vane a change in capacitance takes place and for every changed capacitance value, a voltage pulse is induced. The number of times the capacitance value changes per unit time gives the angular velocity of the rotating shaft.

The induced pulses are applied to pulse shaper and amplifier circuit which shapes the pulses into accurate pulses and then amplifies the pulses. These shaped and amplified pulses are then applied to electronic counter which counts the number of pulses. The counted number of pulses directly gives the value of angular velocity.

Limitations:

1. Capacitive transducers are highly sensitive to temperature. Therefore any variation in temperature affects the performance of the instrument.

2. High output impedance of capacitive transducers lead to loading effects.

3. The presence of duct particles, moisture, etc., changes the capacitance of the capacitor. Due to this error occurs in the output.

4. What are the main elements of velocity transducer?

Ans: The main elements of a velocity transducer are coil and a permanent magnet. In such type of transducers velocity is measured based upon electromagnetic induction principle. These two elements can be arranged in two different configurations (i.e., electrodynamic and electromagnetic) to measure the velocity.

In electrodynamics velocity transducer, moving coil scheme is employed. In this configuration the coil and the magnet are arranged in housing such that the magnet is attached to the base of the housing and the coil is attached to the other side (top) of the housing with the help of a spring so that the coil is suspended in the magnetic field as shown in the figure below. The body whose velocity is too measured is connected to the base of the housing.

Due to the displacement of the body, the housing also gets displaced which in turn caused a displacement of the coil in the magnetic field. This movement of the coil causes a change in the flux linkages between the Magnet and the coil, and thus according to the electromagnetic induction principle an electrical voltage gets induced in the coil. This induced voltage is proportional to the relative velocity of the spring and is given by the equation.

$$e = BLV_r \mathbf{X}\ 10^{-8}$$

Where,

e-Induced voltage

B-Flux density

L-Length of coil

Vr=dx/dt=relative velocity of coil with respect to magnet (cm/s)

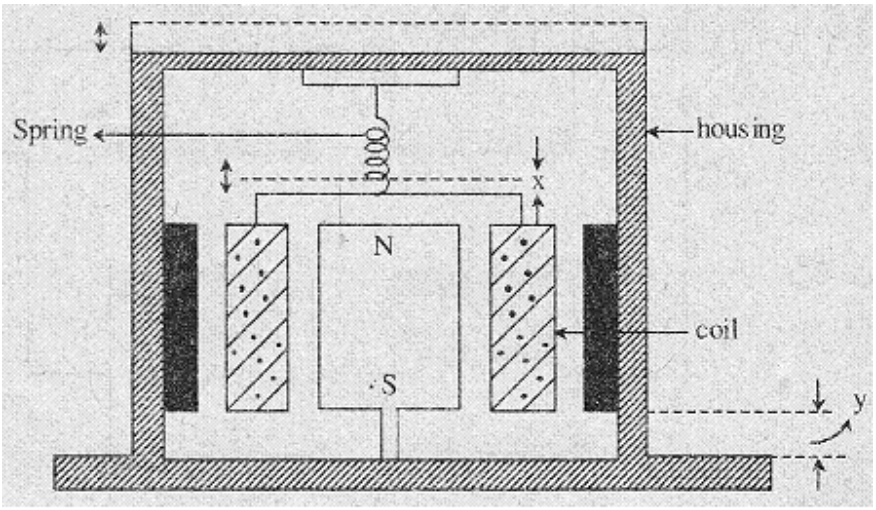

fig 4.1 Velocity transducer

5). Explain about Linear Variable Diffrential Transformer (LVDT)?

Ans: Linear Variable Differential Transformer (LVDT) consists of one primary winding *(P)* and two secondary windings (51 and S2).with equal number of turns wound on a cylindrical former. The two secondary windings are connected in series opposition and are placed identically on either side of primary winding to which an AC excitation voltage is connected. A movable soft iron core is placed within the cylindrical former. When the displacement to be measured is applied to the arm of the core, the LVDT converts this displacement into an electrical signal. The construction of LVDT is illustrated in figure (5.1).

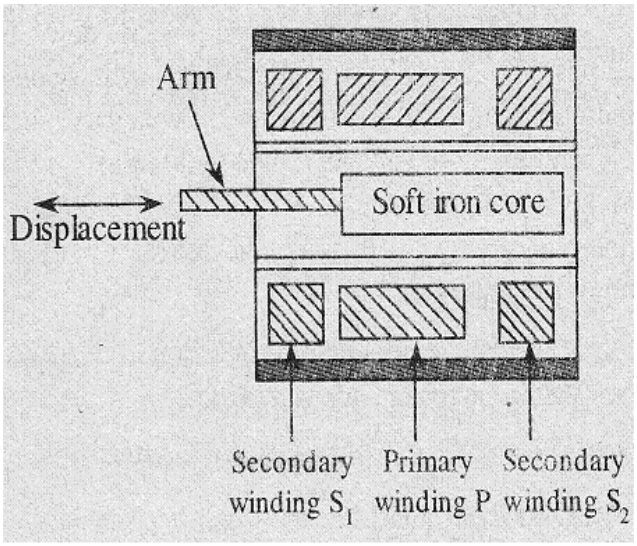

fig 5.1 Construction of LVDT

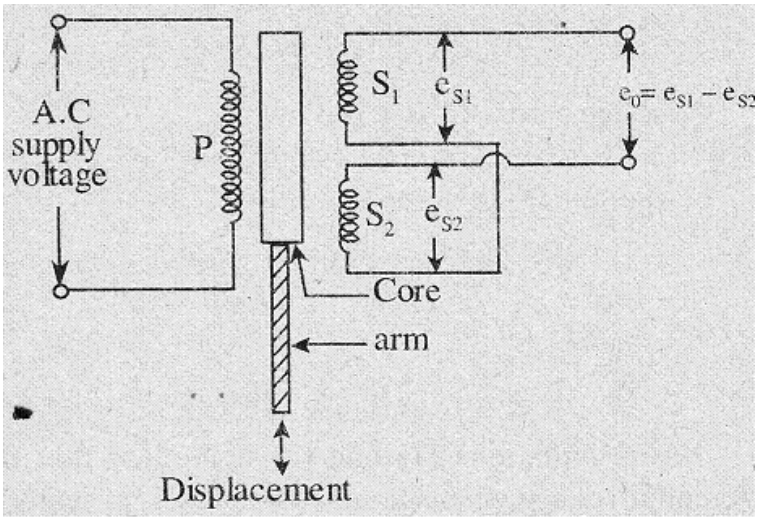

fig 5.2 Circuit Diagram of a LVDT

The operating principle of LVDT depends on mutual inductance. When the primary winding is supplied with A.C. supply voltage, it generates alternating magnetic field. Due to this magnetic field an alternating voltage will be induced in the two secondary windings. In the figure (5.2) e_{s1} is the output voltage of secondary winding S_1 and e_{s2} is the output voltage of secondary winding S_2 In order to get single differential output voltage two secondary windings are connected in series opposition. Thus the differential output voltage is given by,

$$e_0 = e_{s1} - e_{s2}$$

When the core is placed symmetrically with respect to two secondary windings an equal amount of voltage will be induced in both windings. Therefore e_{sl} - e_{s2} and the output voltage is '0'. Hence, this position is known as null position. Now if the core is moved towards up from null position, more magnetic field links with secondary winding S_1, and small field links with secondary winding S_2. Therefore more voltage will be induced in S_1 and less in S_2 i.e., e_{s1} will be larger than e_{s2}. Hence the differential output voltage is e0=es1-es2 and is in phase with primary voltage.

But when the core is moved towards down from null position more magnetic field links with secondary winding S_2 and small field links with secondary winding S_1. Therefore more voltage will be induced in S_2 and less in S_1, i.e.,e_{s2} will be larger than e_{s1}. Hence, the differential output voltage is $e_0 = e_{s2} - e_{s1}$ and is 180° out of phase with primary voltage. Thus the output voltage e_0 position of the core and hence the displacement applied to the arm of the core.

Merits

1. LVDT has good linearity i.e.. it produces linear output voltages.
2. It can measure displacements of very high range usually from 1.25mm to 250mm.
3. It has high sensitivity.
4. Since it produces high output, it does not require amplifier devices.
5. It has low hysteresis.
6. It consume less power (about < 1w)

Demerits

1. It is sensitive to stray magnetic fields.
2. Performance of LVDT is affected by variations in temperature.
3. It has limited dynamic response.
4. To provide high differential output, it requires large displacements.

6. Explain spiral type bourdon tube ?

Ans:

Principle

The working principle of spiral type bourdon tube is that the applied pressure is converted into mechanical deflection or displacement. The generated displacement will give the value of applied pressure. The materials used in the construction of bourdon tube are brass, steel and rubber.

Construction and Working

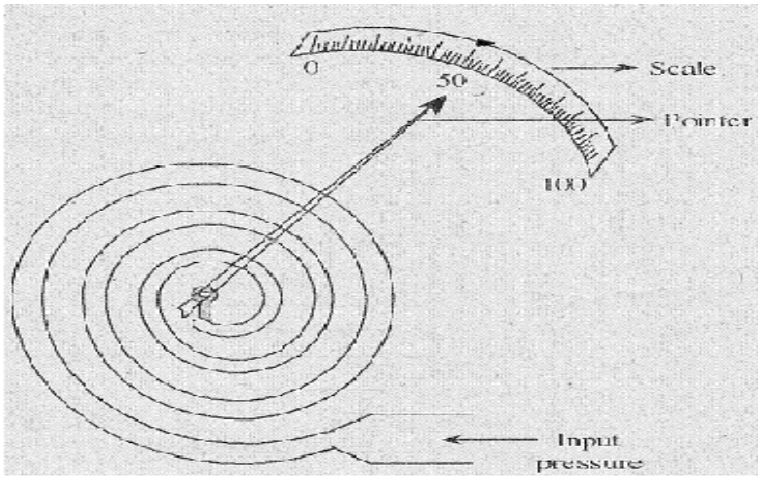

fig 6.1 Spiral type Bourdon tube

Spiral type bourdon tubes are constructed by winding the long tube into several turns in the form spiral shape. One end of the bourdon tube is opened through which the pressure to be measured is applied whereas another end is closed. The sealed end of the tube is connected to a pointer mechanically.

Whenever the fluid whose pressure is to be known is applied to the open end of the spiral tube, it tends to uncoil. Due to this a long movement of the tip (end) takes place and this displacement is transmitted to pointer. Therefore the pointer moves on the calibrated scale, thereby indicating the applied pressure. When compared to C-type bourdon tube spiral type bourdon tube produces the results with very high accuracy.

7. Explain how pressure is measured using Piezoelectric transducer?

Ans:

Principle and Design

Piezoelectric pressure transducers depend on the principle of 'piezoelectric effect' i.e., when some pressure or stress is applied to the surface of the piezoelectric crystal, an electric charge voltage will be developed by the crystal. The materials used in the construction of piezoelectric crystals are quartz, Rochelle salt, dipotassium titrate, lithium sulphate, barium titanate etc.

A piezoelectric pressure transducer is formed by connecting a diaphragm to the piezoelectric crystals and this assembly is shown below.

Working

The pressure which is to be measured is applied to corrugated metal diaphragm. The diaphragm deflects depending on the applied pressure, and this deflection signal is transmitted to the crystal through the mechanical link. In other words, the pressure is applied to the crystal through the the diaphragm and the link. When the crystal senses the pressure it will generate some voltage corresponding to the applied pressure, and the output is measured in measuring voltage is calibrated in device which terms of pressure.

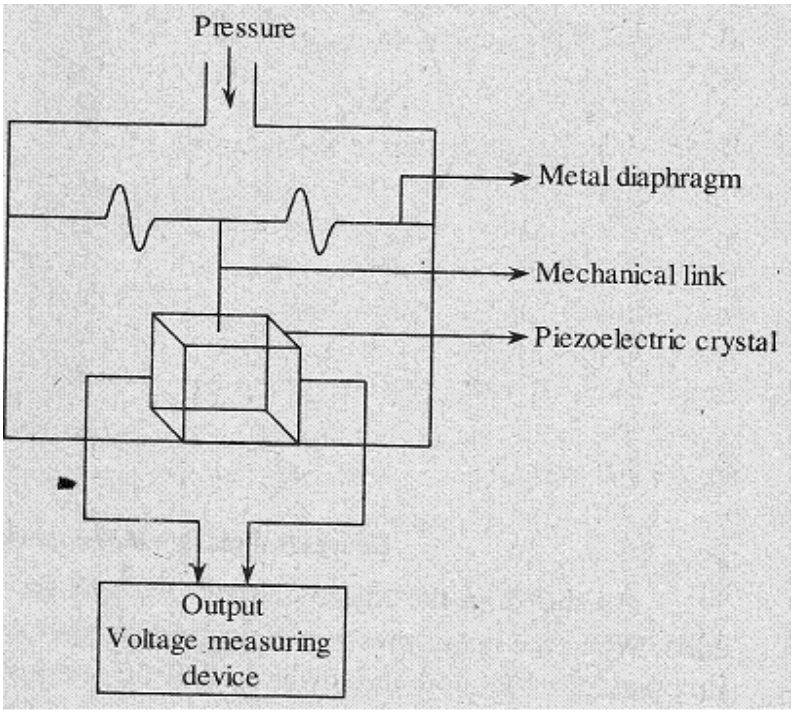

fig 7.1 Piezo electric pressure transducer

Applications

(a) These can be used in the process which

high
(b) Can be

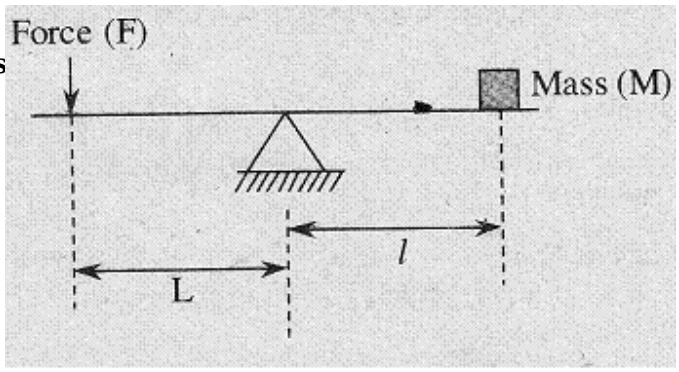

fig 8.1 Balance (Lever System)

requires measurement of pressure.
applied in those systems which requires measured variable in electrical form.

Merits

1. Provides electrical output.
2. This transducer does not require any external power supply.
3. Size in small.
4. Rugged construction.

Demerits

1. It cannot be used for static pressure measurements.
2. The response will get affected by the variations in temperature.
3. In some cases it requires signal conditioning circuitry which is complex.
4. Cost is high.

8. Briefly explain the working principles and measurement of force by any two nonelectric techniques?

Ans: The principles used for the measurement 'of force by non-electrical techniques are,

1. Balance principle
2. Force to pressure conversion principle.

In balance principle, the force to be measured is balanced by a known certain quantity and then the value of unknown force is determined from the amount of balancing quantity required to balance the force. In force to pressure conversion principle, the unknown force is converted into pressure. This pressure is measured and then the value of unknown force is determined from the measure of this pressure. Based on the above principles, the non-electrical devices used for measurement of force are as follows,

(i) Balance type force measuring device

(ii) Hydraulic and pneumatic load cell.

(i) Balance type force measuring device: The force measuring device based upon the principle of balance is usually a simple lever system as shown in figure (8.2) below. This system consists of a rod resting on a pivot at a certain point along its length.

The force to be measured is applied on one of the rod, at a distance T from the pivot. This makes the lever system to be unbalanced. To balance the system, a mass of known value «m' is placed on the other end of the rod, at a distance T from the pivot. At balance, the lever system satisfies the following condition.

$$FL = mgl$$

Where,

g = Acceleration due to gravity/gravitational constant.

The unknown force F can be calculated from the above balance equation.

(ii)Hydraulic and Pneumatic Load Cells

The hydraulic and pneumatic load cells are non-electric type force measuring devices, which provide the measure of force in terms of pressure.

In a hydraulic load cell, a chamber is filled with a liquid (usually oil) and the top/mouth of the chamber is filled with a diaphragm (i.e., the internal edge of the diaphragm is in contact with the oil). The force to be measured is applied on top of 'the diaphragm.

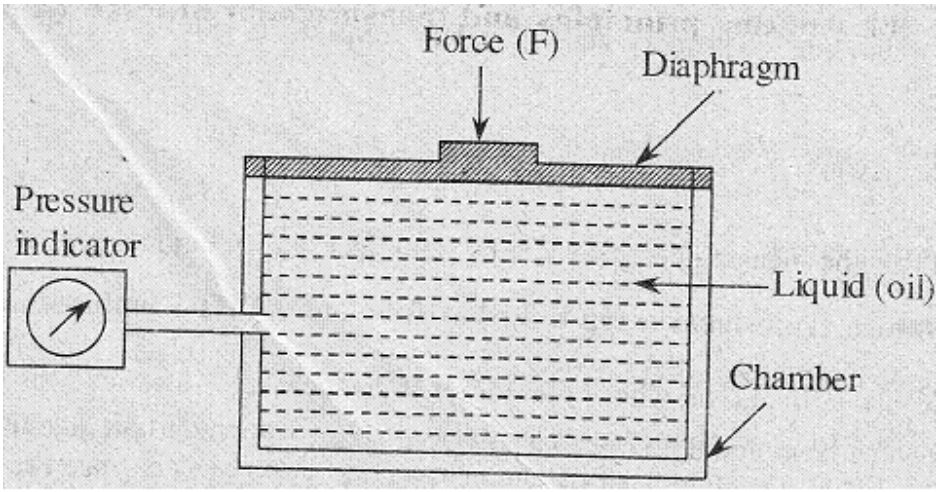

fig 8.2 Hydraulic Load Cell

Due to the application

of force, the diaphragm gets deflected and downwards, thereby produces pressure on the liquid.

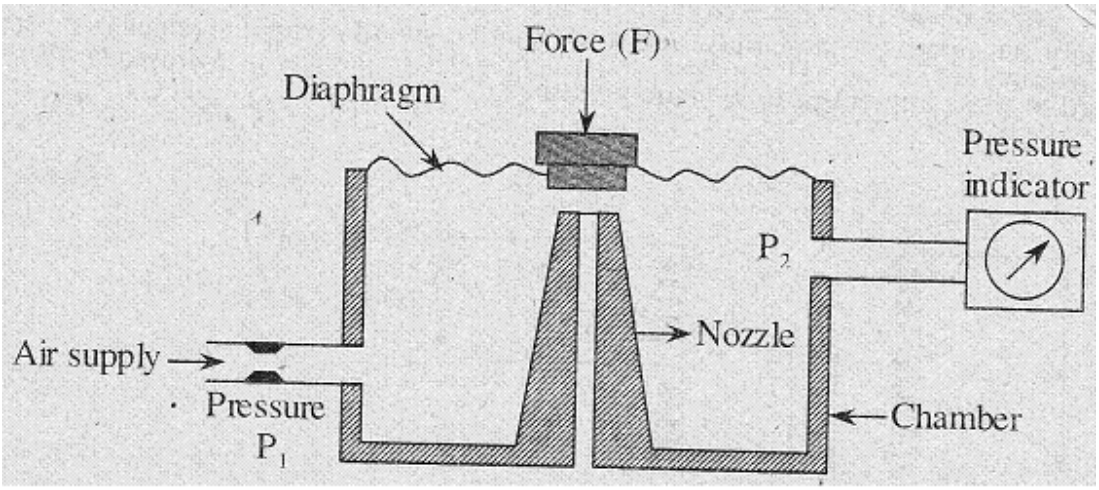

fig 8.3 Pneumatic Load Cell

The pressure indicator connected to the chamber indicates the amount of liquid pressure created by the force. Very large forces of the order of mega Newton's can be measured by a hydraulic cell.

The pneumatic load cell consists of a diaphragm at one end of its chamber and a nozzle at the other end as shown in the figure below. The chamber is provided with a supply of air, under pressure. When unknown, force is applied on the diaphragm, the diaphragm deflects. Due to deflection of the diaphragm, the gap between the nozzle and the diaphragm changes. As a result the air pressure in the chamber also changes. As the gap reduces, the pressure in the chamber increases. A pressure indicator attached to the chamber indicates the air pressure in the chamber. The unknown force can then be evaluated from the measure of the air pressure. Forces upto 20KN can be measured by pneumatic load cell.

9). Explain the working principle of potentiometric type accelerometer?

Ans A potentiometric accelerometer employs a seismic mass, spring arrangement, dashpot, and a resistive element. The seismic mass (potentiometer) is connected between spring and dashpot. The wiper of the potentiometer is connected to the mass.

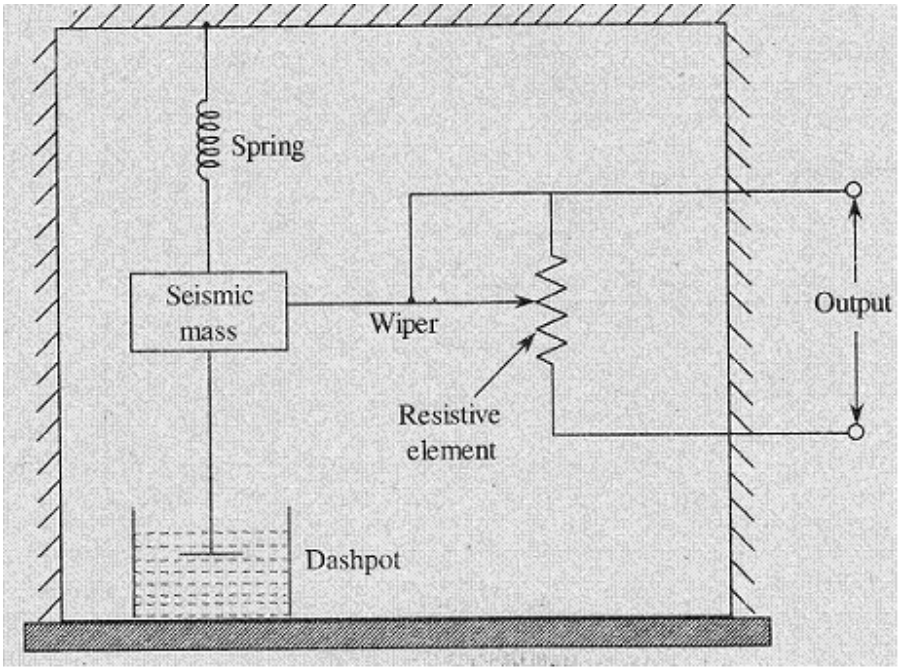

fig 9.1 Potentiometric accelerometer

In the presence of vibration or acceleration, vibrational displacement of seismic mass takes place with respect to the housing of the device. The displacement of mass is transferred to the potentiometers through the wiper. Therefore the resistance of the potentiometer changes. This change in resistance gives the value of displacement and hence the acceleration.

Advantages

1. Construction and operation are very simple.
2. Low cost.

Disadvantages

1. Resolution is low.
2. They cannot be suitable for high frequency vibrations.

10. Explain the stroboscopic method of measuring the angular speed?

Ans:

Stroboscopic Method

The periodic or rotary motions can be measured by using a device known as stroboscope. A stroboscope is a device that consists of a source of variable frequency flashing

brilliant light called Strobotron. The flashing frequency of Strobotron is controlled by a variable frequency oscillator.

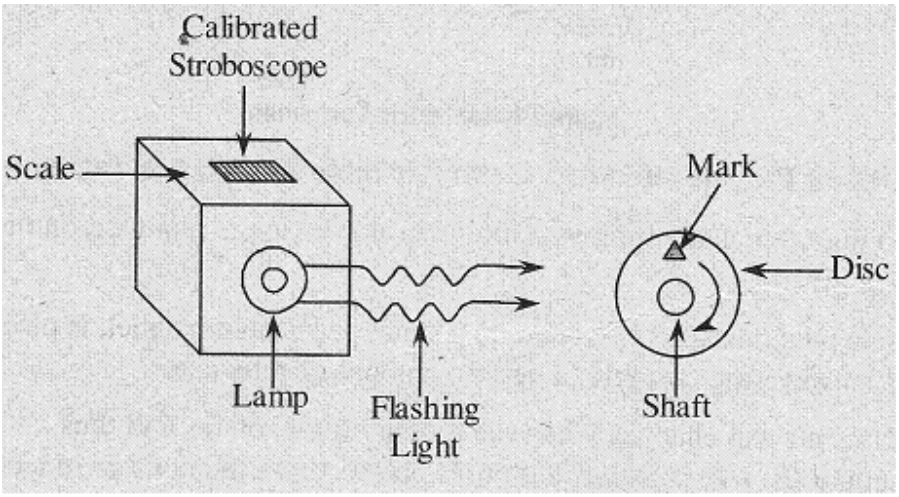

fig 10.1 Shaft Speed Measurement Using Stroboscope

The principle involved in measurement of speed through stroboscope is to make the moving objects visible only at specific intervals of time by adjusting the flashing frequency. The figure below shows a stroboscope measuring the speed of shaft.

The speed of the shaft using a stroboscope is measured in the following manner.

An identification mark is made directly on the shaft or on a disc mounted on the shaft. The flashing light from the stroboscope is made to fall on the mark and the frequency of flashing is adjusted so that the mark appears to be stationary. Under such condition the speed of rotation is equal to the flashing frequency.

The speed can be read directly from the scale of the stroboscope which is calibrated in terms of speed.