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Department of ECE
Course Code: 18ECO133T Subject Name: SENSORS AND TRANSDUCERS

UNIT-V

Measurement of Non-electrical quantity: Introduction Flow Measurement - Introduction, ultrasonic flow meters, Hot wire Anemometers. Electromagnetic flow meters principle and types. Measurement and Types. Measurement of velocity/speed. Introduction and types. Measurement of liquid level. Introduction and types. Measurement of pressure. Introduction and types. Measurement of vibration. Introduction and types. Application of sensors in Industries and home appliances.

FLOW MEASUREMENT:

Flow measurements are important in number of applications such as

- Drinking purpose
- Agriculture purpose
- Industrial purpose.
- construction purpose
- Store water for proper utilization
- To know volume of liquid and rate of flow.
- Laboratory purpose.

classification of flow meters based on

1. weight / quantity (or) volume
2. Rate of flow.

Quantity Meters :-

Quantity meter is defined as one in which fluid passing through primary element is accurately quantified interms of weight or volume of fluid.

It measures volume in liters.

E-g : positive displacement meter,
Reciprocating piston
Nutating discs, etc.

Flow meter can be defined as one the fluid passing through primary element in continuous stream.

Rate of flow means quantity of flow per unit time. Eg : orifice plate
Turbine meter
Electromagnetic flow meter.

classification of Flow meters.

1. Head type flow meters based on differential pressure measurements
   a) orifice plate b) venturi tube c) Flow nozzle
   d) pitot tube
2. Electromagnetic flow meters
3. Rotameters (variable area meters)
4. Mechanical flow meters.
   a) positive displacement
   b) Turbine flow meter
5. Anemometer
   a) cup type b) Hot wire
6. ultrasonic flow meters
7. Vortex flow meter.

ULTRASONIC FLOW METER

ultrasonic flowmeters works in two different principles.
- Doppler Effect ultrasonic flowmeter
- Transit time / Time of flight ultrasonic flowmeter

Transit time ultrasonic Flowmeter - principle

Time for sound to travel between transmitter and receiver is measured. It is not dependable on the particles in the fluid.

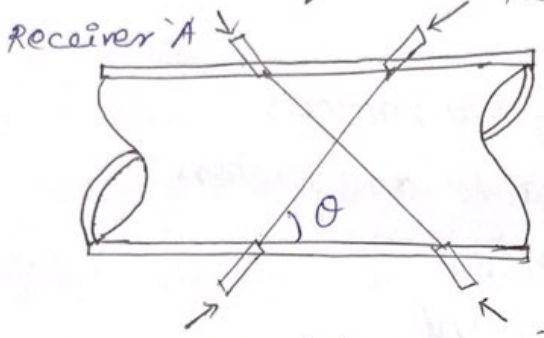


Fig: Transit time ultrasonic flow meter

ultrasonic flowmeter is mounted at an angle or parallel to pipe wall.

Short duration ultrasonic waves are transmitted across the fluid.

Velocity of ultrasonic waves is increased or decreased by the fluid velocity depending upon direction of fluid flow.

CONSTRUCTION :-

Two transmitters of piezoelectric device A and B are the down side of the flow tube with an angle.

Two piezo electric receivers A and B are connected to the pipe at top side with an angle.

OPERATION :-

→ Fluid in pipe flows at velocity V

→ Transmitter transmits short duration ultrasonic signals through fluid at velocity 'c'.

- signal received by receiver A is increased to $c + V\cos\theta$ because it is in the direction of fluid flow.

→ Reception frequency of receiver pulse f_A

$$f_A = \frac{(c + V\cos\theta)}{l}$$

θ - Angle between path of sound and pipe wall.

l - Distance between transmitter and Receiver.

velocity of ultrasonic signal transmitted by A is received by receiver B, will reduced by fluid velocity

It creates a retardation of $c + V\cos\theta$.

Reception frequency is given by

$$f_B = (c - V\cos\theta)/l$$

Difference in frequencies given by

$$\Delta f = f_A - f_B = \frac{(2V\cos\theta)}{l}$$

Time duration

$$\Delta T = (l) / (2V\cos\theta) \quad (\text{since } \Delta T = 1/\Delta f)$$

By measuring the difference in repetition freq Δf and by knowing the value of θ and l, the velocity of fluid can be measured.

Advantages:

- Good accuracy
- Bidirectional measuring capability
- Good and Fast response
- Wide freq range
- used for any size of pipes.
- Measurement is independent of velocity of sound 'c'

Disadvantages: High cost

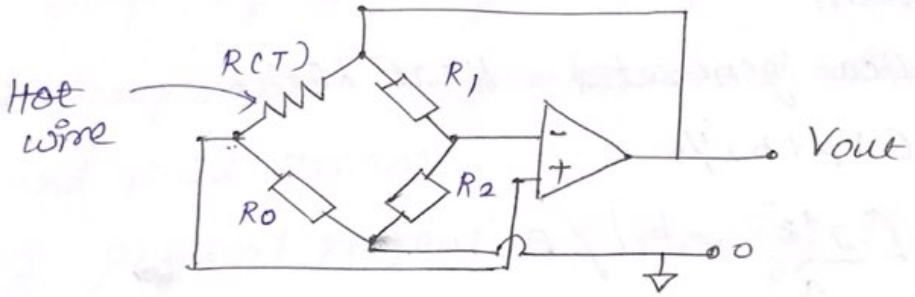
Applications: used mostly for liquids without any pressure.

ANEMOMETER:

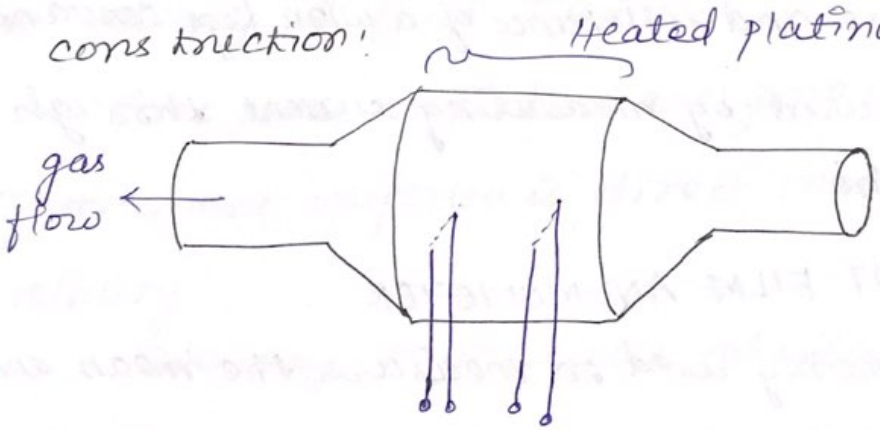
Velocity measuring devices for obtaining velocity of a fluid stream, such as air flow in a ventilating duct, wind tunnel, water flow in a closed channel. Wind speed as in meterology.

Types → cup-type
Hot wire / Hot film anemometer.

Hot wire Anemometer:



construction:



Energy supply to maintain platinum wires at constant temperature.

Operation:

→ Fluid flows over platinum wire, its temperature reduces.

→ Resistance of wire changes, bridge unbalanced.

→ Bridge is balanced by adjusting current through wire and temperature remains constant.

Heat generated $= I^2R$

Heat loss from surface due to fluid flow $= a(Vp+b)^{1/2}$

under equilibrium

Heat generated = Heat loss.

$I^2R = a(Vp+b)^{1/2}$

$$V = \left[\frac{I^4R^2}{a^2} - b\right] / p.$$

Temperature and resistance of a wire kept constant. velocity measured by measuring current through the heated wire..

HOT FILM ANEMOMETER

It is commonly used to measure the mean and fluctuating velocity in fluid flow.

Flow sensing is platinum tungsten wire.

→ It is welded between two prongs of probe.

→ It is placed in one arm of wheatstone's bridge and heated electrically.

The probe is introduced in fluid stream and tends to get cooled by instantaneous velocity, consequently resistance decreases.

Rate of cooling depends on

1. Shape, size and physical properties of wire.
2. Temperature difference b/w heated hot wire and fluid stream.
3. Physical properties of flowing fluid.
4. Velocity of fluid stream.

First three conditions are generally constant Instrument response is direct measurement of velocity.

Two ways to measure velocity using Hot wire Anemometer 1. constant current mode
2. constant temperature mode.

- In both modes, bridge is initially balanced.

→ When there is a fluid flow, hot wire / film resistance changes.

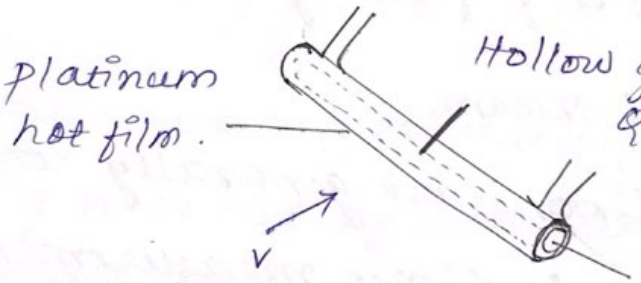
This unbalances the bridge and some output voltage is generated.

O/p is proportional to velocity of fluid flow.

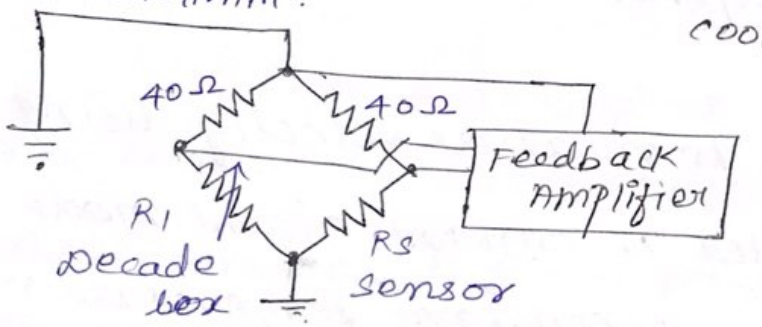
Hot film Anemometer Range

Hot film probes are used for measurements in liquids for flow rates up to 25 m/s.

Frequency response extending up to 150 KHz.



CIRCUIT DIAGRAM:



→ Hot wire Anemometer is another version of Hot-film transducer.

→ Sensor is the thin film of platinum deposited in a glass (or) quartz substrate.

→ Film replaces Hot-wire, remaining circuit is same as Hot-wire.

→ Film transducer gives mechanical strength.

→ It can be used at very high temperatures, using cooling Arrangements.

→ Directional sensitivity of probe, max ay right angles to flow.

→ In the angle $45° < \theta < 135°$, Effective velocity

$$u_{(rms)} = u \sin\theta .$$

→ The property is directly used in flow-direction measurements

→ In steady-flow conditions by rotating probe, until sharply defined null is obtained.

Applications:

used for measurement of propagation velocity of shock in shock tube experiments.

ELECTROMAGNETIC FLOW METER :

The basic principle of operation of Electro magnetic flow meter is Faraday's law of Electro magnetic Induction.

Faraday's Law of Electromagnetic Induction.

- First law states that, whenever a conductor cuts lines of magnetic field, an induced emf is generated.
- Second law states that, magnitude of emf is proportional to the rate of which these lines are cut.

Emf is perpendicular to plane of conductor and Magnetic field.

CONSTRUCTION.

A permanent magnet or Electromagnetic, it may be either Ac or DC around a non conducting pipe

→ Two electrodes are inserted in tubes, their surfaces being flush with the inner surface of the tube and in contact with liquids.

→ As the conductive liquid flows through the insulated tube with an average velocity V.

→ It may be considered as series of flat conductor discs passing through magnetic field.

Mathematical Expressions:

According to faradays law Induced emf generated by $e = Bdv \times 10^{-8}$

E – Induced voltage in volts

B – Magnetic flux density in tesla

D – Distance between electrodes in m.

V – Average velocity of liquid in m/s.

$$V = \frac{e}{Bd} \times 10^{8}$$

The volume of flow rate $Q = AV$.

A – cross sectional area of the pipe

$$Q = e_0 \frac{A}{Bd} \times 10^{8}$$

A, B, d are constants for particular Electromagnetic flow meter.

Induced voltage is proportional to the volume of flow rate.

Advantages: Good accuracy and reliability
Simplicity, ruggedness
Fast response.

Disadvantage:

- Expensive
- Not suitable for conductive fluids.

Applications:

particularly suitable for flow velocity or volume measurement of

- slurries
- corrosive acids
- Sewage
- Detergents, greasy and sticky fluids.

VIBRATION SENSOR:-

It is a device that serves to detect the presence of vibration, then it will be converted in to Electrical signals. Electrical signals are processed in measuring instrument.

Selection of vibration sensor is based on

→ Vibration signal type
→ Measurement freq range
→ Size and weight of vibration object
→ Sensitivity of sensor

Two types

1. contact vibration sensors:

sensors require mounting transducer

to a vibration test piece. It has advantage of moving test article to measure absolute motion

2. Non contact vibration sensors:

probes and machines are not in direct contact

contact vibration sensors	non-contact vibration sensors.

• Acceleration sensor
  • piezoelectric
  • piezoresistive
  • capacitive MEMS
• Strain Gauges
• velocity sensor.
	• Microphones or Acoustic pressure sensors
	• Laser Displacement sensor
	• Eddy current + capacitive displacement sensors

PIEZOELECTRIC ACCELERATION SENSOR:

→ popular for wide availability and high SNR.

→ can't measure static accelerations like gravity and experience issues when excited at internal resonance.

PIEZORESISTIVE ACCELEROMETER:

→ popular one, overcome the issues of piezoelectric

→ It can experience high and low frequencies

CAPACITIVE MEMS

→ most cost-effective, typically PCB mounted, much noisier than piezoelectric, limited to BW below few Hundred Hz.

Electromagnetic velocity:-

operated by using current generated from magnet travelling within a coil. Measure velocity directly and they have a high temperature range.

ACOUSTIC PRESSURE SENSOR.

→ Sound is not a way to measure vibration, After all sound, by defn: vibration travels through air in the form of pressure waves.

→ cost effective means of measuring high freq vibration and helps to determine how system's vibration changes with time.

LASER DISPLACEMENT SENSOR:

→ uses triangulation with TXing + RXing lens.

→ Laser beam emitted towards target through transmitting lens. Light reflect back towards the sensor.

→ Directed by receiver lens to receiving element As target moves closer and farther away. Angle of reflected light changes.

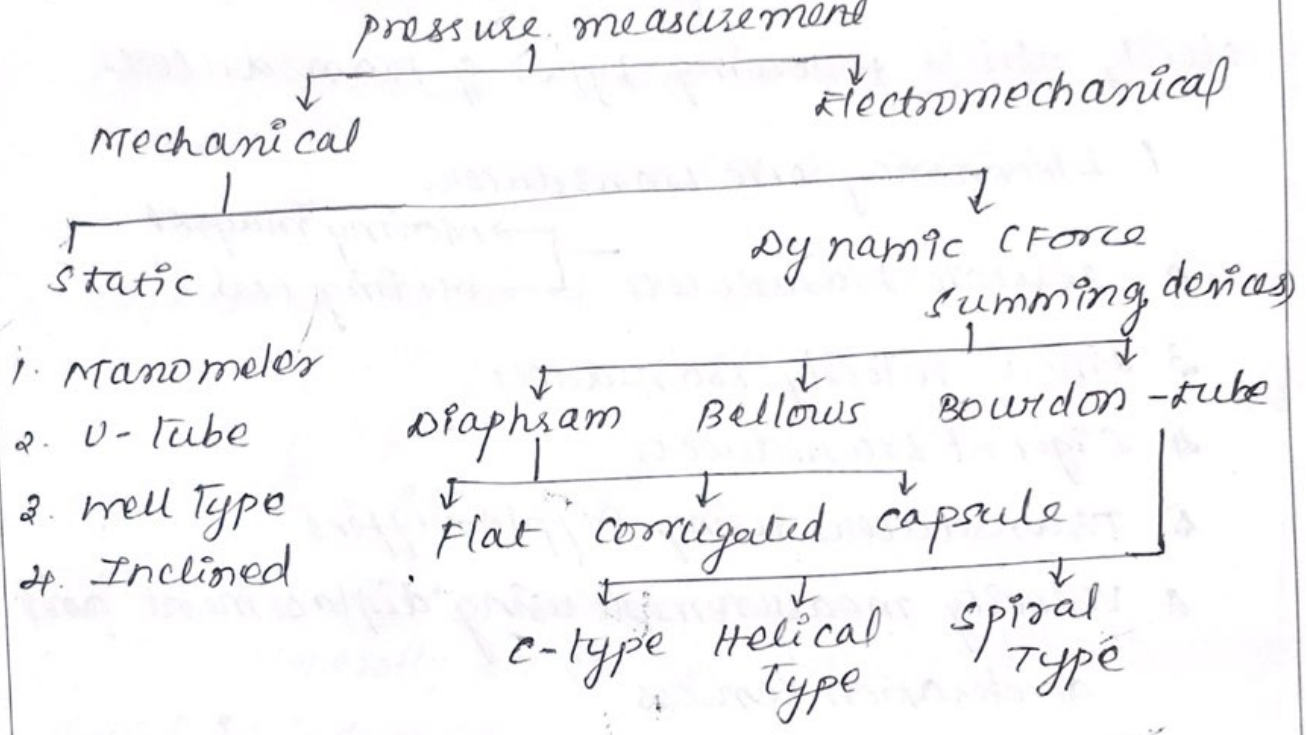
PRESSURE MEASUREMENT - INTRODUCTION & TYPES

Pressure means Force per unit area exerted by a fluid on the surface of the container. $P = F/A$

Two types 1. Static pressure
2. Dynamic pressure

Static: When force in a system under pressure is constant or static.

Dynamic: Force is varying on other hand.



Electromechanical:

- potentiometer
- photoelectric
- capacitive
- piezo electric
- Inductive.

VELOCITY MEASUREMENTS & TYPES

Velocity is the first derivate of displacement linear velocity is defined as rate of change of position vector with time at an instant in time

The methods used for measurement of linear velocity utilize following types of transducers

1. Electromagnetic transducers
2. seismic transducers → Moving magnet, Moving coil
3. Linear velocity transducer.
4. Digital transducers.
5. Transducers using Doppler effect.
6. velocity measurement using displacement and acceleration sensors

Measurement of Speed:

Tachometer is used for measuring rotational speed, can be used to measure speed of rotating shaft.

— used to measure flow of liquid by attaching wheel with inclined vanes.

Types of Tachometers.

1) Mechanical
   - Revolution counter
   - Hand speed indicator
   - Tachoscope
   - Resonance (vibrating reed) Tachometer

2) Electrical
   - Eddy current (or) drag cup
   - Tachogenerator (DC and AC)

3. contactless Electrical Tachometers
   - Magnetic pickup tachometer
   - photo electric Tachometer
   - Stroboscope.

LIQUID LEVEL MEASUREMENT:

Generally two methods are used in measuring liquid in industries.

1. Direct Method:
   uses varying level of liquid as mean for obtaining measurement
2. Indirect Method:
   Variable that changes with liquid level to accurate measuring mechanism.

DIRECT METHOD:

→ Simplest method of measuring liquid level.

→ Measured directly by means of following level indicators.

(i) Slight Glass / Gauge glass

(ii) Float type / Float - operated gauges

(iii) Torque Tube Displacer / Float displacement type level gauges.

INDIRECT METHOD:

Liquid level measurement used in industries

(i) Hydrostatic pressure type

(ii) Electrical method.

(iii) ultrasonic level sensor.

APPLICATION OF SENSORS: