Section C

Motion, Force and Torque Measurement

Introduction

Motion measurement includes:

- Displacement of elastic members due to application of physical parameters like pressure, temperature, force, strain, torque, etc.
- Vibratory motion of structures and machines.

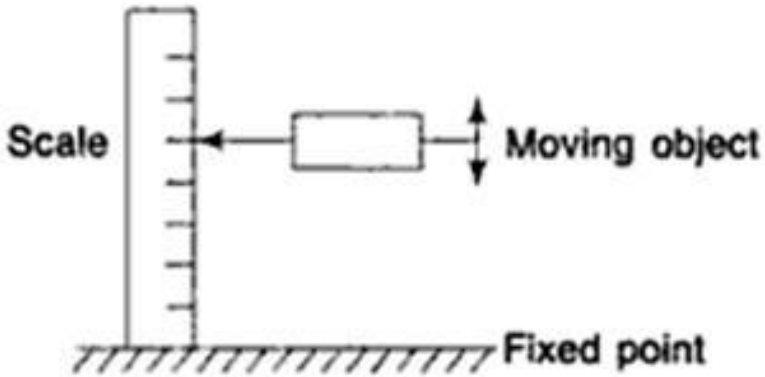
Factors for selection of devices for motion measurement:

- Type of motion
- Contacting or non-contacting type
- Relation of output to motion
- Time dependence – static or dynamic
- Magnitude of motion.

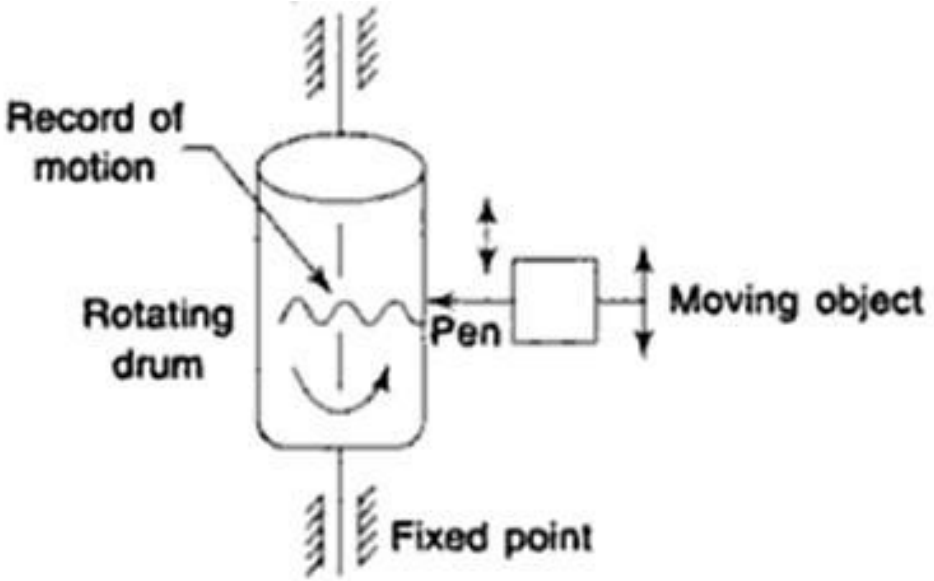
Types of motion measuring devices

1. Relative motion devices –

Motion is measured w.r.t. a fixed reference.



(a) Using scale



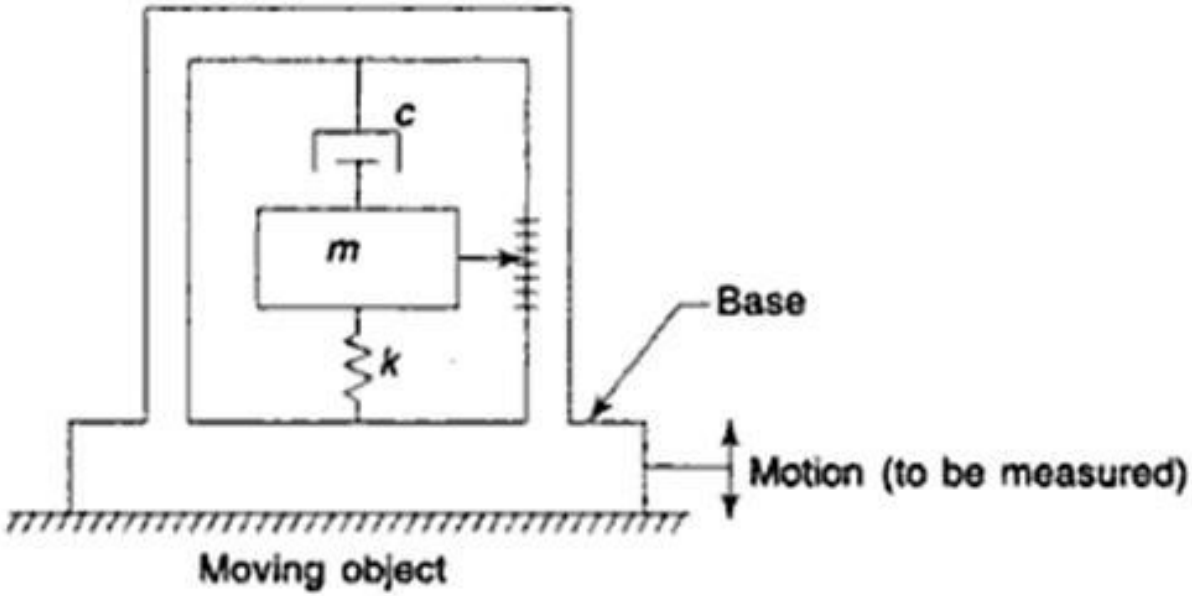
(b) Using pen and rotating drum

2. Absolute motion devices / seismic devices/transducers –

In these devices, the only terminal is the base of a spring mass system. The base is attached to the point whose motion is to be measured.

No fixed reference is available.

e.g. to measure motion of a bridge or an aircraft wing in flight



Relative motion Measuring Devices

- Electromechanical

1. Resistance type
2. Inductive type
3. Capacitance type
4. Piezoelectric type
5. Resistance strain gauge type

- Optical

1. Microscopes
2. Telescopes
3. Interferometers
4. Photo Electric devices
5. Moire-Fringe method based devices

- Pneumatic

Electro-mechanical motion measuring devices

- Commonly used
- Versatile
- Simple in construction
- Can give large output which can be displayed or recorded with ease.
- Can be used for translational or rotational motion.
- Some of inductive & capacitance types can be proximity type.
- Piezo-electric type can be used only for dynamic motion measurement. And others may be used for both static & dynamic motions.
- Resistance , electro-dynamic and inductive transducers are used for large motions.
- Capacitance, piezo-electric & strain gauge transducers are used for measuring small motions.

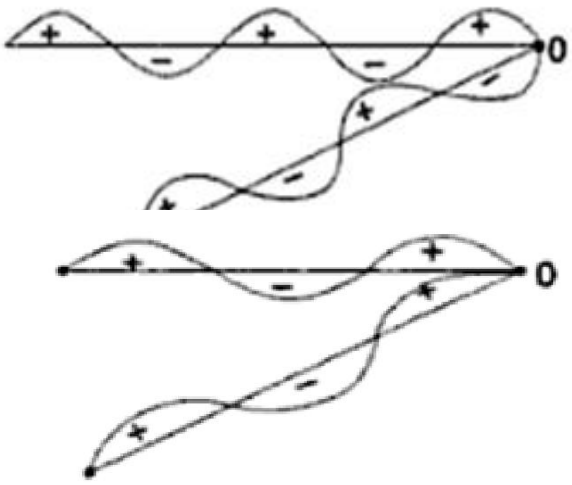
Optical motion measuring devices

1. Microscopes – small motions
2. Telescopes – large motions
3. Interferometers – very small motions (Based on optical interference)
4. Photo Electric devices – (used whereby the intensity of light falling on the cell may be changed by the motion to be measured)
   Types- Photo-emissive, photo-conductive or photo-voltaic types of cells.

5. Moire-Fringe method based devices – this is an optical method of amplifying displacement.

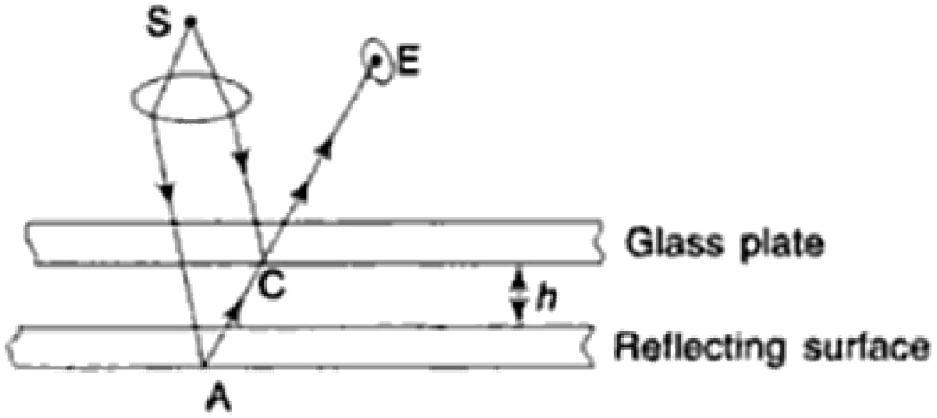
Interferometers

- Used for very small motion measurement
- Based on optical interference
- Two light waves, starting from different points & travelling different paths, meet at 0.
- When two waves are out of phase, they cancel each other & produce a dark spot.
- When two waves are in phase, they add and produce a bright spot.



Interference of light waves

- If two paths are with length *l1 & l2,* the number of wavelengths of light in each path are *l1/λ & l2/λ.*
- If *(l1 – l2)/λ* is a whole number (even multiple of ½), two waves are in phase. (bright spot)
- If *(l1 – l2)/λ* is an odd multiple of ½ like 1/2, 3/2, 5/2…., two waves are out of phase. (dark spot)

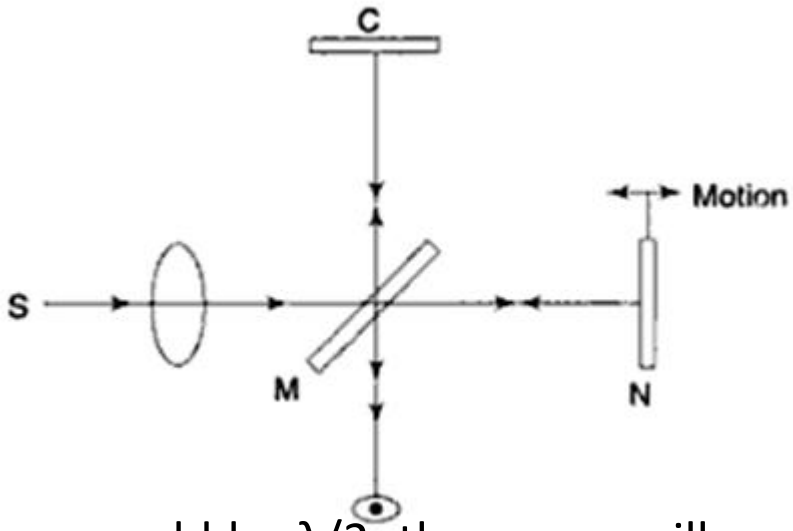


Principle of interferometers

- The two rays starting from source S, get reflected at A and combine at C to travel to the eye at E.
- h is the distance between top glass & bottom reflecting surface.
- Difference in path lengths of two rays is 2h.
- If $2h/\lambda = 1,2,3,\ldots$, the eye will see darkness.
- If h is changed due to motion of on surface, the eye will see alternate brightness & darkness, for every change in $2h/\lambda$ equal to ½.
- λ for yellow light is approx. 5460 Å ($1Å = 10^{-8}$ cm)

Michelson Interferometer

- The mirror M is half reflecting and half transmitting.
- The two waves after reflection from N&C, meet at M and can be seen from E.
- If distance MC = MN, two waves are in phase (brightness)
- If N is moved through distance λ/4,



the difference in paths travelled by two waves would be λ/2, the waves will be out of phase (darkness at E).

- For another motion of λ/4, light will appear at E.
- The number of brightness or darkness will calculate motion of N.
- λ of light changes due to change of air pressure, temp, humidity.
- This change is much less in lasers so for very high pricision, a laser interferometer is used.