

[Measurement of Force and Torque]

Force is an external agent which changes or tries to change the state of any body. It is generally measured in Newton.

The rotary effect of a force is given by Torque and it is equal to product of force and perpendicular distance of line of action of force from axis of rotation.

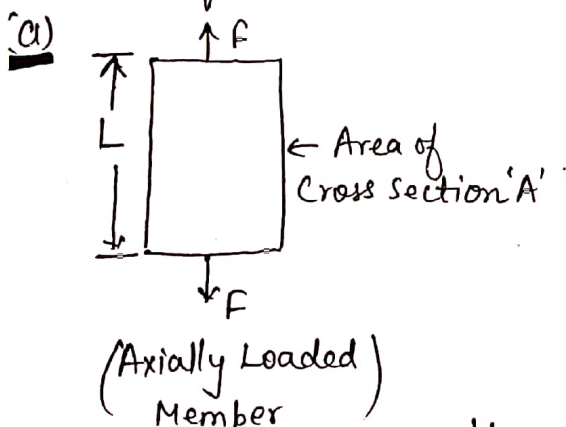
$$\text{Torque } T = r \times F = r F \sin \theta$$

Force Measuring Devices :

- ① Hydraulic Load Cell
- ② Pneumatic load cell
- ③ Strain Gauge load cell
- ④ Piezoelectric load cell
- ⑤ Elastic Force Transducers
- ⑥ LVDT Force Transducer
- ⑦ Analytical Balance.

Elastic Force Transducers :

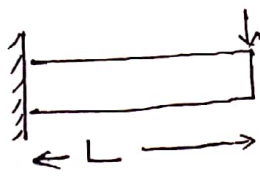
Elastic elements such as cantilever, spring, metallic rings etc. can be used to measure force by measuring the deflection due to applied load.



$$\text{Young's Modulus, } E = \frac{F \cdot L}{A \cdot \Delta L}$$

$$\Rightarrow \boxed{\Delta L = \frac{F \cdot L}{A \cdot E}}$$

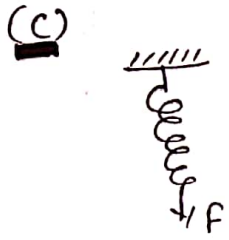
where ΔL is change in length of the member.



$$\text{deflection} = \frac{FL^3}{3EI}$$

where $I \rightarrow$ Moment of Inertia of beam.

(Cantilever type elastic element)

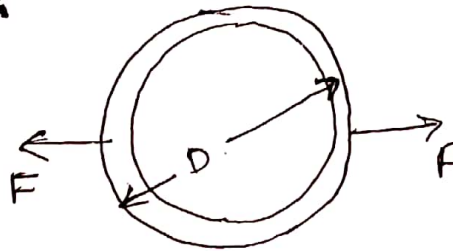


$$\Rightarrow \text{deflection} = \frac{8FD^3}{Ed^4}$$

where $D \rightarrow$ Dia of spring
 $d \rightarrow$ dia of spring wire
 $E \rightarrow$ Modulus of Elasticity

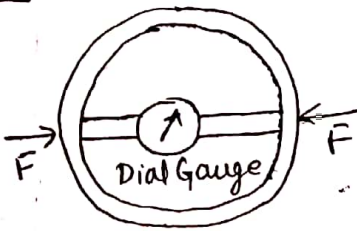
(Spring Type elastic element)

(d)



(Ring Type Elastic Element)

(e)

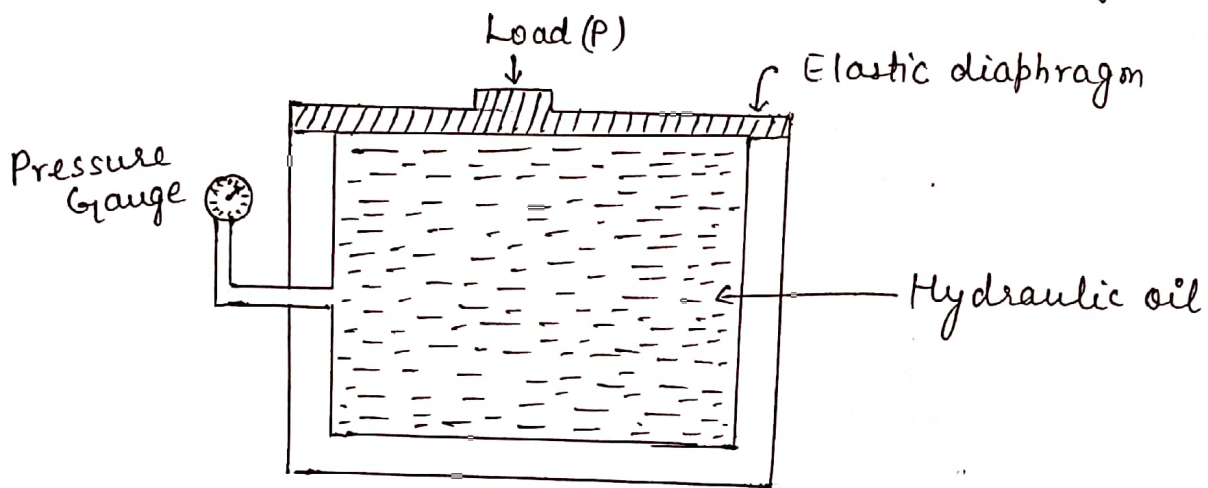


(Proving Ring)

Force can be measured by finding deflection or strain in the elastic members. Dial Gauge can be used to measure deflection of elastic elements. For example proving ring has an accurate dial gauge on its inside, which can be calibrated in terms of force.

Hydraulic Load Cell :

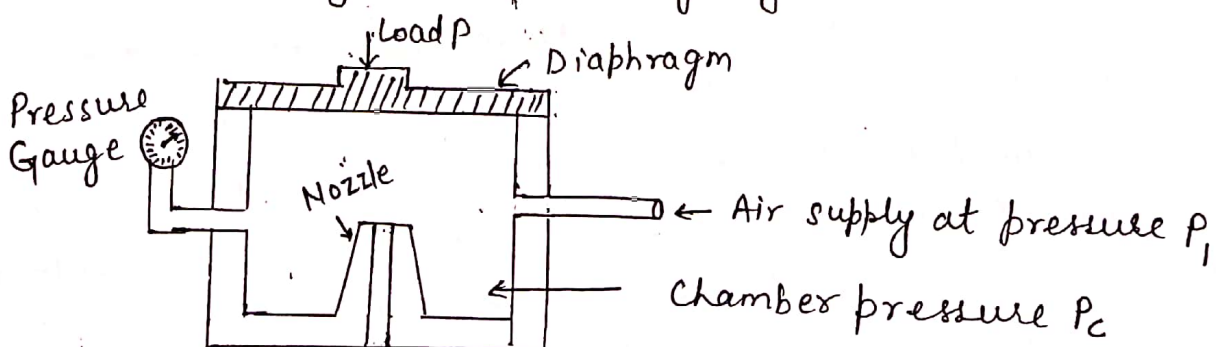
It can be used to measure force of very high magnitude. It consists of a closed container filled with oil and covered with diaphragm. A pressure measuring device such as Bourdon tube pressure gauge is connected to the container. When load 'P' acts on the diaphragm, it gets deflected and transmits the force to the oil as a result of which pressure develops in the oil. The magnitude of pressure developed is indicated by the pressure gauge which can be converted into force.



(Hydraulic Load Cell).

Pneumatic Load Cell :

It consists of a chamber with a nozzle and covered with elastic diaphragm. Pressurised air is supplied through a pipe to the chamber. The pressure in the chamber is detected by the pressure gauge.

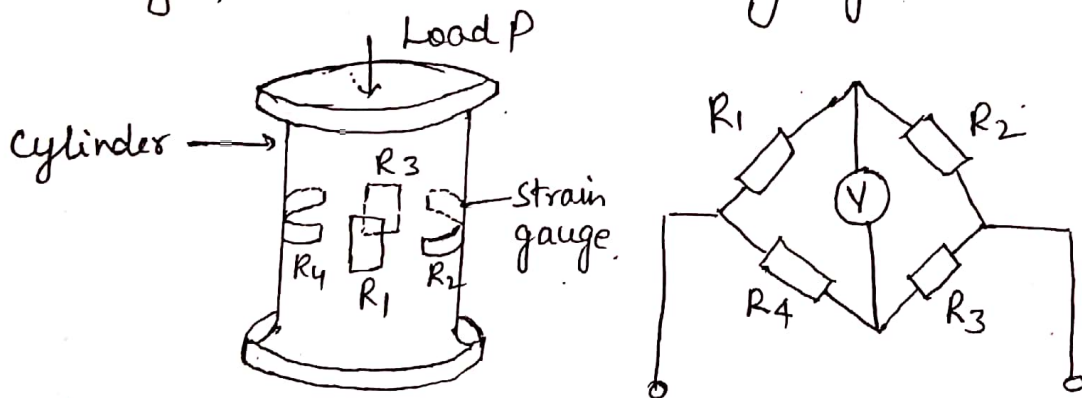


(Pneumatic Load Cell)

As load P acts on the diaphragm, it deflects and the gap between diaphragm and nozzle decreases while pressure P_c in the chamber increases. Rise in pressure P_c applies outward force on the diaphragm opposite the force P . For any force P , the diaphragm attains equilibrium under the impact of two equal and opposite forces. At this state, chamber pressure is noted using pressure gauge which can also be directly calibrated in terms of load.

Strain Gauge Load Cell :

It measures load in terms of strain. A strain gauge load cell consists of a steel cylinder having four identical strain gauges mounted upon it.



The gauges R_1 and R_3 are along the direction of applied load whereas R_2 and R_4 are attached circumferentially at right angles to gauges R_1 and R_3 . R_1 , R_2 , R_3 and R_4 are connected to the wheat stone bridge circuit.

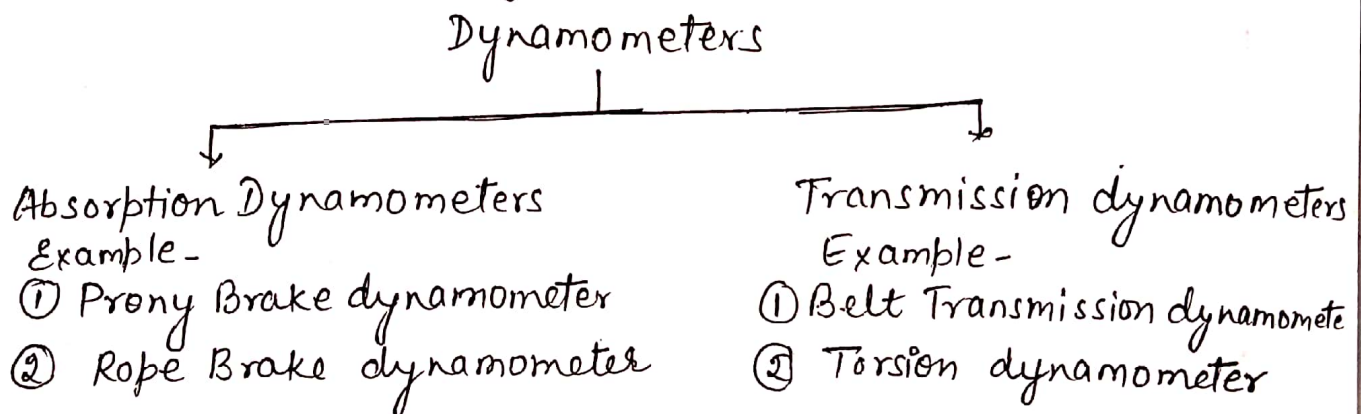
Under no load, four gauges have same resistance, so the bridge is balanced and the output voltage V_o is zero. When compressive load ' P ' is applied R_1 and R_3 undergo compression so their resistance decreases. But gauges R_2 & R_4 undergo tension. Thus an output voltage appears. This output voltage is measure of load.

Piezoelectric Load Cell :

It is used to measure dynamic loads. Such a load cell makes use of piezoelectric transducers which produces an electrostatic charge when an external force acts on it. Thus output is in terms of coulombs per unit input. The signal generated can be amplified by using charge amplifiers. These load cells are small in size and have high resolution, accuracy and precision.

Torque and Power Measurement :

Torque and Power transmitted by a shaft can be measured by a device known as dynamometer.



In absorption dynamometers, the energy produced by the engine is absorbed by the frictional resistance of brakes and is transformed into heat energy during the process of measurement.

In transmission dynamometers, energy is not wasted in friction but is used for doing work.