③ Damping Systems

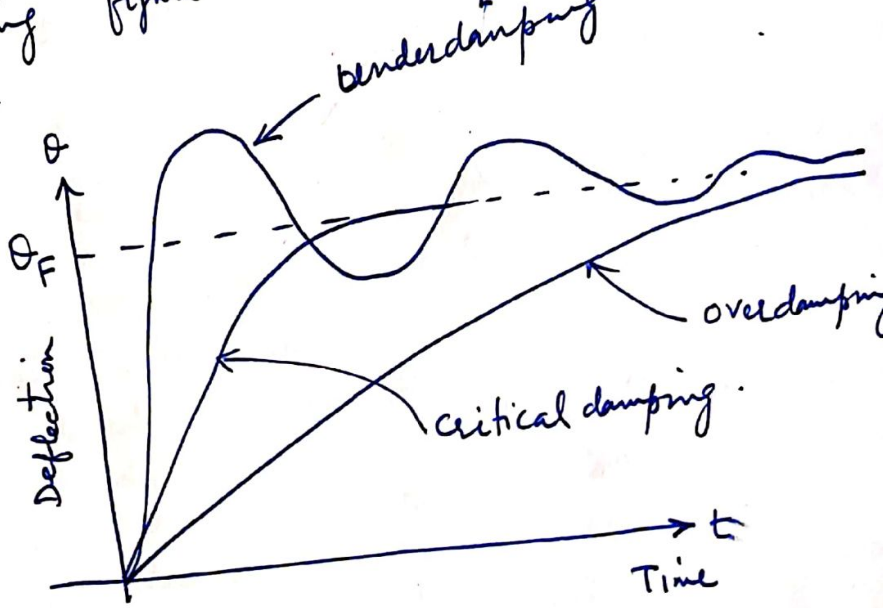
The damping torque should be of such a magnitude that the pointer quickly comes to final steady position without any oscillations (overshoots & undershoots). The various levels of damping results in the following damping systems:-

(i) underdamped: the moving system oscillates around a final steady position with decreasing amplitude and takes some time to come to rest.

ii) critically damped: the moving system moves rapidly but smoothly to its final steady position without any oscillations.

(iii) overdamped: If damping torque is more than what is required for critical damping, the instrument reaches to its final position in a lethargic fashion without any oscillations.

The following figure illustrates these three levels of damping:-

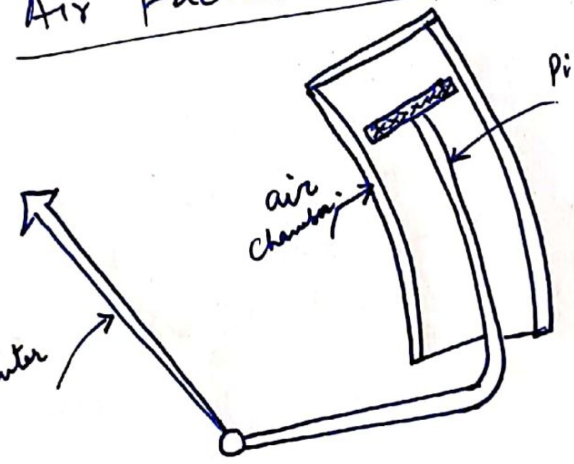


The damping device should be such that it produces a damping torque only while the moving system is in motion, i.e. the damping torque should be proportional to the velocity of the moving system but independent of operating current. It must not affecting the controlling torque.

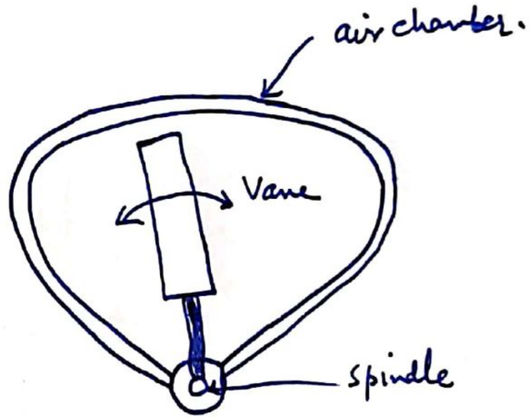
Methods of Producing Damping torque

four methods ;

① Air Friction Damping



(a)



(b).

Two arrangements are possible as shown in (a) & (b) above.

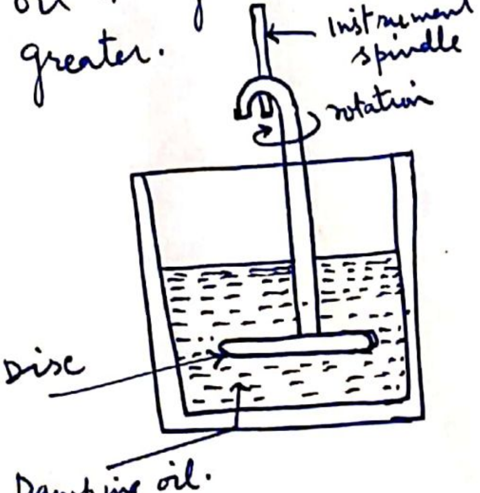
Fig(a) consists of a light Aluminium piston which is attached to the moving system. The piston moves in a fixed air chamber which is closed at one end. The clearance b/w piston and the airchamber walls is uniform throughout and is very small. When there are oscillations the piston moves in and out of the air chamber. When the piston moves into the chamber, the air inside is compressed and the pressure of air thus built up opposes the motion of piston and hence of whole of moving system

When the piston moves out of the air chamber, the pressure on the closed space falls and pressure on the open side piston is greater than on the other side. Thus there is again an opposition to motion.

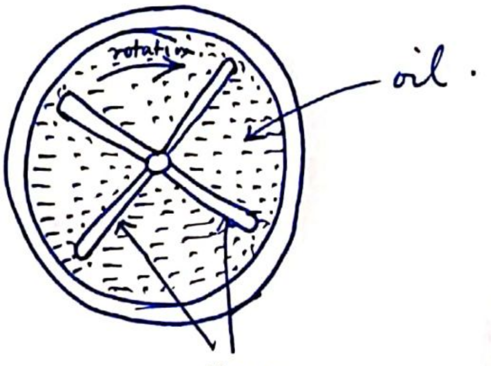
Fig (b) consists of a Aluminium vane which moves in a sector shaped chamber. The air chamber is a recess cast in a bakellite moulding or die Casting. The chamber is completed by providing a Cover plate the top. The Aluminium piston should be carefully fitted so that it does not touch the wall otherwise a serious error will be caused.

② Fluid Friction Damping

This is similar to air friction damping. oil is used in place of air and as the viscosity of oil is greater than air, the damping force is also greater.



(a)



(b).

In Fig(a) a disc is attached to the moving system. The disc dips into an oil pot and is completely submerged in oil. When the moving system moves, the disc moves in oil and a frictional drag is produced.

This frictional drag always opposes the motion. In fig (b) a number of vanes are attached to the spindle. These vanes are submerged in oil and move in a vertical plane. This arrangement gives greater damping torque.

③ Eddy Current Damping

When a conductor moves in a magnetic field an emf is induced in it and if a closed path is provided, a current (known as eddy current) flows. This current interacts with the field to produce an electromagnetic torque which opposes the motion. The torque is proportional to the strength of field and the current produced. The current is proportional to emf which in turn is proportional to velocity of conductor. Thus if strength of field is constant (permanent magnet), the torque is proportional to velocity of conductor.

④ Electromagnetic Damping

The movement of coil in a magnetic field produces a current in the coil which interacts with the field to produce a torque. This torque opposes the movement of coil and slows the response. The magnitude of current and hence the damping torque is dependent upon the resistance of the circuit to which the instrument is connected. The electromagnetic damping is used in galvanometers.

Comparison of the Methods of Damping

* Air friction damping provides a very simple and cheap method of damping. But care must be taken to ensure that the piston is not bent or twisted otherwise it will touch the walls of air chamber thereby causing a serious error due to solid friction. used in hot wire & moving iron instruments.

* Fluid friction damping has the advantage that the oil which is required for damping can be used for insulation purposes in some forms of instruments which are submerged in oil. This method is suitable for electrostatic type instruments where the movement is suspended rather than pivoted. Due to upthrust of oil, the load on bearings or suspension is reduced, thus reducing frictional errors.

It can be used in instruments which are in vertical position. Also because of creeping of oil, the instruments can not be kept clean, thus the application is restricted to electrostatic type laboratory instruments and not for portable instruments.

* Eddy Currant damping is the most effective and efficiant form of damping. It is very convenient to use in instruments where a mettalic disc or a former and a permanent magnet already form part of the operating system. For this reason, this method is used in hot wire, moving coil, and induction type instruments.

This method can not be used in instruments where introduction of a permanent magnet required for producing eddy currents will distort the existing magnetic field, as in moving iron and dynamometer type of instruments.

Eddy current Damping Torque produced by a Metal Former

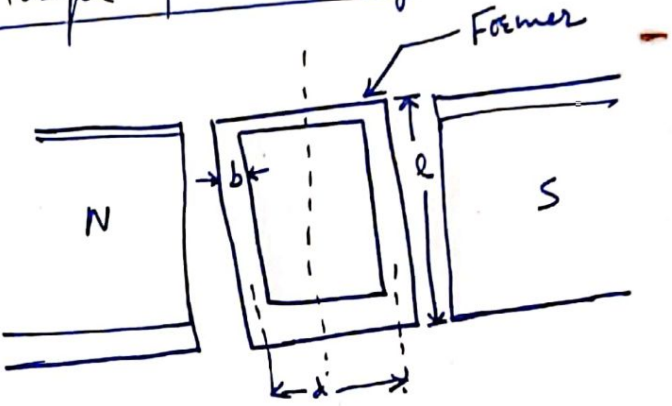
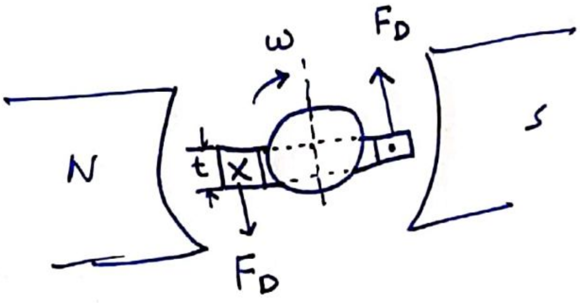


Fig shows the metallic former in the field of a permanent magnet.



Let.

B = strength of mag. field wb/m^2
ω = angular speed of former, rad/sec
l = length of former (m)
t = thickness of former (m)
b = width of former (m)
d = breadth of former (m).
ρ = resistivity of former material (Ω m).

Linear velocity of former $v = \frac{d}{2} \times \omega$

Emf generated in the former $= E_e = 2 \times B \times l \times \frac{d}{2} \times \omega$
$= B l d \omega$

Resistance of the path of eddy currents $= R_e = \frac{\text{Resistivity} \times \text{length}}{\text{area}}$

$$R_e = \frac{\rho\,(2(l+d))}{b \times t} = \frac{2\rho(l+d)}{bt},$$

Eddy current $I_e = \frac{E_e}{R_e} = \frac{B l d \omega}{2\rho(l+d)/bt} = \frac{B l d \omega bt}{2\rho(l+d)}$

Damping force $F_D = B I_e l = B \times \frac{B l d \omega bt}{2\rho(l+d)} \times l$

$$= \frac{B^2 l^2 d \omega bt}{2\rho(l+d)}.$$

Damping Torque $T_D = F_D \times d = \frac{B^2 l^2 d^2 bt\omega}{2\rho(l+d)}.$

Now $\frac{B^2 l^2 d^2 bt}{2\rho(l+d)} = K_D =$ Damping constant.

$= N\text{-}m/\text{rad sec}^{-1};$

$$\boxed{T_D = K_D \omega}$$

out of all the dimensions we can change the damping torque by changing the thickness of the ~~material~~ former.
