NARSIMHA REDDY ENGINEERING COLLEGE
UGC AUTONOMOUS INSTITUTION
Maisammaguda (V), Kompally - 500100, Secunderabad, Telangana State, India

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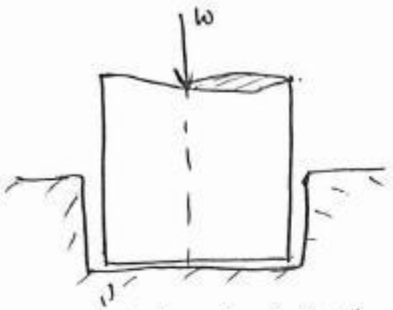
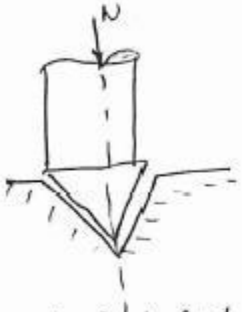
Unit-III

Pivot Bearing

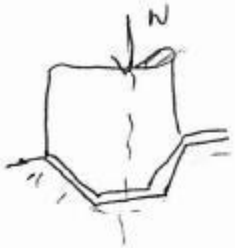
The rotating shafts are frequently subjected to axial thrust. These shafts can be kept in correct axial position if bearing surfaces are provided. The bearing surfaces which are flat (or) conical carry the axial thrust. The bearing surfaces placed at the end of a shaft are known as pivots. The pivot may flat, conical (or) truncated conical surfaces.



Flat (bearing) pivot

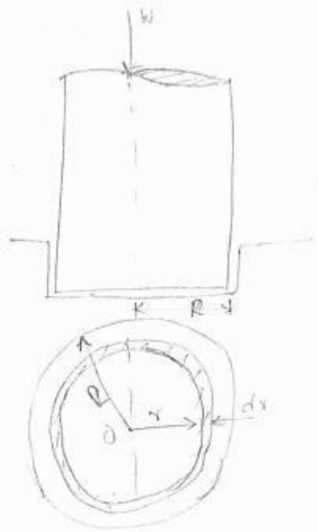


Conical pivot



Truncated pivot

* Flat Pivot :-



The bearing surface placed at the end of shaft is known as pivot. If the surface is flat as shown, then bearing surface is called flat-pivot (or)-foot-step. There will be friction along the surface of contact between shaft & bearing. The power lost can be obtained by calculating torque.

let, W → Axial load, (or) load transmitted to the bearing surface

R → Radius of pivot.

μ → co-effecient of friction.

p → Intensity of Pr , N/m².

T → Total frictional torque.

r → radius of ring

dr → thickness of ring.

consider a circular ring of radius r & thickness dr as shown.

∴ Area of ring = $2\pi r \cdot dr$.

We will consider 2 cases; namely,

(i) Uniform pressure over bearing surface &

(ii) Uniform wear over bearing surface

i) Case of Uniform Pr. :

When the Pr is assumed to be uniform over the bearing surface, then intensity of pressure is given by.

$$p = \frac{\text{Axial load}}{\text{Area of c/s}} = \frac{W}{\pi R^2} \quad -(1)$$

Now, the load transmitted to the ring & frictional torque on the ring,

Load transmitted to the ring,

dW = Pr on ring × Area of ring

$= p \times 2\pi r dr$

frictional force on ring,

$dF = \mu \times dW$

= μ × load on ring

$= \mu \times p \times 2\pi r dr$

Frictional torque on the ring, Moment of frictional force about the axis,

dT = Frictional force × Radius of ring

$= dF \times r$.

$\therefore dT = \mu \times p \times 2\pi \cdot r \cdot dr \cdot r$

$= \mu \cdot p \times 2\pi r^2 \cdot dr$. —(a)

Now, the total frictional torque will be obtained by integrating above eq. ⓐ.

∴ Total frictional torque, $T = \int_0^R 2\pi \mu p r^2 \cdot dr$

$= 2\pi \mu p \int_0^R r^2 \cdot dr$

$= 2\pi \mu \cdot p \left[\frac{r^3}{3}\right]_0^R$

$= \frac{2}{3} \mu \pi p R^3$

$= \frac{2}{3} \pi \times \mu \times R^3 \times \frac{W}{\pi R^2}$ $\quad [\because p = \frac{W}{\pi R^2}]$

$$\boxed{T = \frac{2}{3} \mu W R}$$

∴ Power lost in frict^n = $T \times \omega$

$= \frac{T \times 2\pi N}{60}$

$= \frac{2\pi N T}{60}$

(ii) <u>In case of Uniform Wear</u>:- For uniform wear of bearing surface, the load transmitted to the various circular rings should be same.

But load transmitted to any circular ring is equal to the product of pressure & area of ring. Area of ring is directly proportional to the radius of ring.

Hence for uniform wear, the product of pr radius should be constant. i.e; $p \times r$ = constant.

For Uniform wear, $p \times r$ = constant

i.e; $p \times r = C$.

$\therefore p = \frac{C}{r}$ — ⓐ.

Load transmitted to the ring,

$= p_r \times$ Area of ring

$= p \times 2\pi r \cdot dr$

$= \frac{C}{r} \times 2\pi \cdot r \cdot dr$

$dW = 2\pi C \cdot dr$ — (6).

Total load transmitted to the bearing, is obtained by integrating from '0 to R'

∴ Total load transmitting to the bearing,

$W = \int_0^R dW$

$= \int_0^R 2\pi C\,dr = 2\pi C \int_0^R dr = 2\pi C [r]_0^R$

$W = 2\pi CR$

$$\boxed{C = \frac{W}{2\pi R}}$$

Now frictional ~~torque~~ force on the ring,

$dF = \mu \times$ load on ring $= \mu \times dW$

$= \mu \times 2\pi C dr$

Hence frictional torque on the ring, = Frictional force on ring × radius

$dT =$ Frictional force on ring × r

$= dF \times r$

$= \mu \times 2\pi C \cdot dr \cdot r$

$= \mu \cdot 2\pi C \cdot r \cdot dr$

∴ Total frictional torque, $T = \int_0^R dT$

$= \int_0^R \mu 2\pi C \cdot r \cdot dr$

$= 2\pi \cdot C \cdot \mu \cdot \int_0^R r\,dr$

$= 2\pi C \cdot \mu \left[\frac{r^2}{2}\right]_0^R = 2\pi C \cdot \mu \left[\frac{R^2}{2}\right]$

$= 2\pi \times \frac{W}{2\pi R} \times \mu \left[\frac{R^2}{2}\right]$

$$\boxed{T = \frac{1}{2}\mu W R}$$

∴ Power lost in friction, $P = \frac{2\pi N T}{60}$

Problem: Find the power lost in friction assuming (i) uniform Pr. & (ii) Uniform wear. When a vertical shaft of 100mm dia. rotating at 150rpm rests on a flat end-foot step bearing. The coeffecient of friction is equal to 0.05 & shaft carries a vertical load of 15 kN.

Sol:

Given:

Dia, $D = 100mm \Rightarrow 0.1m$ $\therefore R = \frac{0.1}{2} = 0.05m$

$N = 150$ rpm ; Co-efficient of friction, $\mu = 0.05$

load, $W = 15KN = 15\times10^3 N$.

i) Power lost in friction assuming uniform pressure.

For uniform Pr.:

$$T = \frac{2}{3}\mu W R$$

$$T = \frac{2}{3}(0.05)(15\times10^3)(0.05)$$

$$T = 25 \text{ N-m}$$

Power lost, $P = \frac{2\pi N T}{60} \Rightarrow \frac{2\pi 150\times25}{60}$

$$\boxed{P = 392.7W}$$

ii) For uniform wear,

$$T = \frac{1}{2}\mu W R.$$

$$= \frac{1}{2}\times 0.05\times15\times10^3\times0.05$$

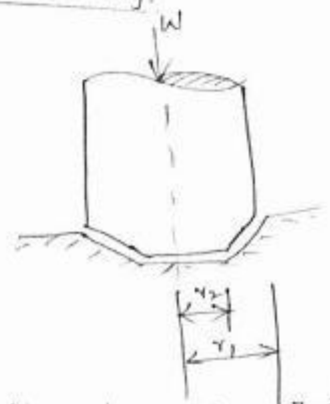
$$T = 18.75 Nm$$

$$P = \frac{2\pi N T}{60}$$

$$P = \frac{2\pi\times150\times18.75}{60}$$

$$\boxed{P = 294.5W}$$

* Truncated Pivot Bearing:-



The above fig. shows truncated conical pivot of external & internal radii r_1 & r_2 respectively.

(i) Case of Uniform Pressure:-

vertical load transmitted to the bearing

$$dW = p \times 2\pi r \times dr \quad -(a)$$

for total vertical load, integrating with limits r_2 to r_1.

$$W = \int_{r_2}^{r_1} p \times 2\pi r \, dr$$

$$= p\, 2\pi \int_{r_2}^{r_1} r\,dr = p \times 2\pi \left[\frac{r^2}{2}\right]_{r_2}^{r_1}$$

$$W = p \times 2\pi \left[\frac{r_1^2 - r_2^2}{2}\right]$$

$$p = \frac{W}{\pi\left[r_1^2 - r_2^2\right]} \quad -(b).$$

frictional force, $\mu \times dW$ normal to the surface
$= \mu \times p \times 2\pi r\,dr / \sin\alpha$

Frictional torque on the rings.

$$dT = \mu \times p \times 2\pi r \times \frac{dr}{\sin\alpha} \times r.$$

total frictional torque, $T = \int_{r_2}^{r_1} dT$

$$T = \int_{r_2}^{r_1} \mu \times p \times 2\pi r \times \frac{dr}{\sin\alpha} \cdot r$$

$$= \frac{2\pi \times \mu \cdot p}{\sin\alpha} \int_{r_2}^{r_1} r^2 dr$$

$$= \frac{2\pi \mu \cdot p}{\sin\alpha} \left[\frac{r^3}{3} \right]_{r_2}^{r_1} = \frac{2\pi \times \mu \cdot p}{\sin\alpha} \left[\frac{(r_1^3 - r_2^3)}{3} \right]$$

$$= \frac{2\pi \times \mu}{3\sin\alpha} \cdot \frac{W}{\pi (r_1^2 - r_2^2)} \cdot (r_1^3 - r_2^3)$$

$$\therefore \boxed{T = \frac{2}{3} \frac{\mu W}{\sin\alpha} \left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2} \right]}$$

Power lost in friction, $P = \frac{2\pi N T}{60}$.

(ii) Uniform Wear:

$$p \times r = C.$$

$$p = C/r.$$

Vertical load transmitted, $dW = p \times 2\pi r \, dr$

Total vertical load, $W = \int_{r_2}^{r_1} p \times 2\pi r \, dr$

$$= \int_{r_2}^{r_1} \frac{C}{r} \cdot 2\pi r \, dr \Rightarrow 2\pi C \int_{r_2}^{r_1} dr = 2\pi C \left[r \right]_{r_2}^{r_1}$$

$$W = 2\pi C [r_1 - r_2]$$

$$C = \frac{W}{2\pi (r_1 - r_2)}$$

total frictional torque, $T = \int_{r_2}^{r_1} 2\pi \mu \times C \times r \times dr / \sin\alpha$

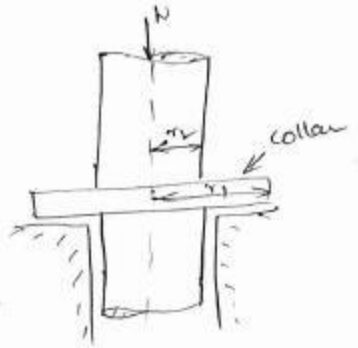
$$T = \frac{2\pi \mu \cdot C}{\sin\alpha} \int_{r_2}^{r_1} r \cdot dr \Rightarrow T = \frac{1}{\sin\alpha} \cdot 2\pi \cdot \mu \cdot C \left[\frac{r^2}{2} \right]_{r_2}^{r_1}$$

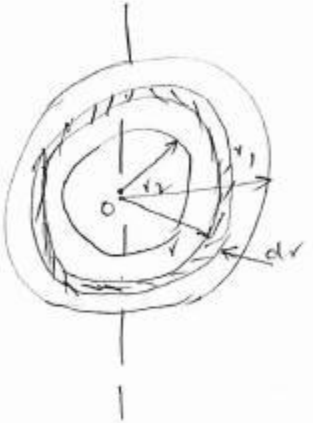
$$\Rightarrow T = \frac{1}{\sin\alpha} 2\pi \cdot \mu \cdot \frac{W}{2\pi (r_1 - r_2)} \left[\frac{(r_1^2 - r_2^2)}{2} \right]$$

$$\boxed{T = \frac{1}{2} \frac{\mu W (r_1 + r_2)}{\sin\alpha}}$$

Power lost in friction, $\boxed{P = \frac{2\pi N T}{60}}$

Flat Collar:- The bearing surface provided at any position on the shaft (but not at the end) to carry axial thrust is known as collar. Collar bearings are also known as thrust bearings.





let,
$r_1 \to$ External radius of collar
$r_2 \to$ Internal radius of collar
$p \to$ intensity of Pr.
$W \to$ Axial load or total load transmitted to bearing surface
$\mu \to$ co-effecient of friction
$T \to$ Total frictional torque.

Consider a circular ring of radius 'r' & thickness dr

$\therefore$ Area of ring, $= 2\pi r \cdot dr$.

load on ring, $=$ Pr $\times$ Area of ring

$= p \times 2\pi \cdot r \cdot dr$.

Friction torque $=$ friction force $\times$ Radius

$= p \cdot \mu \times 2\pi r dr \times r$

$= 2\pi \mu p r^2 \cdot dr$.

$\therefore$ total frictional torque,

$$T = \int_{r_2}^{r_1} dT$$

$$T = \int^{r_1} 2\pi \mu \cdot p r^2 \cdot dr.$$

(i) Uniform Pressure:-

$p =$ constant.

Total load transmitted to the bearing,

$$W = \int_{r_2}^{r_1} \text{load on ring } (dW)$$

$$= \int_{r_2}^{r_1} p \times 2\pi r\, dr$$

$$= p \times 2\pi \int_{r_2}^{r_1} r dr \Rightarrow p \times 2\pi \left[\frac{r^2}{2}\right]_{r_2}^{r_1}$$

$$\Rightarrow p \times 2\pi \left[\frac{r_1^2 - r_2^2}{2}\right] \Rightarrow p \times \pi \left[r_1^2 - r_2^2\right] = W$$

$$p = \frac{W}{\pi \left[r_1^2 - r_2^2\right]}.$$

Total frictional torque

$$T = \int_{r_2}^{r_1} 2\pi \mu \cdot p r^2 dr$$

$$= 2\pi \mu \cdot p \int_{r_2}^{r_1} r^2 \cdot dr$$

$$= 2\pi \mu \cdot p \left[\frac{r^3}{3}\right]_{r_2}^{r_1} = 2\pi \mu p \cdot \left(\frac{r_1^3 - r_2^3}{3}\right)$$

$$= \frac{2}{3} \pi \mu \cdot \frac{W}{\pi \left[r_1^2 - r_2^2\right]} \cdot \left[r_1^3 - r_2^3\right] \Rightarrow \boxed{T = \frac{2}{3} \mu W \left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]}$$

power lost in friction, $P = \frac{2\pi N T}{60}$

ii) For Uniform Wear:

$p \times r =$ constant

$p \times r = C$

$p = C/r$

Total load transmitted to the bearing.

$W = \int_{r_2}^{r_1}$ load on ring $= \int_{r_2}^{r_1} dW$

$W = \int_{r_2}^{r_1} p \times 2\pi r\, dr$

$W = \int_{r_2}^{r_1} \frac{C}{r} \times 2\pi\, dr \cdot r$

$= 2\pi \cdot C \int_{r_2}^{r_1} dr$

$= 2\pi C [r]_{r_2}^{r_1} \Rightarrow 2\pi C [r_1 - r_2] = W$

$C = \frac{W}{2\pi [r_1 - r_2]}$

Total frictional torque

$T = \int_{r_2}^{r_1} dT = \int_{r_2}^{r_1} dF \times r$

$= \int_{r_2}^{r_1} 2\pi \mu p\, r^2\, dr$

$= 2\pi \mu \int_{r_2}^{r_1} \frac{C}{r} \cdot r^2\, dr$

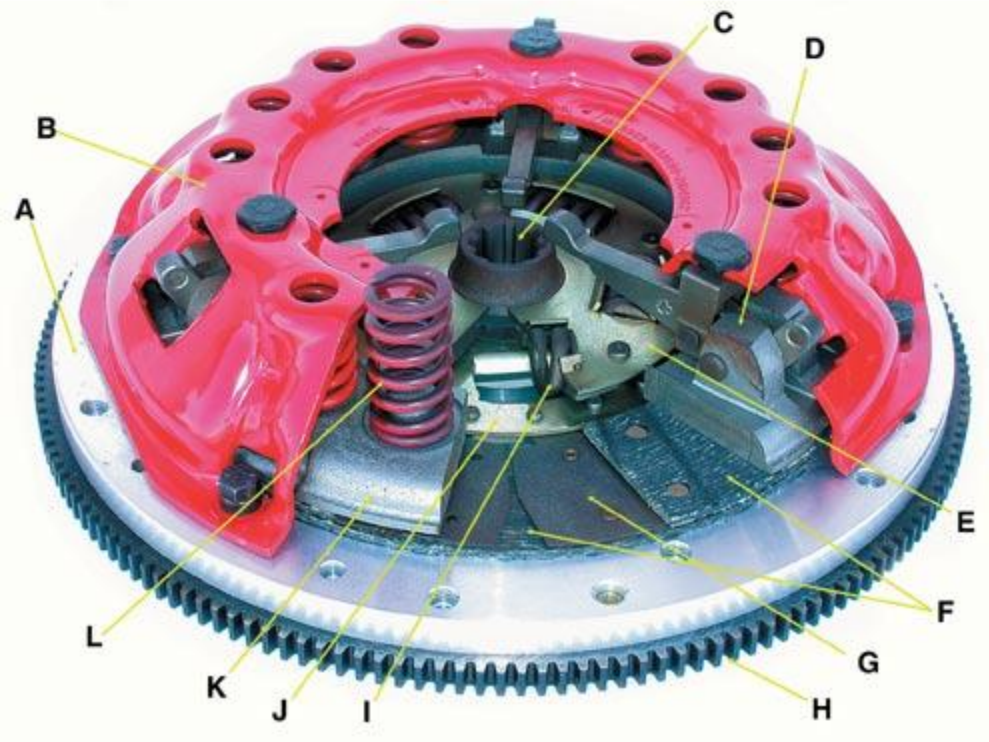
$= 2\pi \mu C \int_{r_2}^{r_1} r\, dr = \pi \mu C [r_1^2 - r_2^2] = T$

$= \pi \mu \cdot \frac{W}{2\pi (r_1 - r_2)} [r_1^2 - r_2^2]$

$$T = \frac{1}{2} \mu W (r_1 + r_2)$$

Power lost in friction, $P = \frac{2\pi N T}{60}$

Clutches

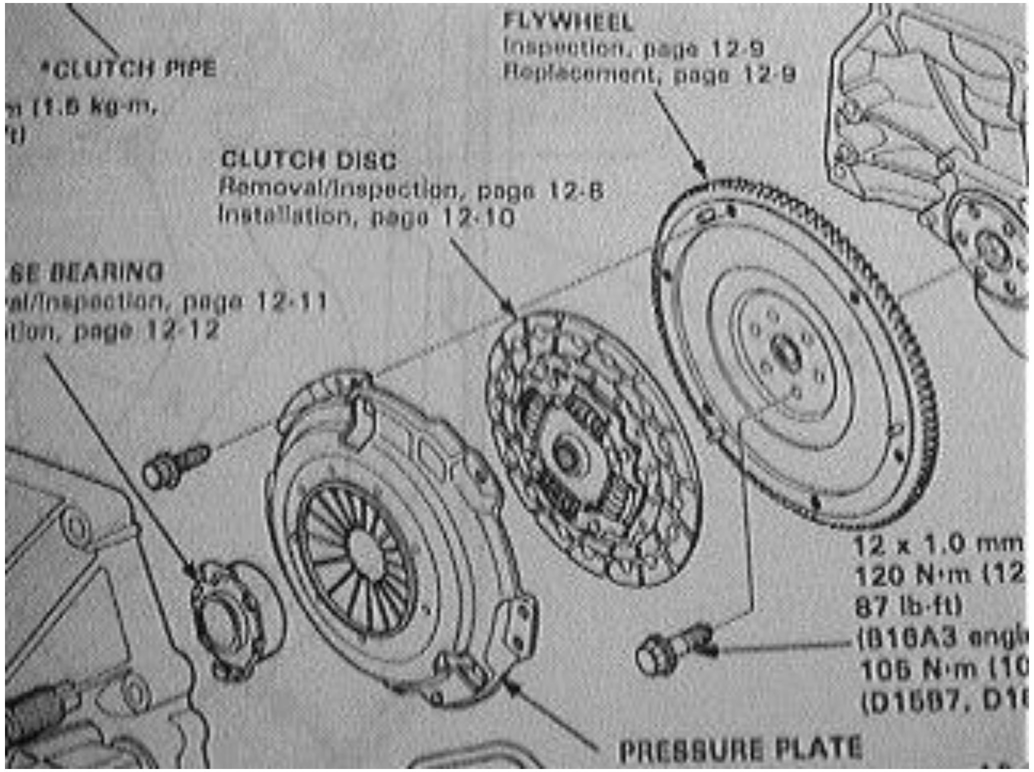


Purpose

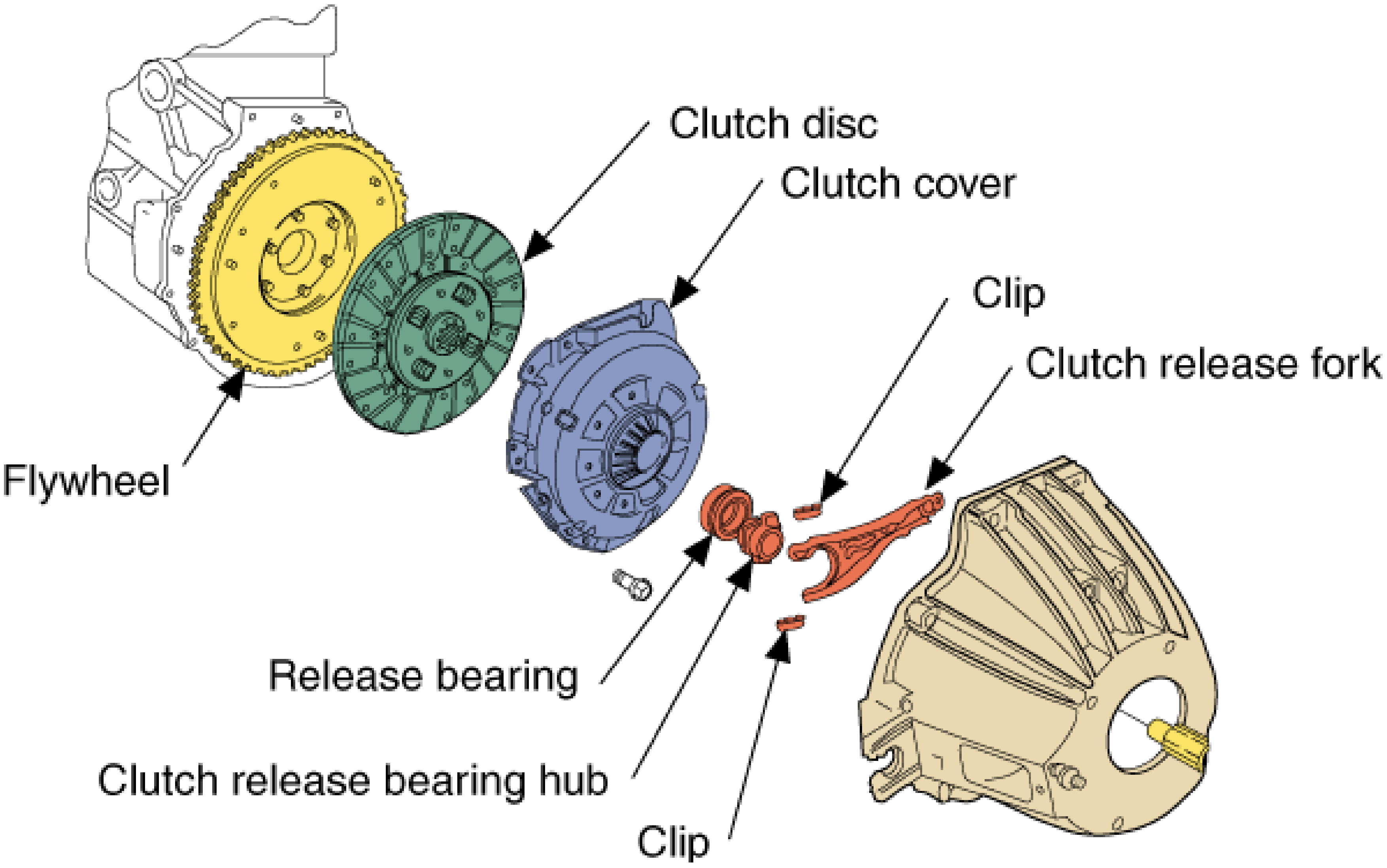
- A clutch is designed with the following requirements
  - Allow the vehicle to come to a stop while the transmission remains in gear
  - Allow the driver to smoothly take off from a dead stop
  - Allow the driver to smoothly change gears
  - Must not slip under heavy loads and full engine power

Components

- Primary components
  - Flywheel
  - Clutch disc
  - Pressure plate
  - Throwout bearing
- Secondary components
  - Pilot bearing
  - Release fork
  - Slave cylinder



[How a Clutch Works]

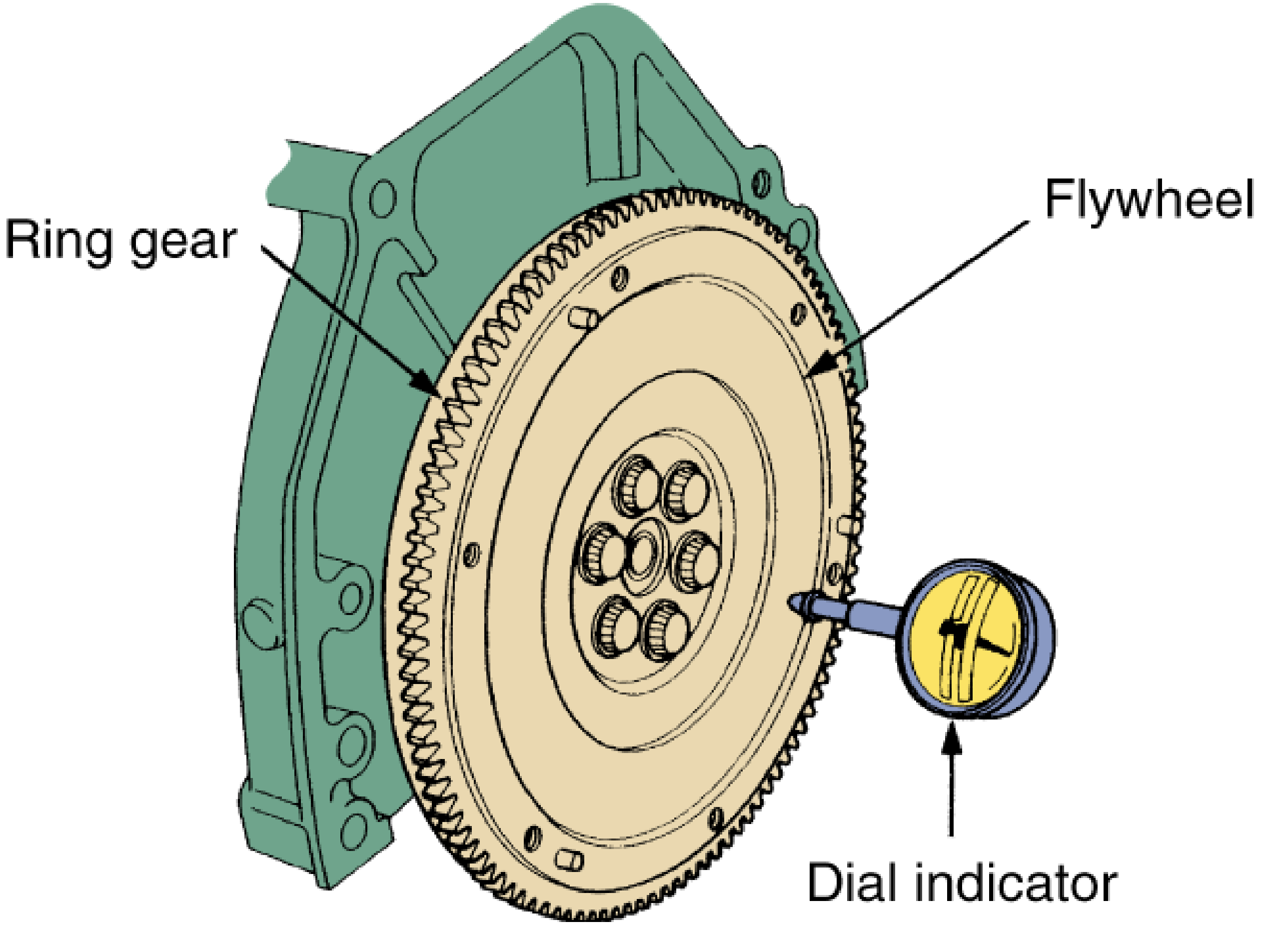

Clutch disc
Clutch cover
Clip
Clutch release fork
Flywheel
Release bearing
Clutch release bearing hub
Clip

Operation

- Flywheel
  - The flywheel attaches to the crankshaft flange
  - The flywheel's mass is used to store rotational energy to allow the vehicle to smoothly start out
  - The flywheel has a machined surface, which the clutch disc rides on
  - The pressure plate bolts to the flywheel

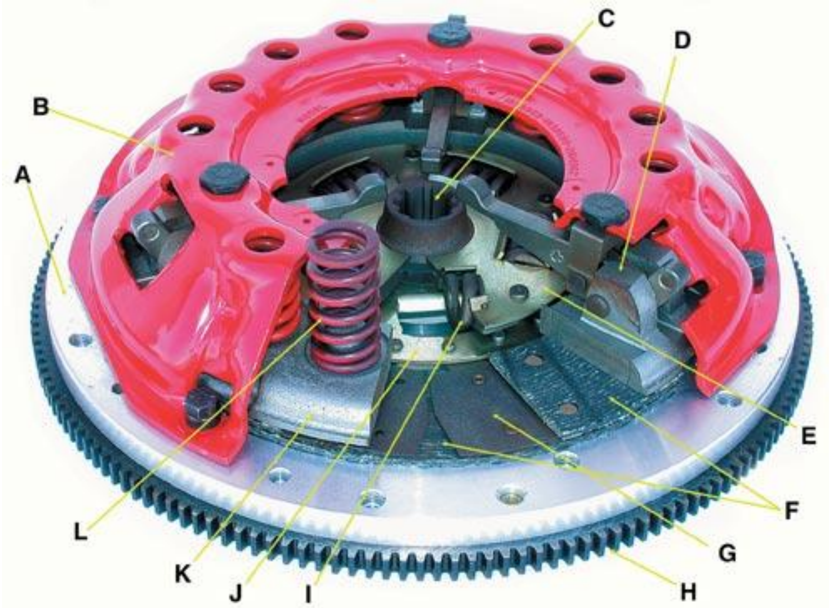
Flywheel

Standard (new): 0.05 mm (0.002 in) max.
Service limit: 0.15 mm (0.006 in) max.

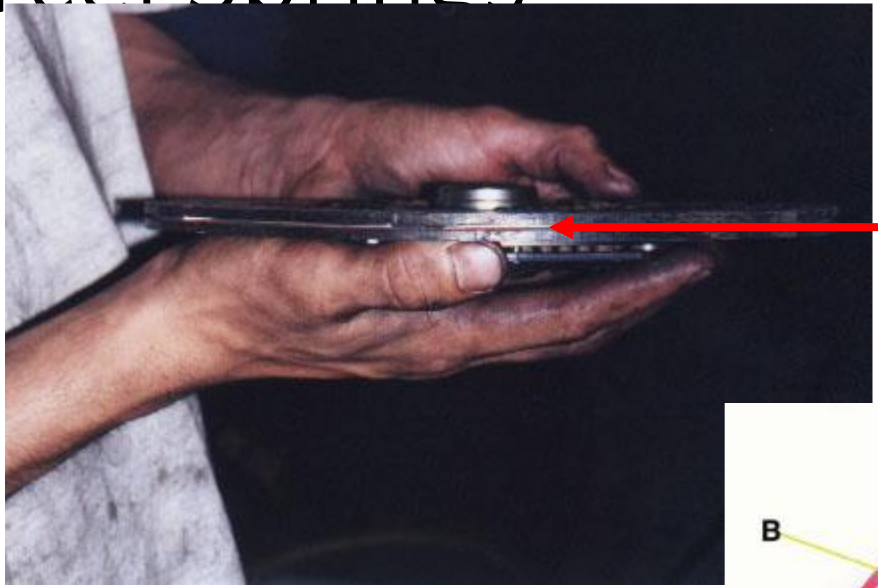


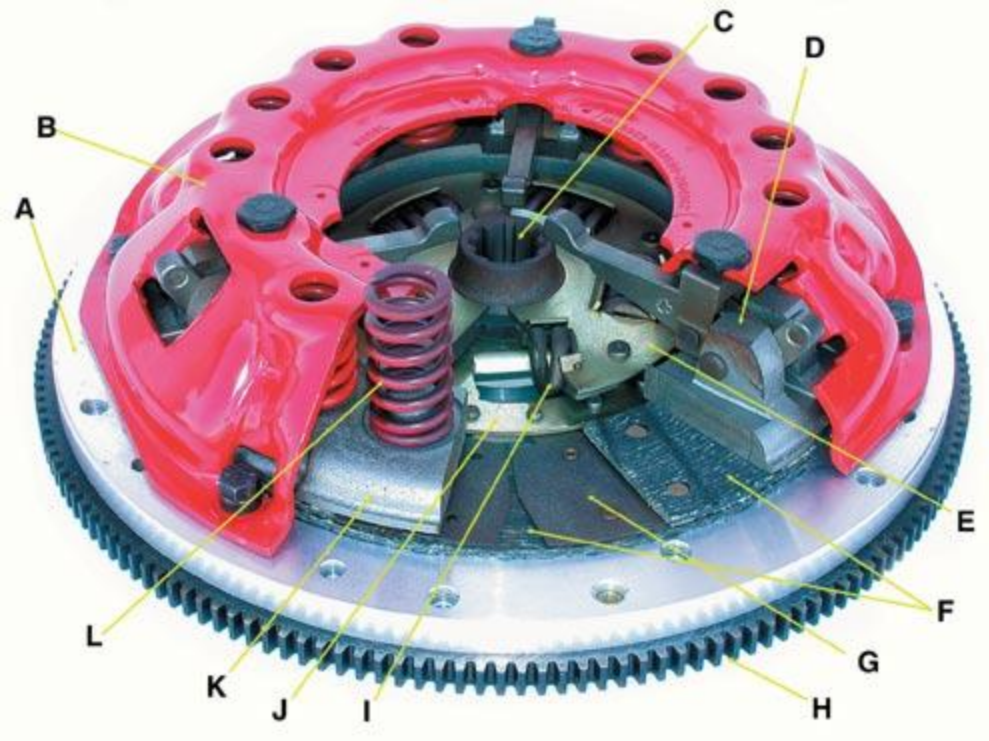
Operation

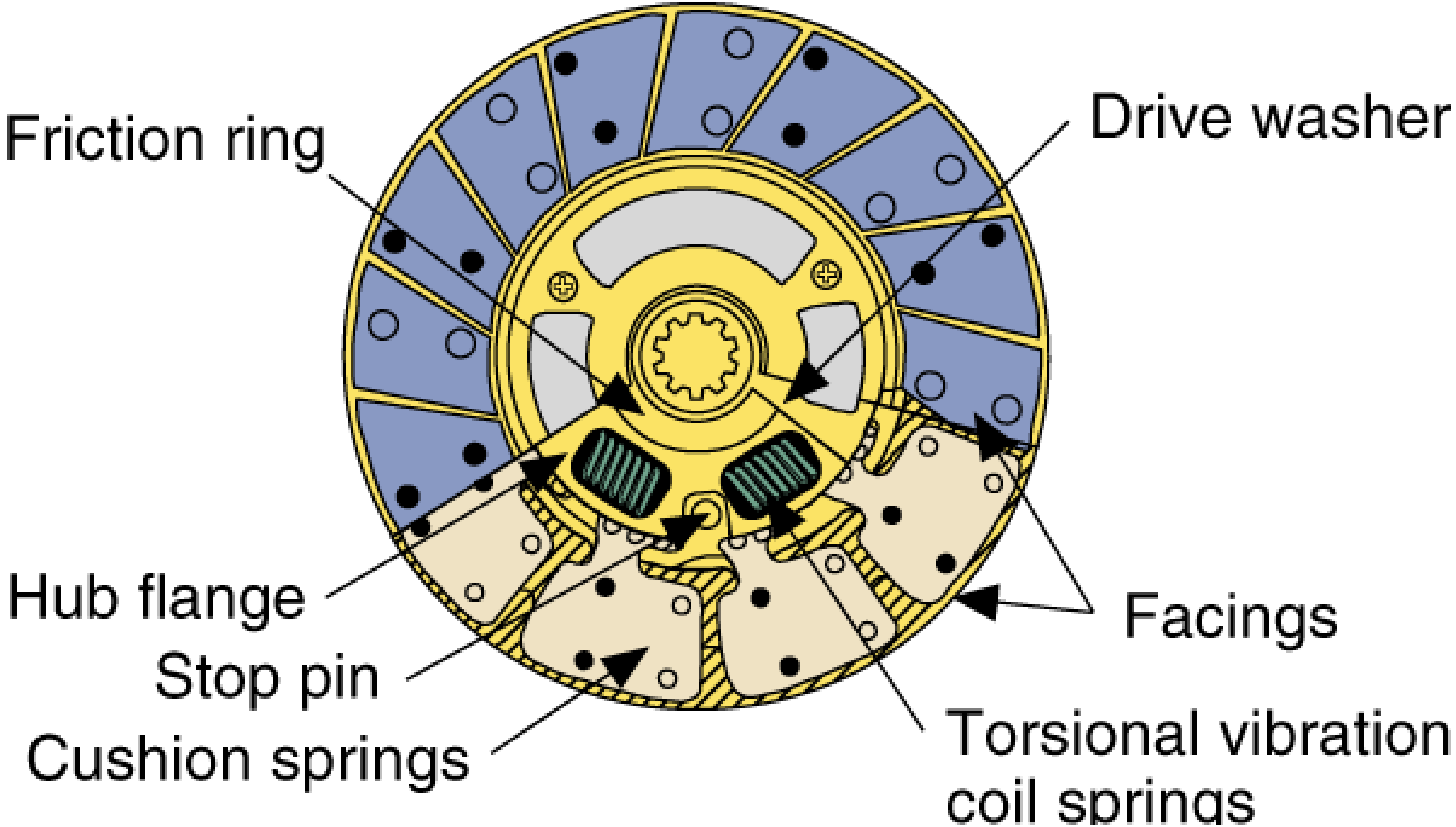
- Clutch disc
  - Lined on both sides with a friction lining similar to a brake pad
  - The internal hub splines to the input shaft of the transmission
  - The two friction linings are separated by Marcel springs
    - These springs allow the linings to "slip" on apply and release
  - The friction linings are connected to the central hub by torsional dampening springs
    - These springs help dampen the apply and isolate engine/driveline vibration/pulsations

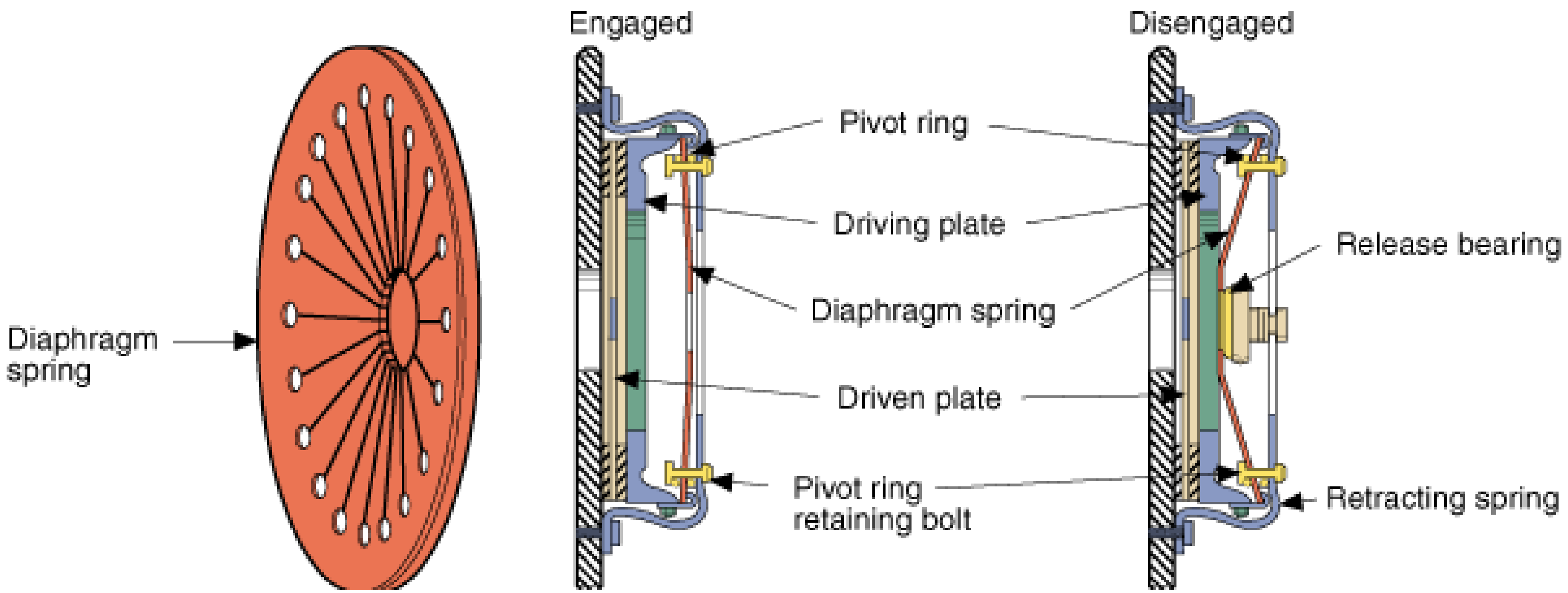


Marcel Springs



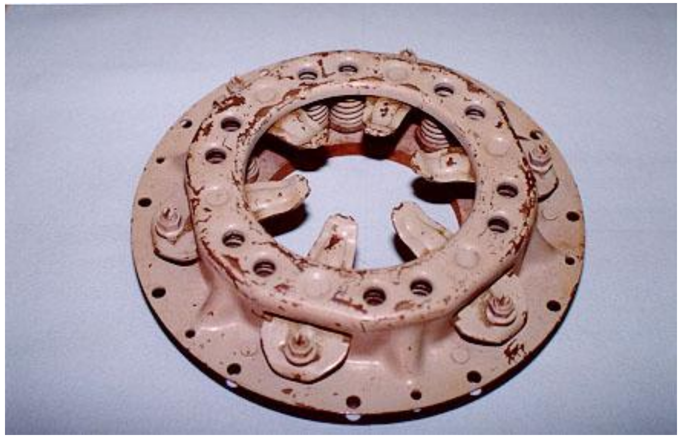


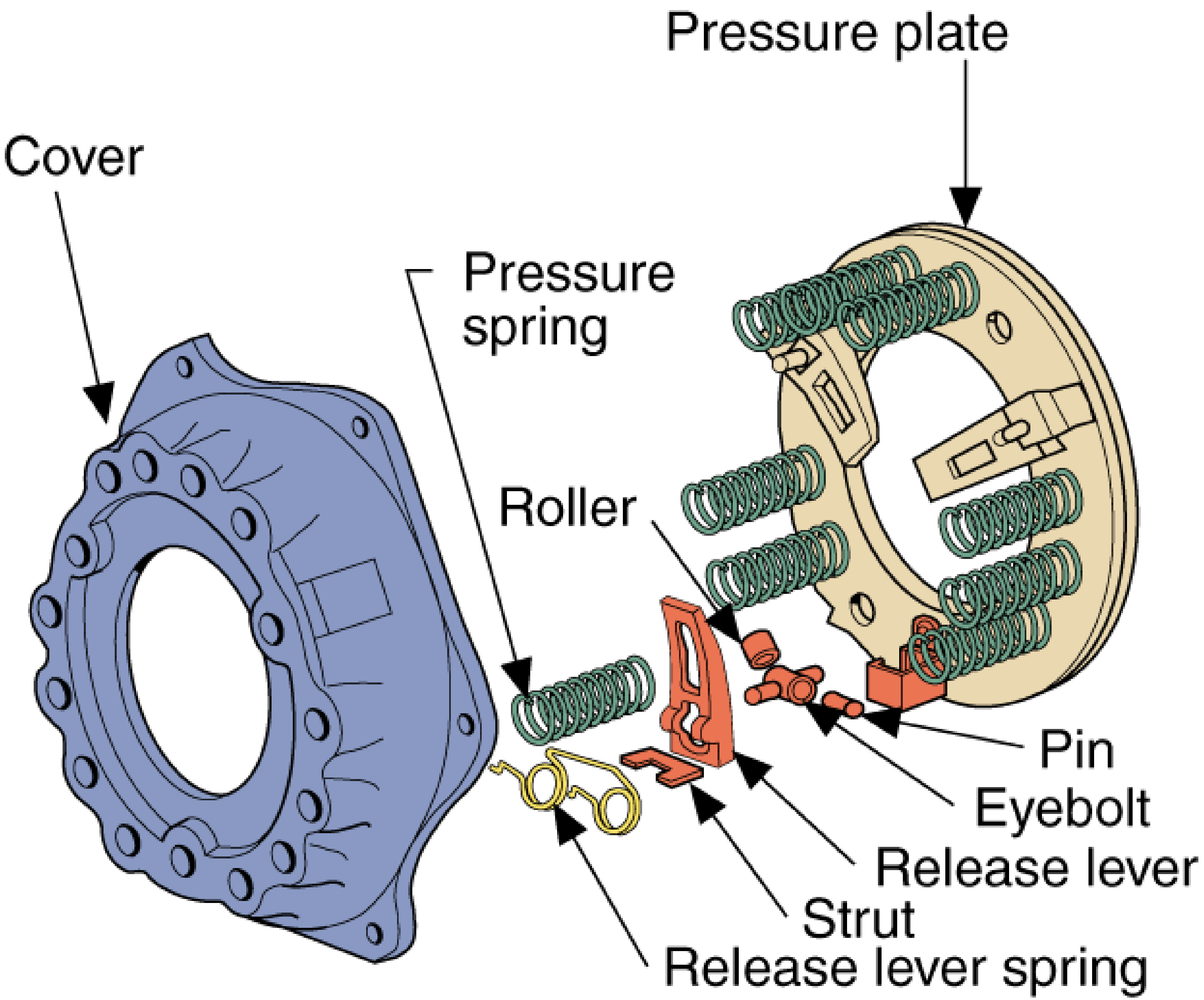

Friction ring
Drive washer
Hub flange
Facings
Stop pin
Cushion springs
Torsional vibration
coil springs


Engaged
Disengaged
Diaphragm spring
Pivot ring
Driving plate
Release bearing
Diaphragm spring
Driven plate
Pivot ring retaining bolt
Retracting spring

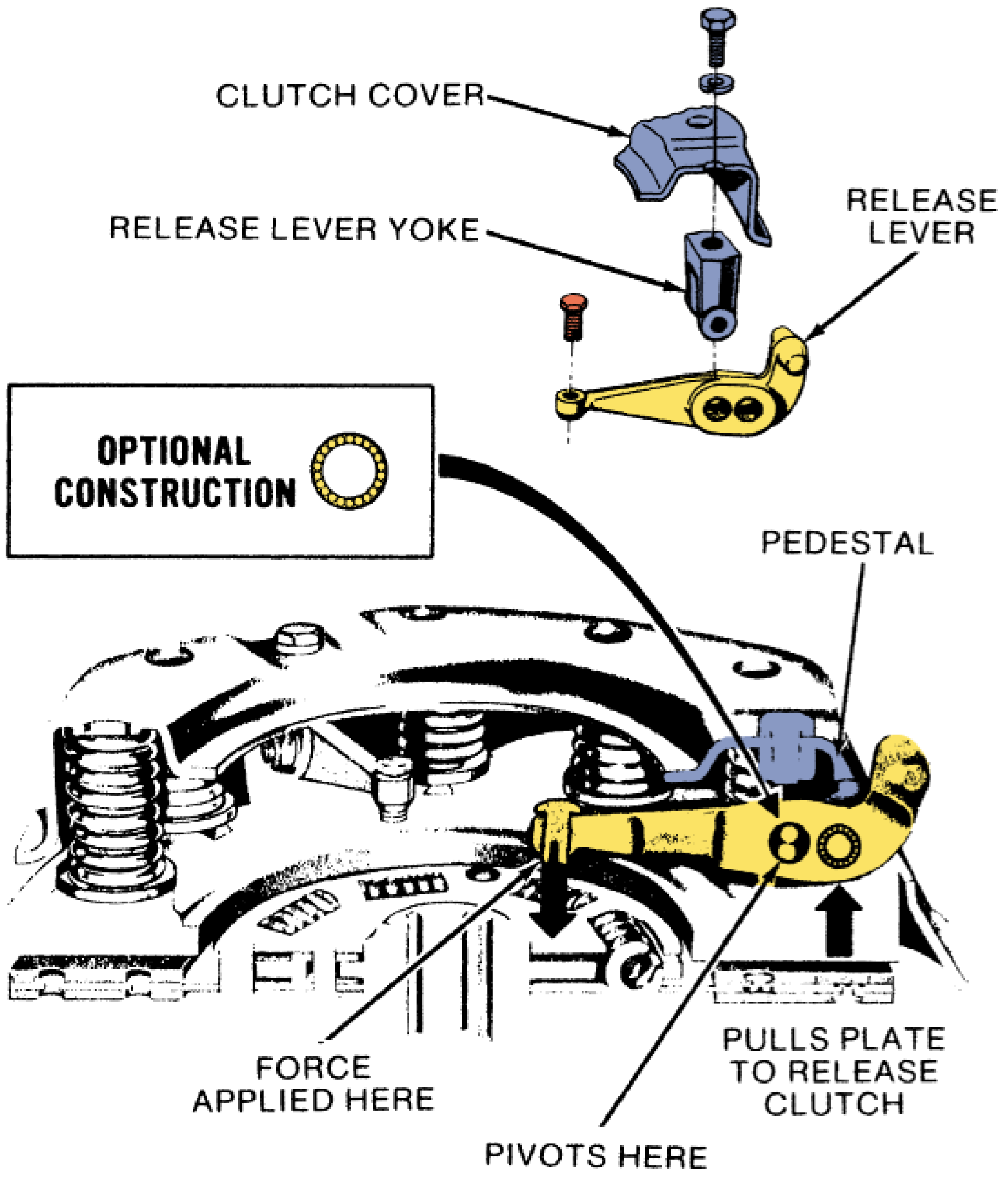
Operation

- Pressure Plate
  - Apply pressure to the clutch disc
    - “Squeezes” the clutch disc between itself and the flywheel
  - Allow the clutch disc to release
    - When vehicle is stopped or driver is shifting
  - Different designs used
    - Long
      - Old Fords, muscle cars, and trucks
    - Borg and Beck
      - Chrysler and some early GM
      - 12 Coil springs
      - Very stiff pedal
    - Diaphragm
      - Most common
      - Uses a Diaphragm spring





Pressure plate
Cover
Pressure spring
Roller
Pin
Eyebolt
Release lever
Strut
Release lever spring


CLUTCH COVER
RELEASE LEVER YOKE
RELEASE LEVER
OPTIONAL CONSTRUCTION
PEDESTAL
FORCE APPLIED HERE
PIVOTS HERE
PULLS PLATE TO RELEASE CLUTCH

Operation

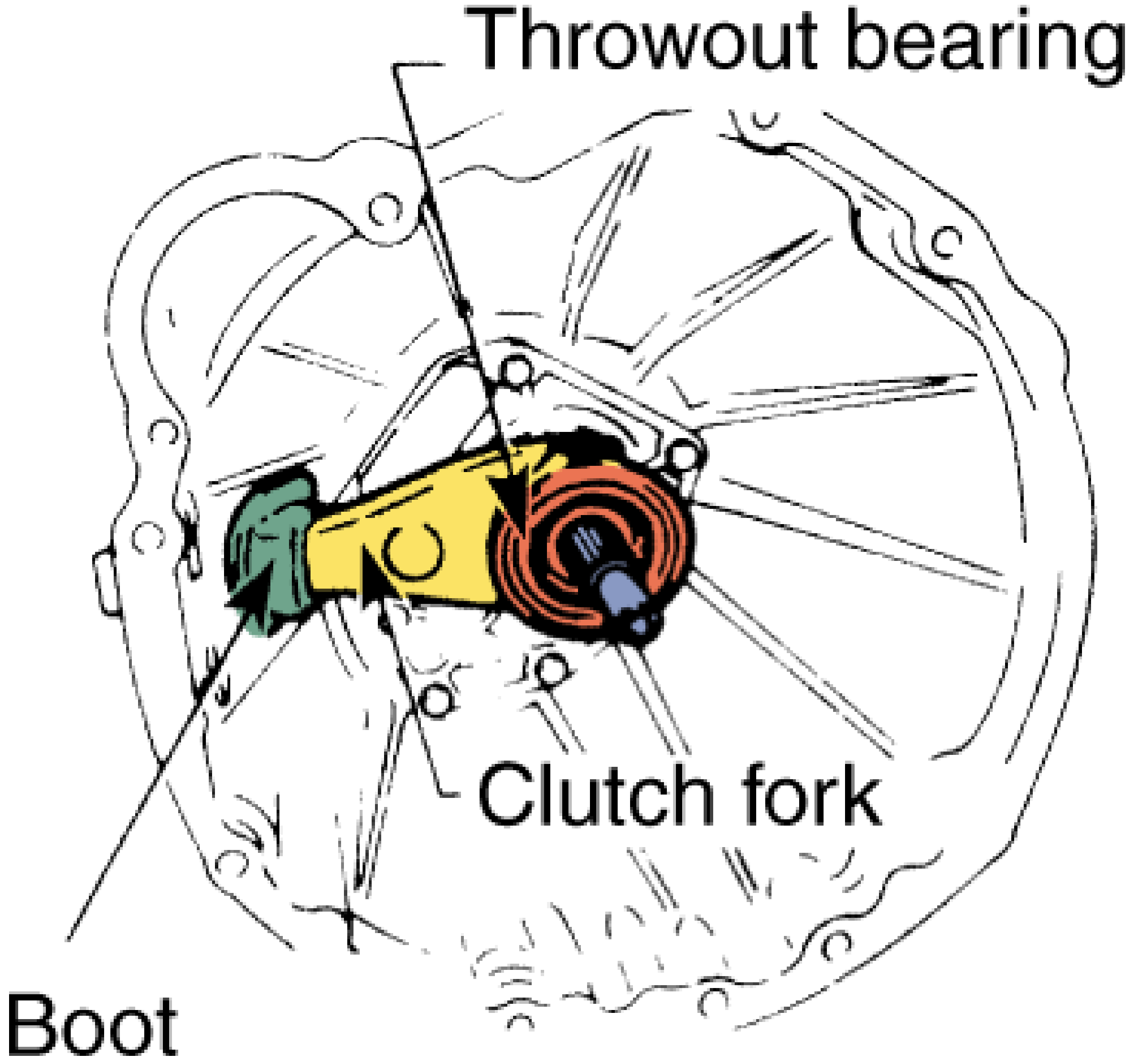
- Throwout Bearing
  - Exerts force on the pressure plate to compress the springs and release the clutch disc
  - May be mechanically or hydraulically operated

Operation

- Pilot Bushing/Bearing
  - Located in the rear of the crankshaft
  - Supports and centers the transmission input shaft
  - Replace when servicing a clutch

Release Fork

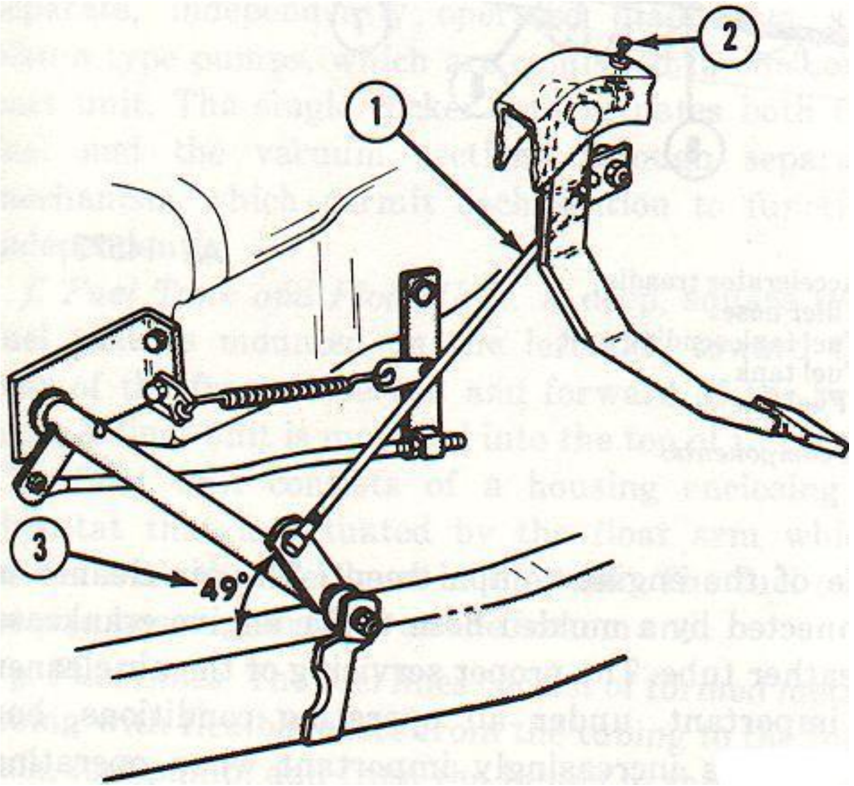
Link between the linkage or slave cylinder and the throwout bearing

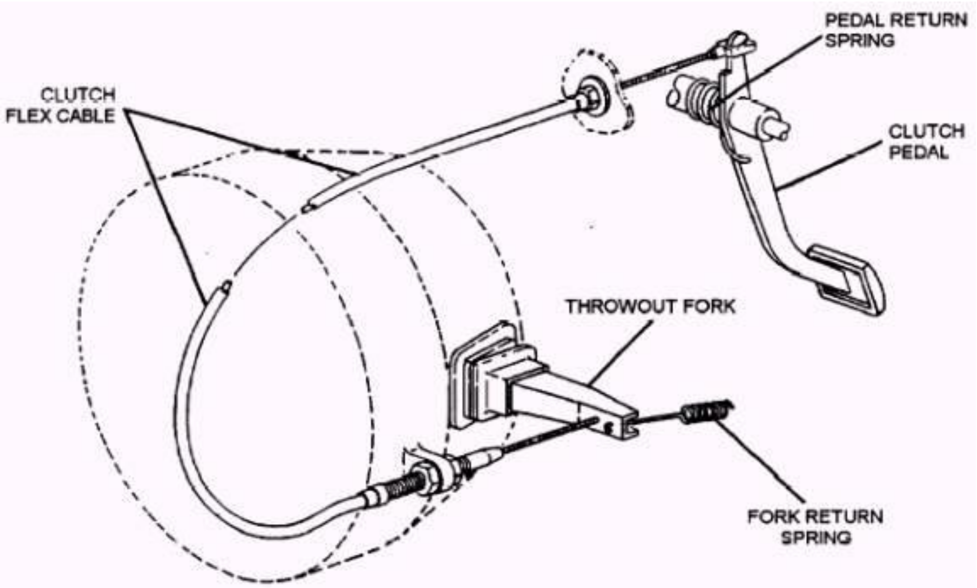


Release Systems

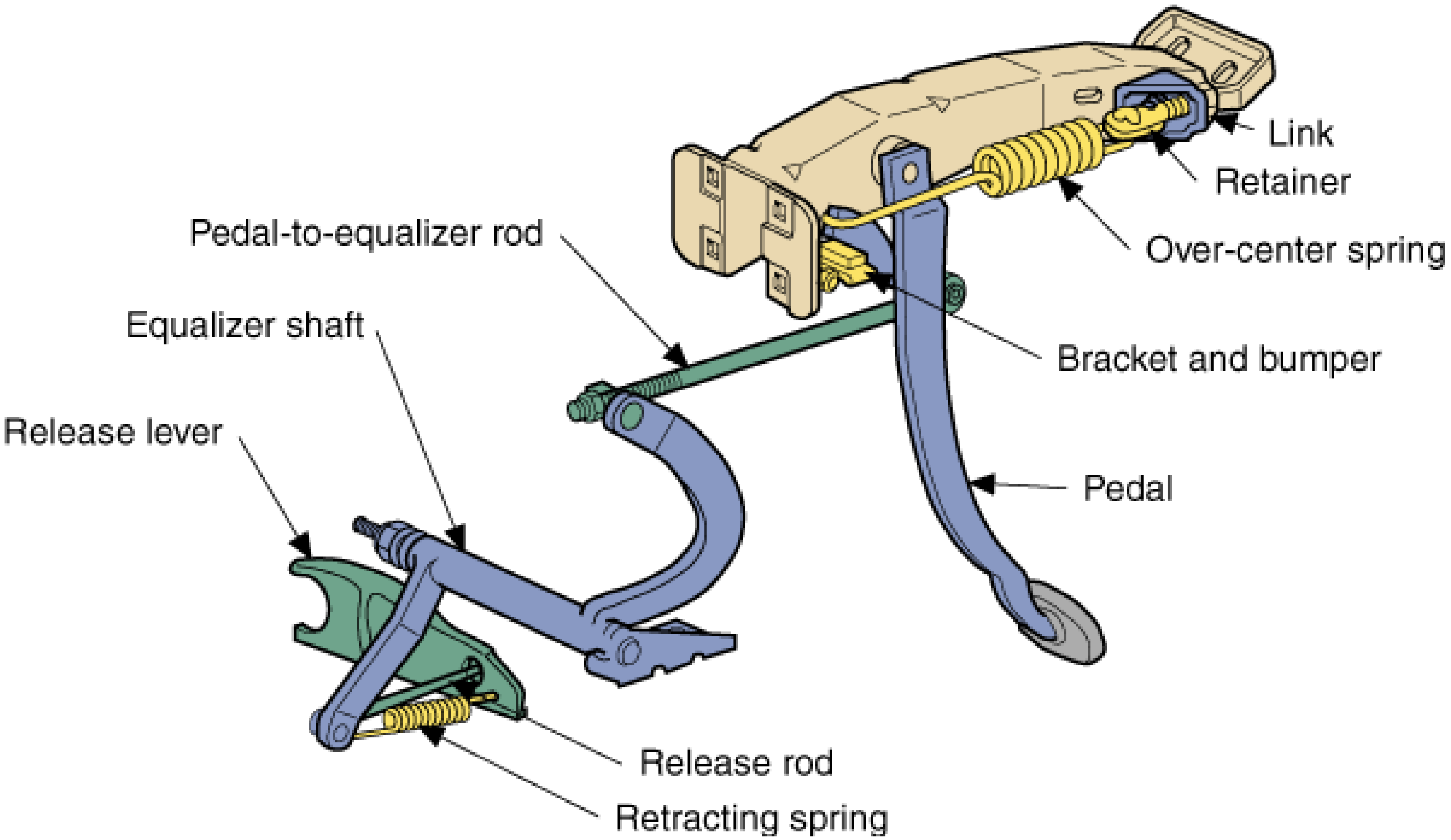
- Mechanical
  - A system of levers and linkages and/or cables connecting the clutch pedal with the release fork
- Hydraulic-Mechanical
  - A hydraulic master cylinder is used to transmit force to the slave cylinder which pushes on the release fork
- Hydraulic
  - A hydraulic master cylinder is used to transmit force to the slave cylinder which is located in the bellhousing and pushes directly on the throwout bearing

Mechanical Release

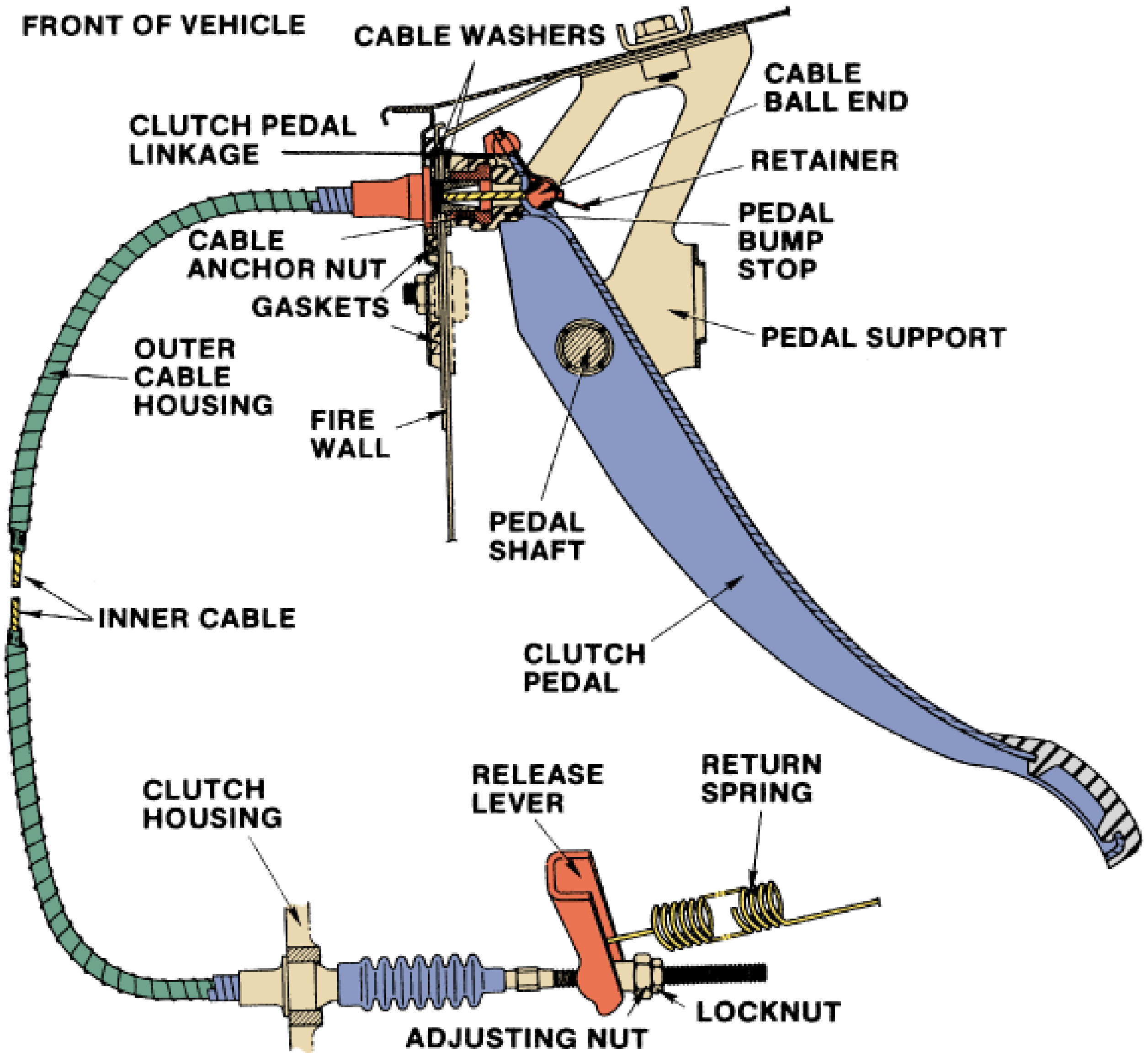




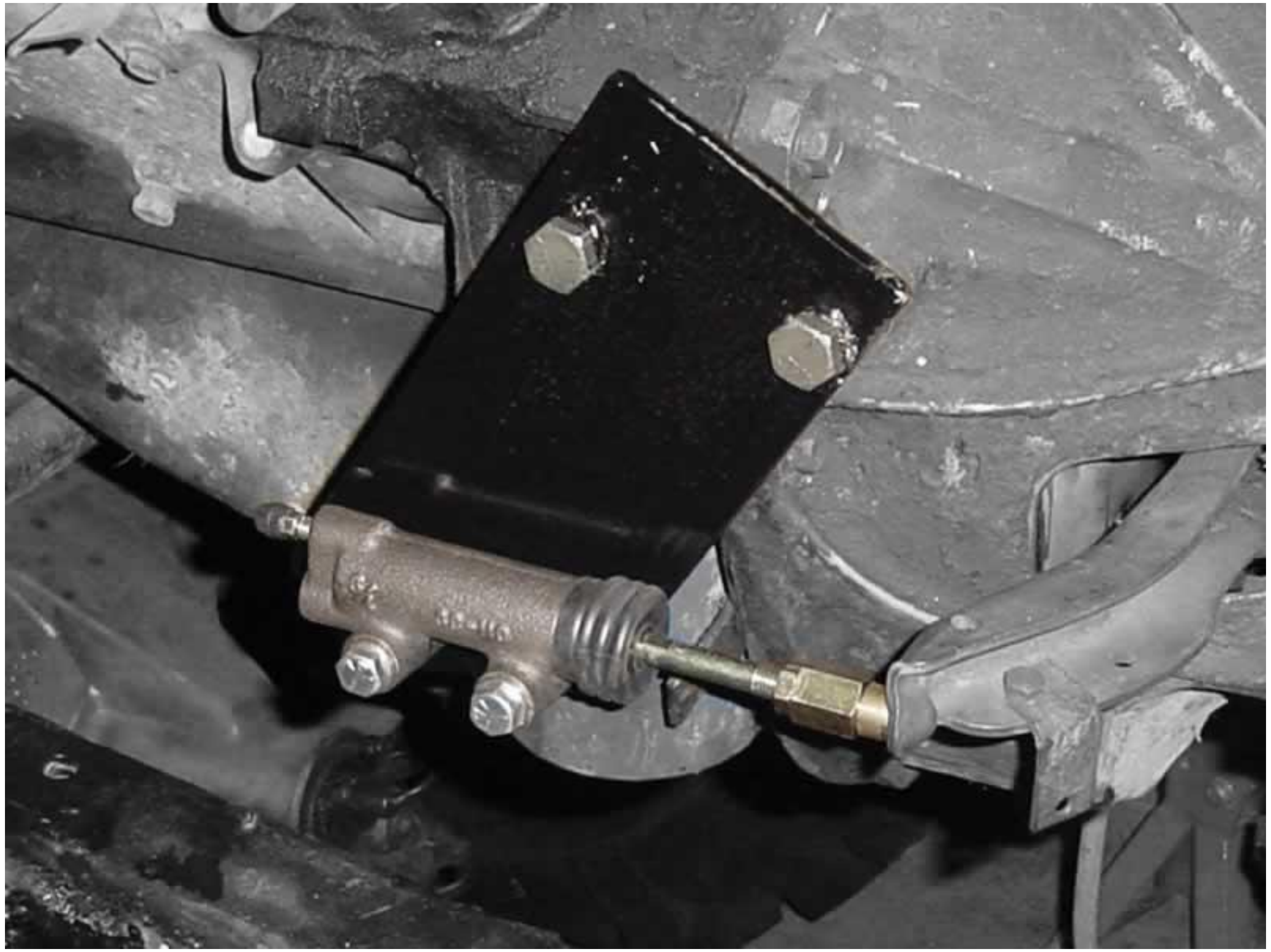
Mechanical Release



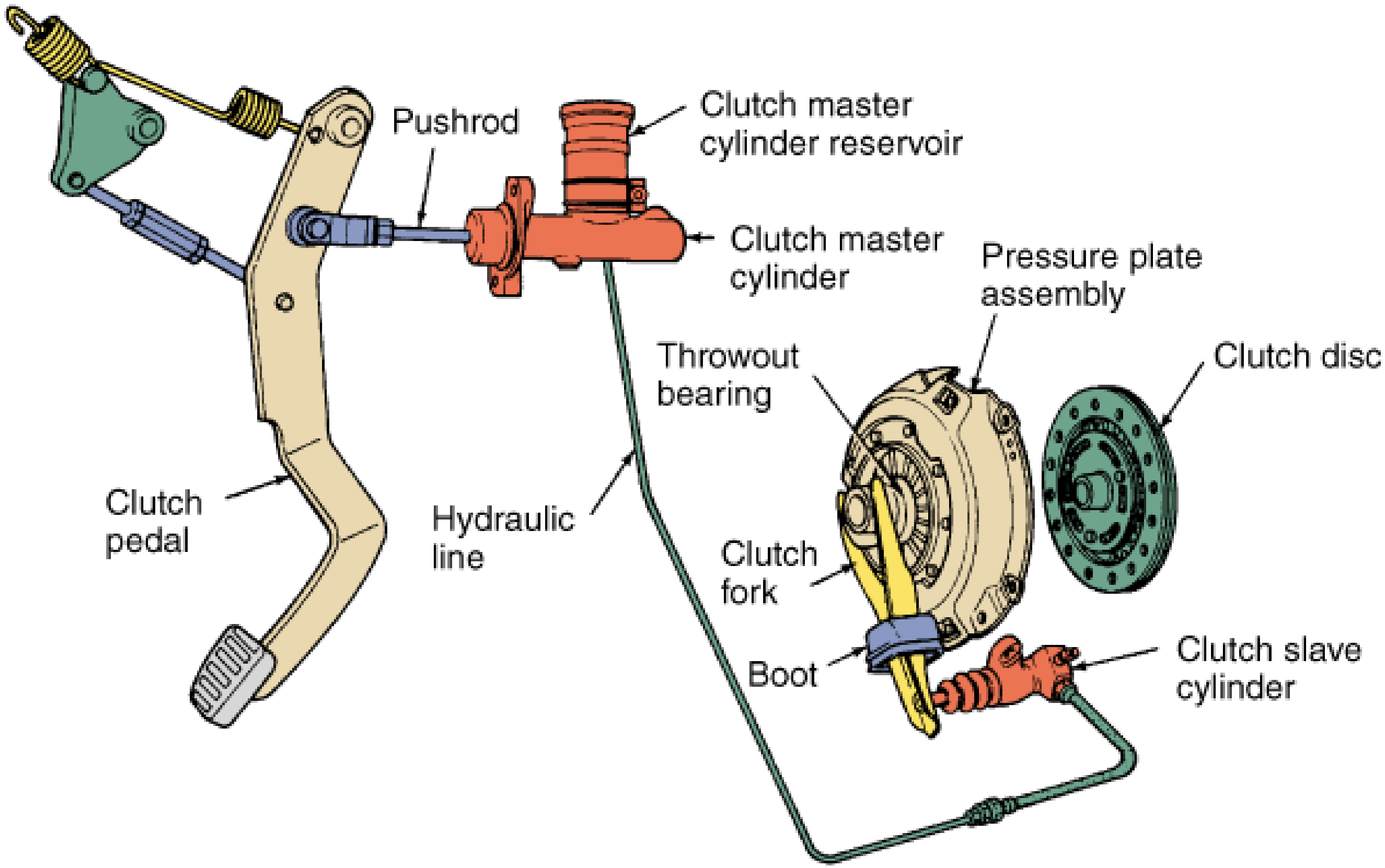
Cable Release



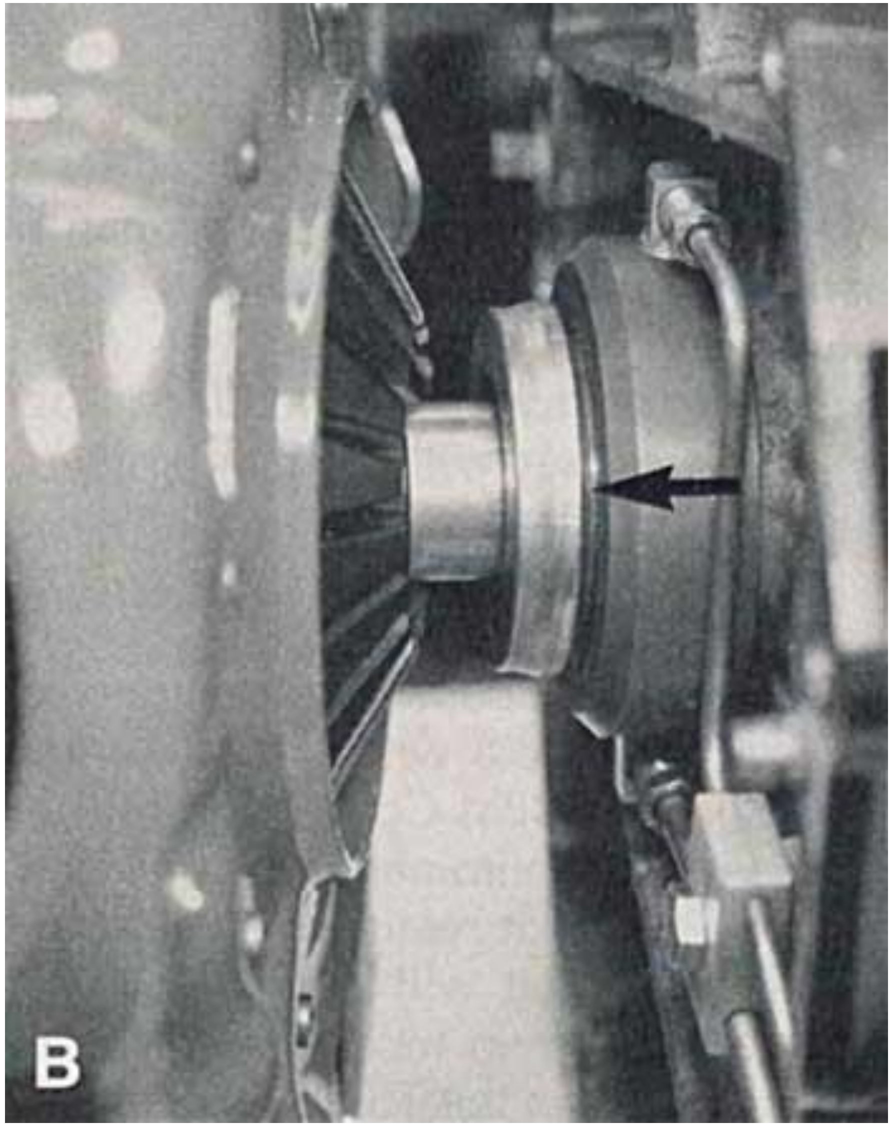
Mechanical-Hydraulic Release

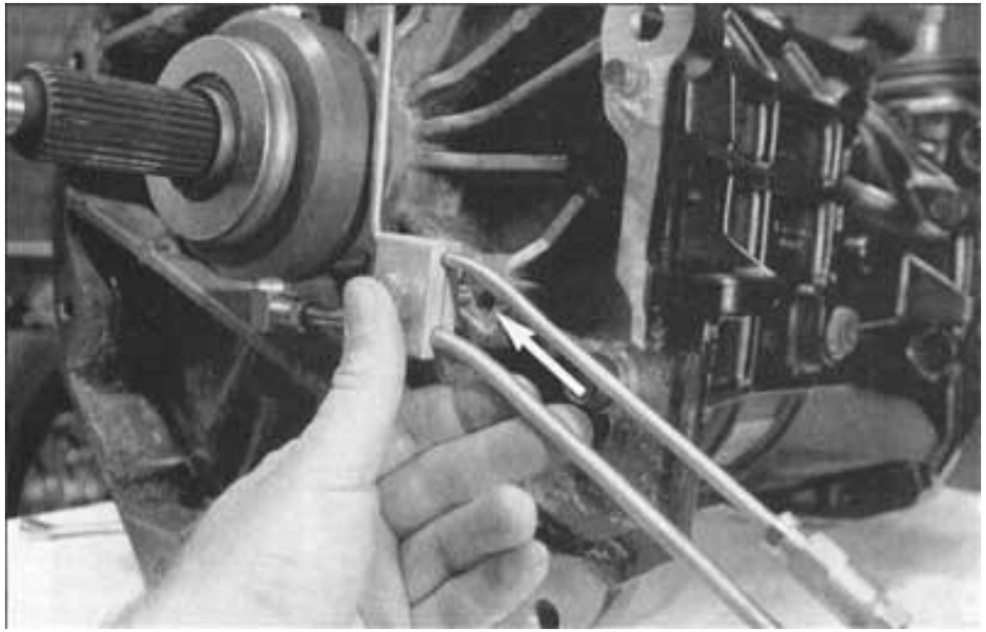


Mechanical-Hydraulic Release



Hydraulic Release



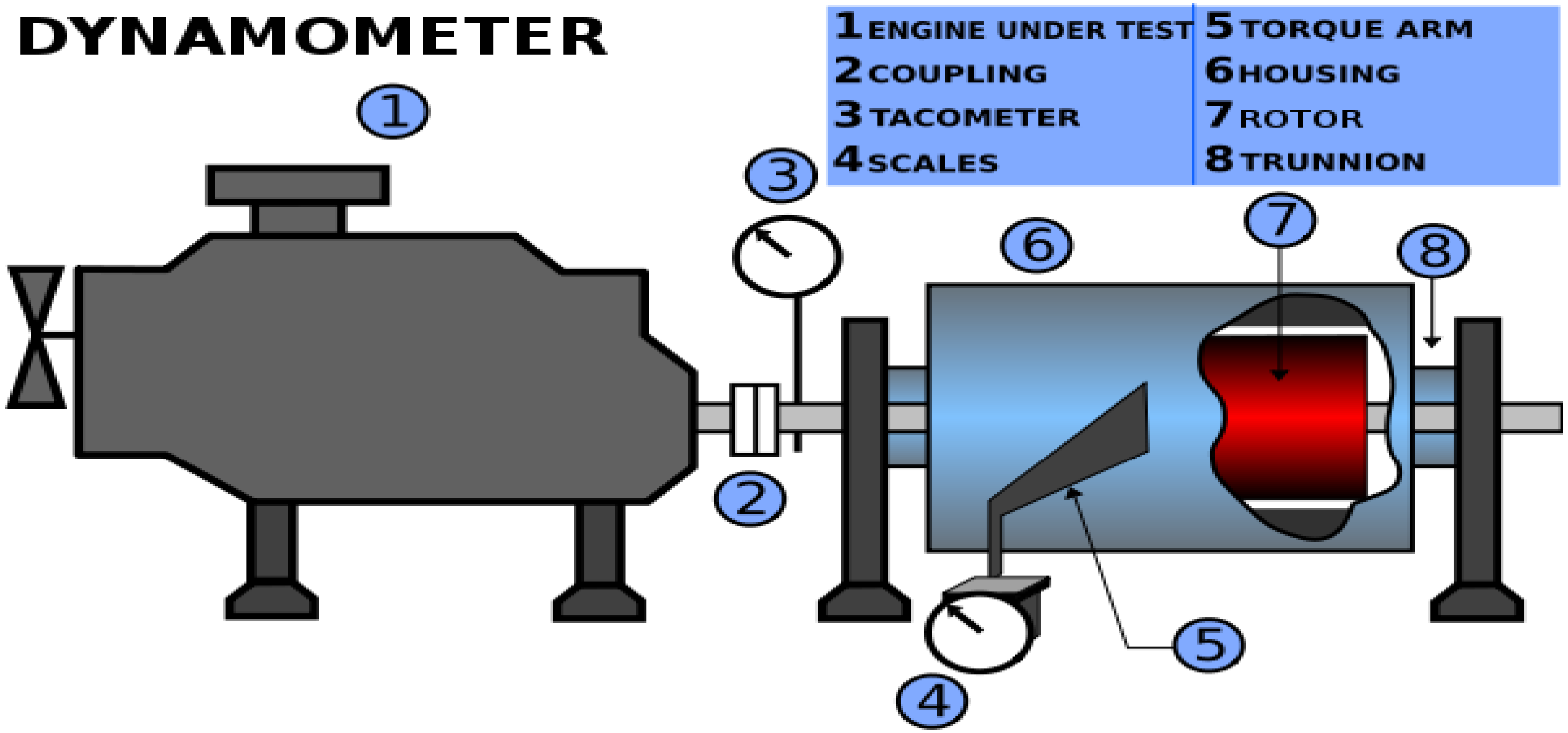


[How a Clutch Works]

Dynamometers

DEFINITION

- A dynamometer is a brake but in addition it has a device to measure the frictional resistance. Knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine.



Types Of Dynamometers

1) Absorption Type

 a) Prony Brake Dynamometer

 b) Rope Brake Dynamometer

2)Transmission Type

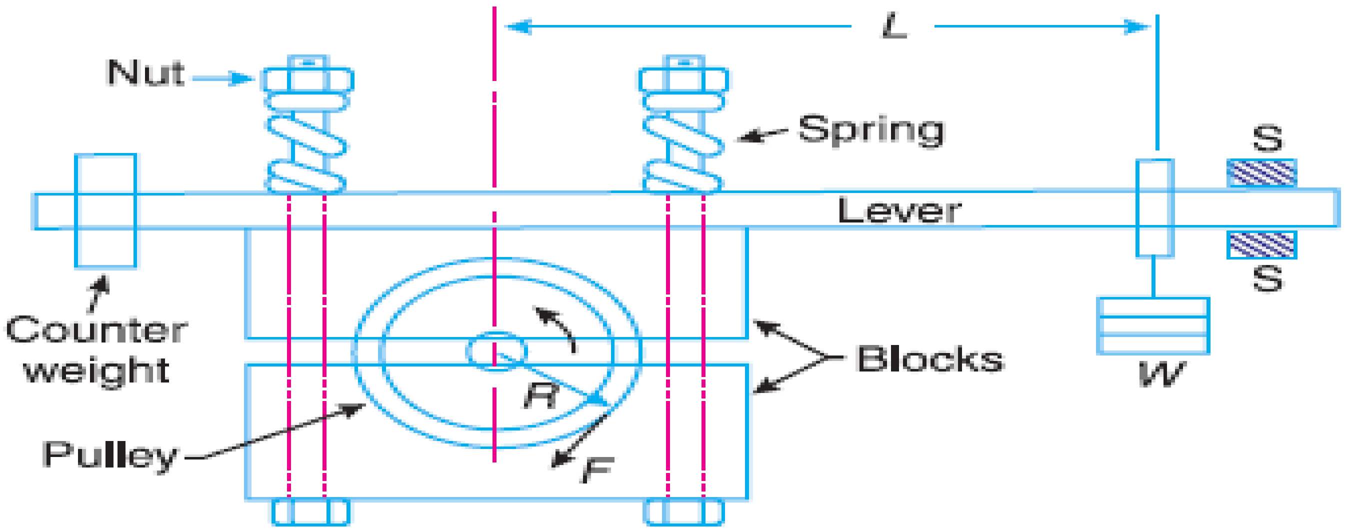
 a)Epicyclic train dynamometer

 b) Belt Transmission dynamometer

 c) Torsion dynamometer

- In the *absorption* ***dynamometers, the*** entire energy or power produced by the engine is absorbed by the friction resistances of the brake and is transformed into heat , during the process of measurement. But in the ***transmission dynamometers, the energy*** is not wasted in friction but is used for doing work. The energy or power produced by the engine is transmitted through the dynamometer to some other machines where the power developed is suitably measured.

Prony Brake Dynamometer



When the brake is to be put in operation, the long end of the lever is loaded with suitable weights *W and the nuts are tightened until the engine shaft runs at a constant speed and the lever is in* horizontal position. Under these conditions, the moment due to the weight *W must balance the moment* of the frictional resistance between the blocks and the pulley.

Let W = *Weight at the outer end of the lever in newtons,*
L = *Horizontal distance of the weight* W
from the centre of the pulley in metres,
F = *Frictional resistance between the blocks* and the pulley in newtons,
R = *Radius of the pulley in metres, and*
N = *Speed of the shaft in r.p.m.*
We know that the moment of the frictional resistance or torque on the shaft,

$$T = W.L = F.R \text{ N-m}$$

Work done in one revolution

$$= \text{Torque} \times \text{Angle turned in radians}$$

$$= T \times 2\pi \text{ N-m}$$

$\therefore$ Work done per minute

$$= T \times 2\pi N \text{ N-m}$$

We know that brake power of the engine,

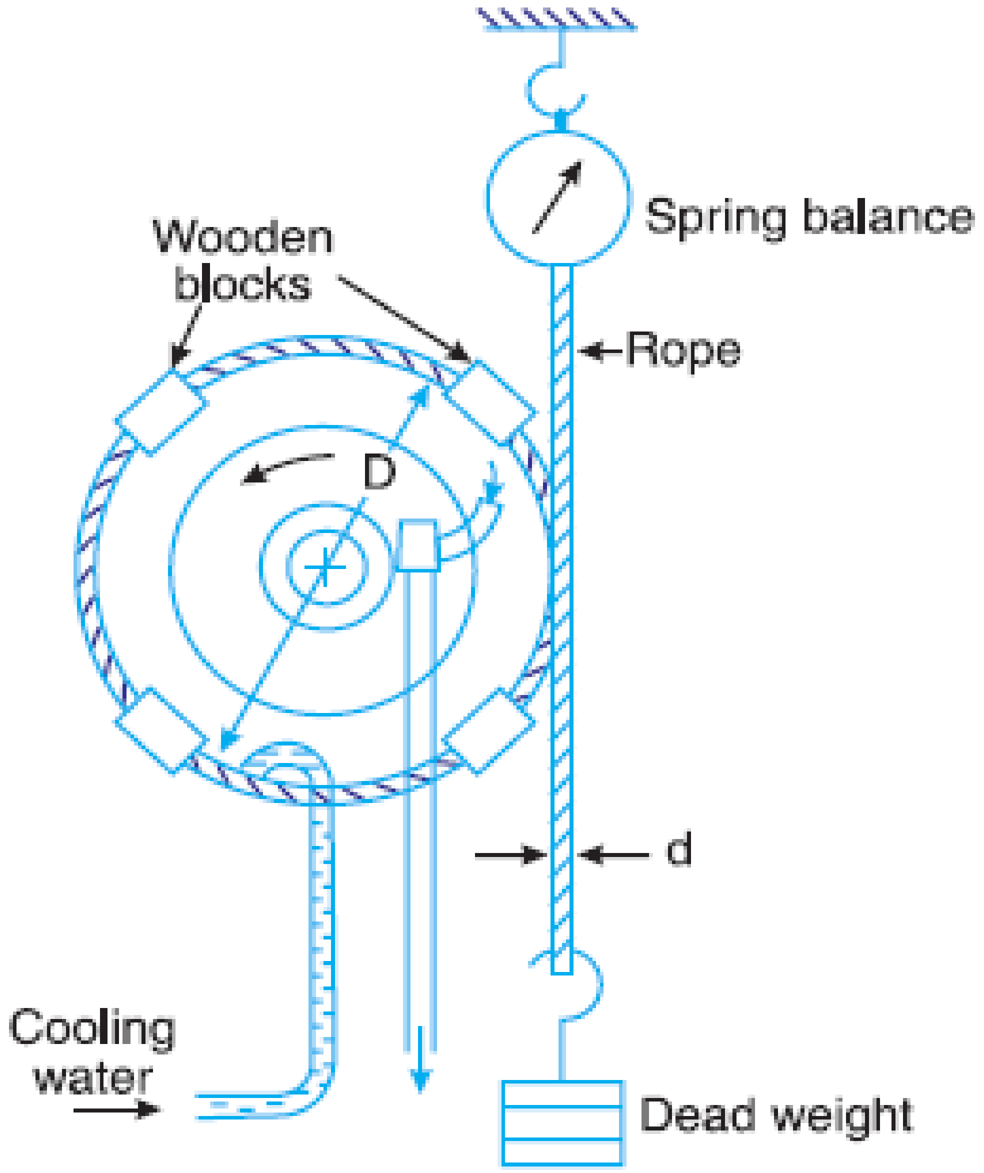
$$B.P. = \frac{\text{Work done per min.}}{60} = \frac{T \times 2\pi N}{60} = \frac{W.L \times 2\pi N}{60} \text{ watts}$$

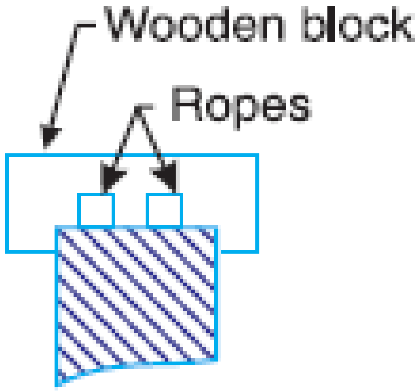
Rope Brake Dynamometer

It is another form of absorption type dynamometer which is most commonly used for measuring the brake power of the engine. It consists of one, two or more ropes wound around the flywheel or rim of a pulley fixed rigidly to the shaft of an engine. The upper end of the ropes is attached to a spring balance while the lower end of the ropes is kept in position by applying a dead weight as shown in Fig. In order to prevent the slipping of the rope over the flywheel, wooden blocks are placed at intervals around the circumference of the flywheel.

In the operation of the brake, the engine is made to run at a constant speed. The frictional torque, due to the rope, must be equal to the torque being transmitted by the engine.

Let *W = Dead load in newtons,*
S = Spring balance reading in newtons,
D = Diameter of the wheel in metres,
d = diameter of rope in metres, and
N = Speed of the engine shaft in r.p.m.





Section of wheel rim

∴ Net load on the brake

$$= (W - S) \text{ N}$$

We know that distance moved in one revolution

$$= \pi(D + d) \text{ m}$$

∴ Work done per revolution

$$= (W - S)\,\pi\,(D + d) \text{ N-m}$$

and work done per minute

$$= (W - S)\,\pi\,(D + d)\,N \text{ N-m}$$

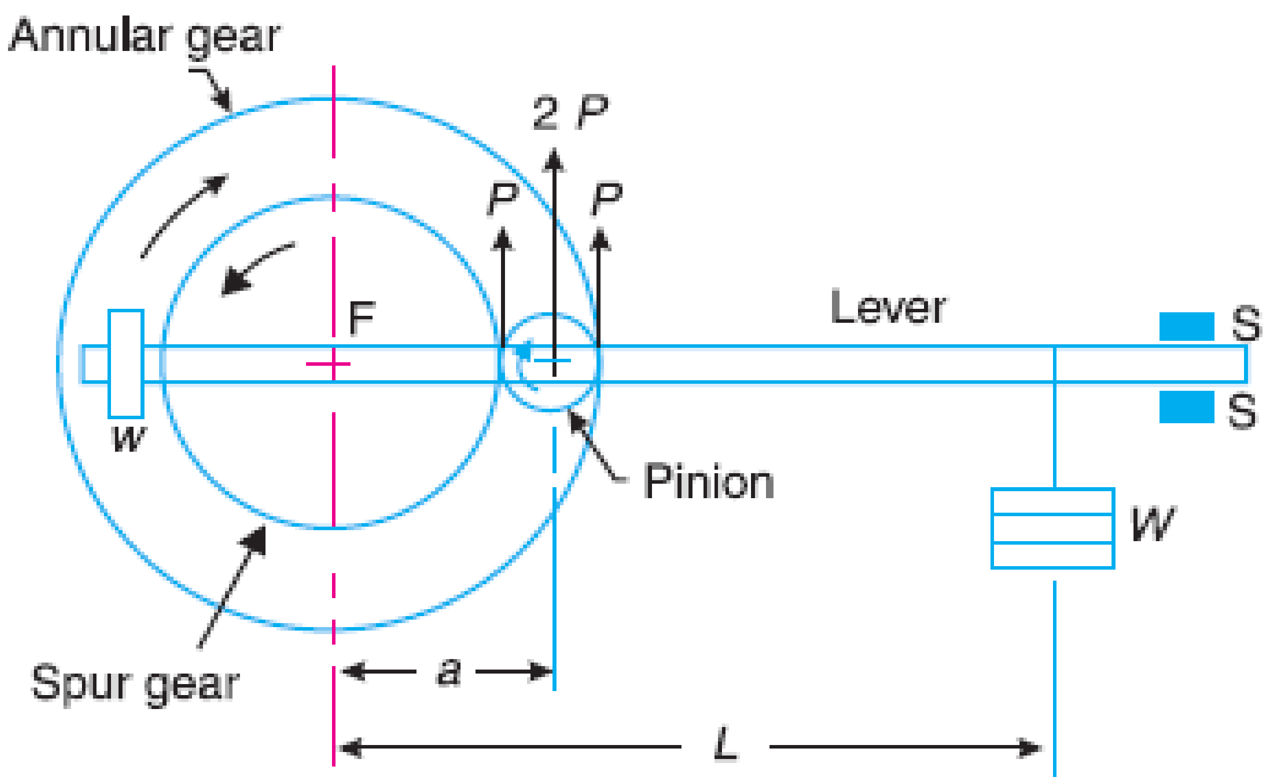
∴ Brake power of the engine,

$$\text{B.P} = \frac{\text{Work done per min}}{60} = \frac{(W - S)\,\pi\,(D + d)N}{60} \text{ watts}$$

If the diameter of the rope (d) is neglected, then brake power of the engine,

$$\text{B.P.} = \frac{(W - S)\,\pi D\,N}{60} \text{ watts}$$

Epicyclic-train Dynamometer



For equilibrium of the lever, taking moments about the fulcrum F,

$$2P \times a = W.L \quad \text{or} \quad P = W.L/2a$$

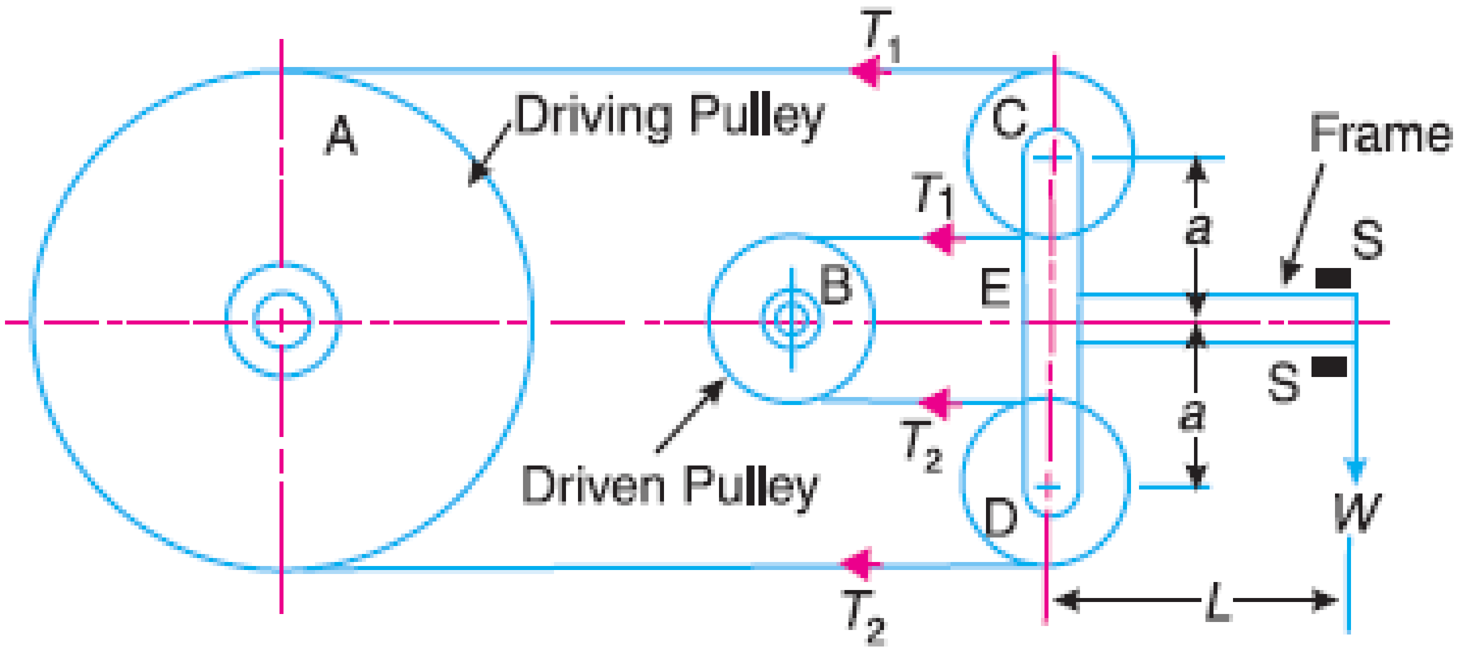
Let R = Pitch circle radius of the spur gear in metres, and

N = Speed of the engine shaft in r.p.m.

$\therefore$ Torque transmitted, $T = P.R$

and power transmitted $= \dfrac{T \times 2\pi N}{60} = \dfrac{P.R \times 2\pi N}{60}$ watts

Belt Transmission Dynamometer-Froude or Thorneycroft Transmission Dynamometer



When the belt is transmitting power from one pulley to another, the tangential effort on the driven pulley is equal to the difference between the tensions in the tight and slack sides of the belt. A belt dynamometer is introduced to measure directly the difference between the tensions of the belt,while it is running.

Now taking moments about the pivot E, neglecting friction,

$$2T_1 \times a = 2T_2 \times a + W.L \quad \text{or} \quad T_1 - T_2 = \frac{W.L}{2a}$$

Let D = diameter of the pulley A in metres, and

N = Speed of the engine shaft in r.p.m.

$\therefore$ Work done in one revolution $= (T_1 - T_2)\,\pi\, D$ N-m

and workdone per minute $= (T_1 - T_2)\,\pi\, DN$ N-m

$\therefore$ Brake power of the engine, $\text{B.P.} = \dfrac{(T_1 - T_2)\,\pi\, DN}{60}$ watts

Torsion Dynamometer

A torsion dynamometer is used for measuring large powers particularly the power transmitted along the propeller shaft of a turbine or motor vessel. A little consideration will show that when the power is being transmitted, then the driving end of the shaft twists through a small angle relative to the driven end of the shaft. The amount of twist depends upon many factors such as torque acting on the shaft (*T), length of the shaft (l), diameter of the shaft (D) and modulus of rigidity (C) of the* material of the shaft. We know that the torsion equation is

$$\frac{T}{J} = \frac{C.\theta}{l}$$

where θ = Angle of twist in radians, and

J = Polar moment of inertia of the shaft.

For a solid shaft of diameter D, the polar moment of inertia

$$J = \frac{\pi}{32} \times D^4$$

and for a hollow shaft of external diameter D and internal diameter d, the polar moment of inertia,

$$J = \frac{\pi}{32}(D^4 - d^4)$$

From the above torsion equation,

$$T = \frac{C.J}{l} \times \theta = k.\theta$$

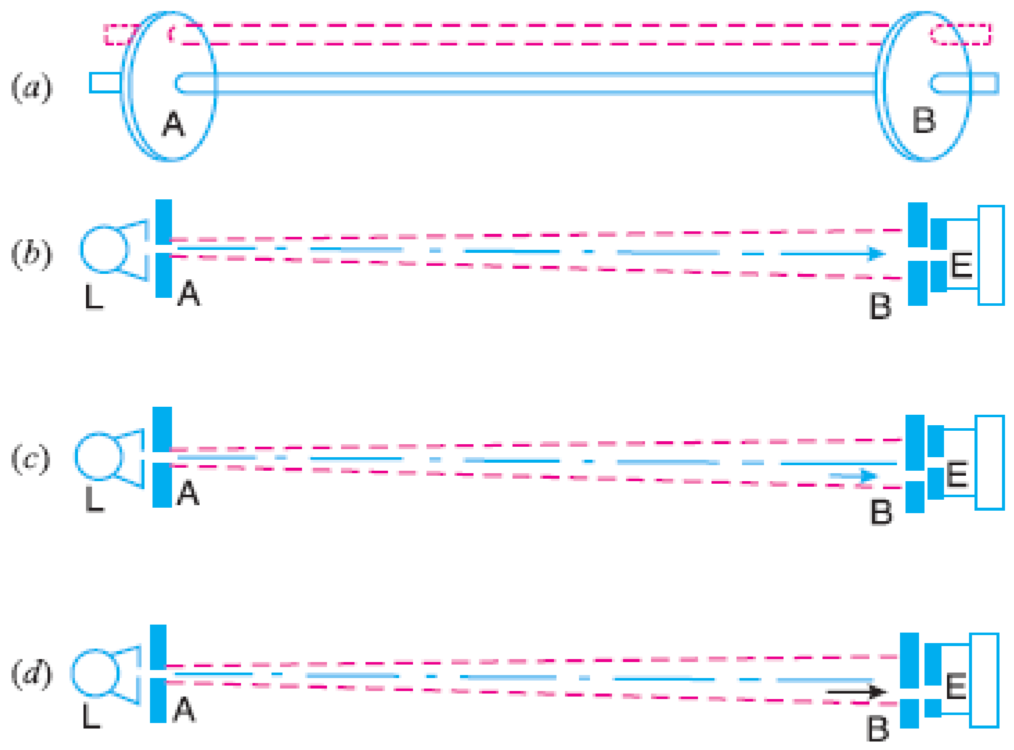
where $k = C.J/l$ is a constant for a particular shaft. Thus, the torque acting on the shaft is proportional to the angle of twist. This means that if the angle of twist is measured by some means, then the torque and hence the power transmitted may be determined.

We know that the power transmitted

$$P = \frac{T \times 2\pi N}{60} \text{ watts, where } N \text{ is the speed in r.p.m.}$$

A number of dynamometers are used to measure the angle of twist, one of which is discussed in Art. 19.21. Since the angle of twist is measured for a small length of the shaft, therefore some magnifying device must be introduced in the dynamometer for accurate measurement.

Bevis-Gibson Flash Light Torsion Dynamometer



Perforated disc