Design of Coupling

- Shafts are usually available up to 7 meters length due to inconvenience in transport.
- In order to have a greater length, it becomes necessary to join two or more pieces of the shaft by means of a coupling

- Shaft couplings are used in machinery for several purposes,
- 1.To provide for the connection of shafts of units that are manufactured separately such as a motor and generator and to provide for disconnection for repairs or alternations.
- 2.To provide for misalignment of the shafts or to introduce mechanical flexibility.
- 3.To reduce the transmission of shock loads from one shaft to another.
- 4.To introduce protection against overloads.

- Requirements of a Good Shaft Coupling
- 1.It should be easy to connect or disconnect.
- 2. It should transmit the full power from one shaft to the other shaft without losses.
- 3.It should hold the shafts in perfect alignment.
- 4.It should reduce the transmission of shock loads from one shaft to another shaft.
- 5.If should have no projecting parts.

Types of Shafts Couplings

- 1. Rigid coupling 2. Flexible coupling

1. Rigid coupling : It is used to connect two shafts which are perfectly aligned.

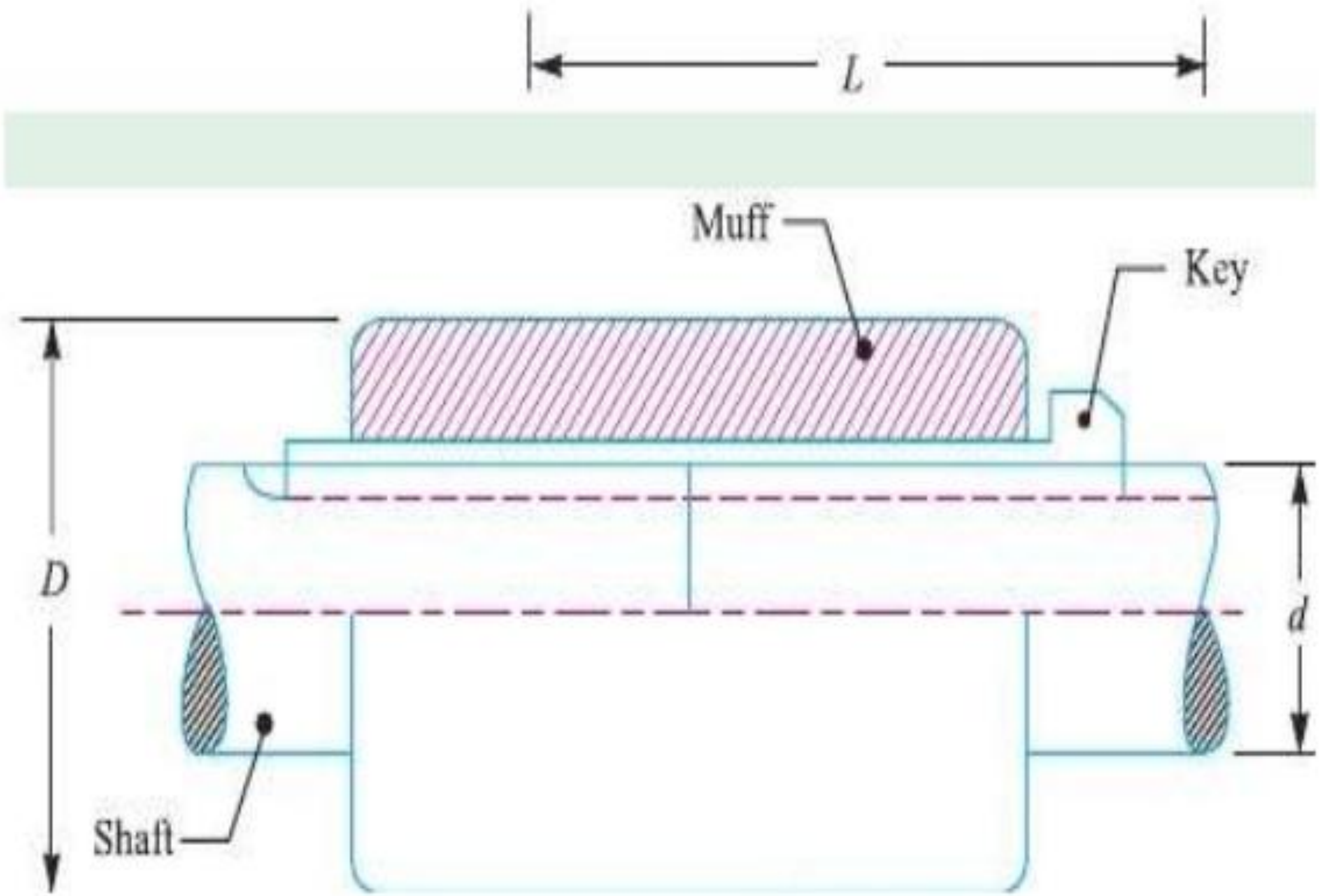
- types of rigid coupling are
- a)Sleeve or muff coupling.
- b)Clamp or split-muff or compression coupling,
- c)Flange coupling

- 2.Flexible coupling : It is used to connect two shafts having both lateral and angular misalignment.

- Types of flexible coupling are

- a)Bushed pin type coupling,
- b)Universal coupling, and
- c)Oldham coupling

a. Sleeve or Muff-coupling



- It is the simplest type of rigid coupling, made of cast iron.

- It consists of a hollow cylinder whose inner diameter is the same as that of the shaft **(sleeve).**

- It is fitted over the ends of the two shafts by means of a **gib head key**, as shown in Fig.

- The power is transmitted from one **shaft** to the other shaft by means of a **key** and a **sleeve.**

- SHAFT - (d, T)

d = diameter of the shaft , T= torque

- SLEEVE – <u>(D, L)</u>

D= Outer diameter of the sleeve

- KEY- RED
- l= length, w= width, t=thickness

1. Design for sleeve

- The usual **proportions** of a cast iron sleeve coupling
- Outer diameter of the sleeve, **D =2d + 13 mm**

  length of the sleeve, **L=3.5d**

  Where **d = diameter of the shaft**

- The **sleeve** is designed by considering it as a **hollow shaft.**

- **T**=Torque to be transmitted by the coupling
- τ_c=Permissible shear stress for the material of the sleeve which is cast rion.
- τ_c = **14 MPa.**
- Torque transmitted by a hollow section

$$T = (\pi/16)\times\tau_c\times(D^4-d^4)/D$$

$$= (\pi/16)\times\tau_c\times D^3(1-K^4)$$

$$\ldots (\because k = d / D)$$

- From this expression, the induced **shear stress in the sleeve** may be checked

2. Design for key

- The length of the coupling key = sleeve **(i.e. . 3.5d).**
- The coupling key is usually made into two parts
- length of the key in each shaft

  l= L/2=3.5d/2

- After fixing the length of key in each shaft, the induced shearing and crushing stresses may be checked. We know that torque transmitted,

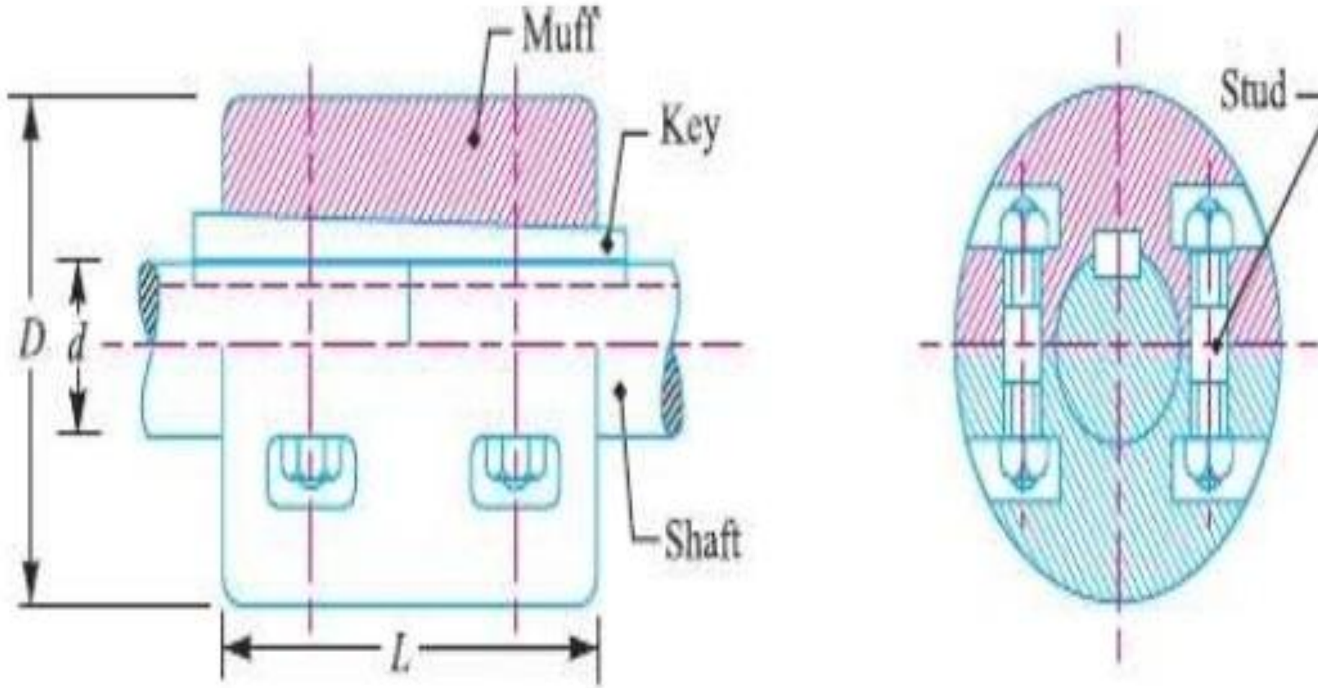
- $T = l \times w \times \tau \times (d/2)$

  (Considering shearing of the key)

- $T = l \times t/2 \times \sigma_c \times (d/2)$

  (Considering crushing of the key

b. Clamp or Compression Coupling



- the muff or sleeve is made into two halves and are bolted together.
- The halves of the muff are made of cast iron.
- The shaft ends are made to a butt each other
- a single key is fitted directly in the keyways of both the shafts.
- One-half of the muff is fixed from below and the other half is placed from above.
- Both the halves are held together by means of mild steel studs or bolts and nuts.
- The number of bolts may be two, four or six.
- The advantage of this coupling is that the position of the shafts need not be changed for assembling or disassembling of the couplings

1. Design of muff

- The usual **proportions** of a cast iron sleeve coupling
- Outer diameter of the sleeve, **D =2d + 13 mm**
- length of the sleeve, **L=3.5d**

  Where **d = diameter of the shaft**

- The **sleeve** is designed by considering it as a **hollow shaft.**

- **T**=Torque to be transmitted by the coupling
- τ_c=Permissible shear stress for the material of the sleeve which is cast iron.
- τ_c = 14 MPa.
- Torque transmitted by a hollow section

$$T = (\pi/16)\times\tau_c\times(D^4-d^4)/D$$

$$= (\pi/16)\times\tau_c\times D^3(1-K^4)$$

$$\ldots (\because k = d / D)$$

- From this expression, the induced **shear stress in the sleeve** may be checked

2. Design for key

- The length of the coupling key = length of the sleeve **(i.e. . 3.5d).**
- The coupling key is usually made into two parts
- length of the key in each shaft

  $l = L/2 = 3.5d/2$
- After fixing the length of key in each shaft, the induced shearing and crushing stresses may be checked. We know that torque transmitted

- $T = l \times w \times \tau \times (d/2)$

  (Considering shearing of the key)

- $T = l \times t/2 \times \sigma_c \times (d/2)$

  (Considering crushing of the key

3. Design of clamping bolts

- T =Torque transmited by the shaft,
- d =Diameter of shaft,
- d_b=Root or effective diameter of bolt
- n=Number of bolts,
- σ_t =Permissible tensile stress for bolt material,
- μ=Coefficient of friction between the muff and shaft, and
- L=Length of muff.

- force exerted by each bolt **(F) $=(\pi/4)\,(d_b^{\,2})\,\sigma_t$**
- Force exerted by the bolts on each side of the shaft **(F)$= (\pi/4)\,(d_b^{\,2})\,(\sigma_t)(n/2)$**
- (P)be the pressure on the shaft and the muff surface due to the force, then for uniform pressure distribution over the surface
- P=Force/Projected area
- **$P= (\pi/4)\,(d_b^{\,2})\,(\sigma_t)(n/2)/(1/2)Ld$**

- ∴Frictional force between each shaft and muff,

F =μ× pressure × area

- $F=(\mu \times (\pi/4)(d_b^2)(\sigma_t)(n/2)/(\cancel{(1/2)Ld}) \times \pi \cancel{(1/2)\, d\, L}$

- $F= \mu \times (\pi^2/8)(d_b^2)(\sigma_t)(n)$

- Torque that can be transmitted by the coupling

$$T = F \times d/2$$

$$T = \mu \times (\pi^2/8)(d_b{}^2)(\sigma_t)(n) \times d/2$$

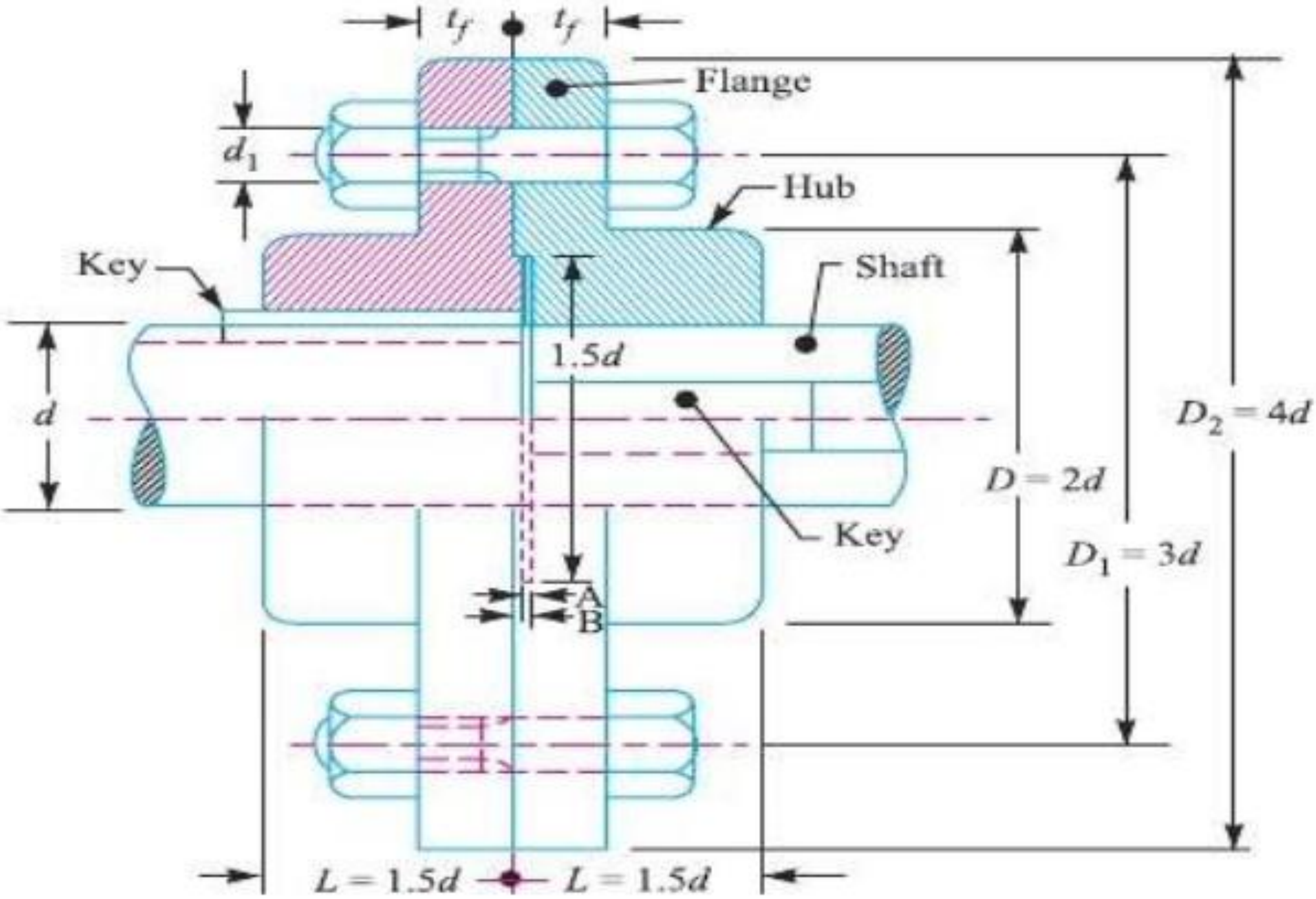
- From this relation, the root diameter of the bolt **(d_b)**

may be evaluated . **$\mu = 0.3$**

c. Flange coupling

- A flange coupling usually applies to a coupling having two separate cast iron flanges.
- Each flange is mounted on the shaft end and keyed to it.
- The faces are turned up at right angle to the axis of the shaft
- Flange coupling are
- 1.Unprotected type flange coupling
- 2. Protected type flange coupling
- 3. Marine type flange coupling

1.Unprotected type flange coupling



- In an unprotected type flange coupling each shaft is keyed to the boss of a flange with a counter sunk key and the flanges are coupled together by means of bolts.

- Generally, three, four or six bolts are used

Design of Unprotected type Flange Coupling

- The usual **proportions** for an unprotected type cast iron flange couplings
- d = diameter of the shaft or inner diameter of the hub
- D= Outside diameter of hub **D=2d**
- Length of hub, **L= 1.5d**
- Pitch circle diameter of bolts, **D_1=3d**
- Outside diameter of flange,

  $$D_2 = D_1 + (D_1 - D) = 2D_1 - D = 4d$$

- Thickness of flange **t_f =0.5d**
- **Number of bolts =3, ford upto 40 mm**

  =4, for d upto 100 mm

  =6, for d upto 180 mm

- d =Diameter of shaft or inner diameter of hub,
- τ_s =Allowable shear stress for shaft,

- D=Outer diameter of hub,
- t_f =Thickness of flange
- τ_c=Allowable shear stress for the flange material

- d_1=Nominal or outside diameter of bolt,
- D_1 =Diameter of bolt circle,
- n=Number of bolts,
- $\tau_{b=}$ Allowable shear stress for bolt
- $\sigma_{cb,,}$ =Allowable crushing stress for bolt

- $\tau_{k=}$ Allowable shear stress for key material
- $\sigma_{ck=}$ key material

1. Design for hub

- The hub is designed by considering it as a hollow shaft,
- transmitting the same torque (T) as that of a solid shaft

$$T = \mathbf{T = (\pi/16)\times\tau_c\times(D^4 - d^4)/D}$$

The outer diameter of hub is usually taken as twice the diameter of shaft.

- The length of hub $\mathbf{(\ L\ ) = 1.5d}$

2. Design for key

The material of key is usually the same as that of shaft. The length of key is taken equal to the length of hub

$$l = L$$

- $T = l \times w \times \tau \times (d/2)$

  (Considering shearing of the key)

- $T = l \times t/2 \times \sigma_c \times (d/2)$

  (Considering crushing of the key

3. Design for flange

- T =Circumference of hub × Thickness of flange × Shear stress of flange × Radius of hub

- $$T = \pi D \times t_f \times \tau_c \times D/2$$

  $$T = \pi \times t_f \times \tau_c \times D^2/2$$

  The thickness of flange is usually taken as half the diameter of shaft

4. Design for bolts

- Load on each bolt (F)=

$$(\pi/4)\ (d_1^{\,2})\ (\tau_b)$$

- Total load on all the bolts (F) =

$$(\pi/4)\ (d_1^{\,2})\ (\tau_b)(n)$$

- The bolts are subjected to shear stress due to the torque transmitted

$$(T) = (\pi/4)\ (d_1^{\,2})\ (\tau_b)(n)\ (D_1/2)$$

From this equation, the diameter of bolt **(d_1)** may be obtained.

- We know that area resisting crushing of all the bolts = $n \times d_1 \times t_f$

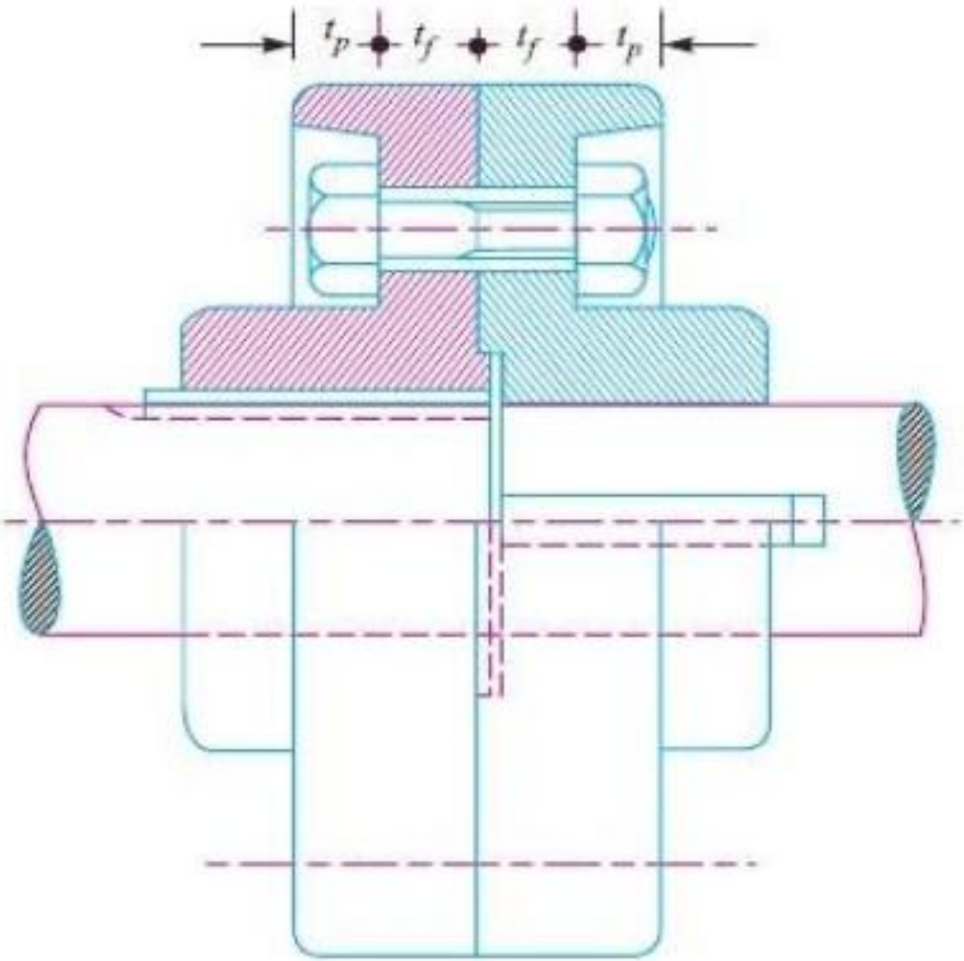
- crushing strength of all the bolts

$$= n \times d_1 \times t_f \times \sigma_{Cb}$$

$$\text{Torque} = n \times d_1 \times t_f \times \sigma_{Cb} \times (D_1/2)$$

- From this equation, the induced crushing stress in the bolts may be checked

Protected type flange coupling

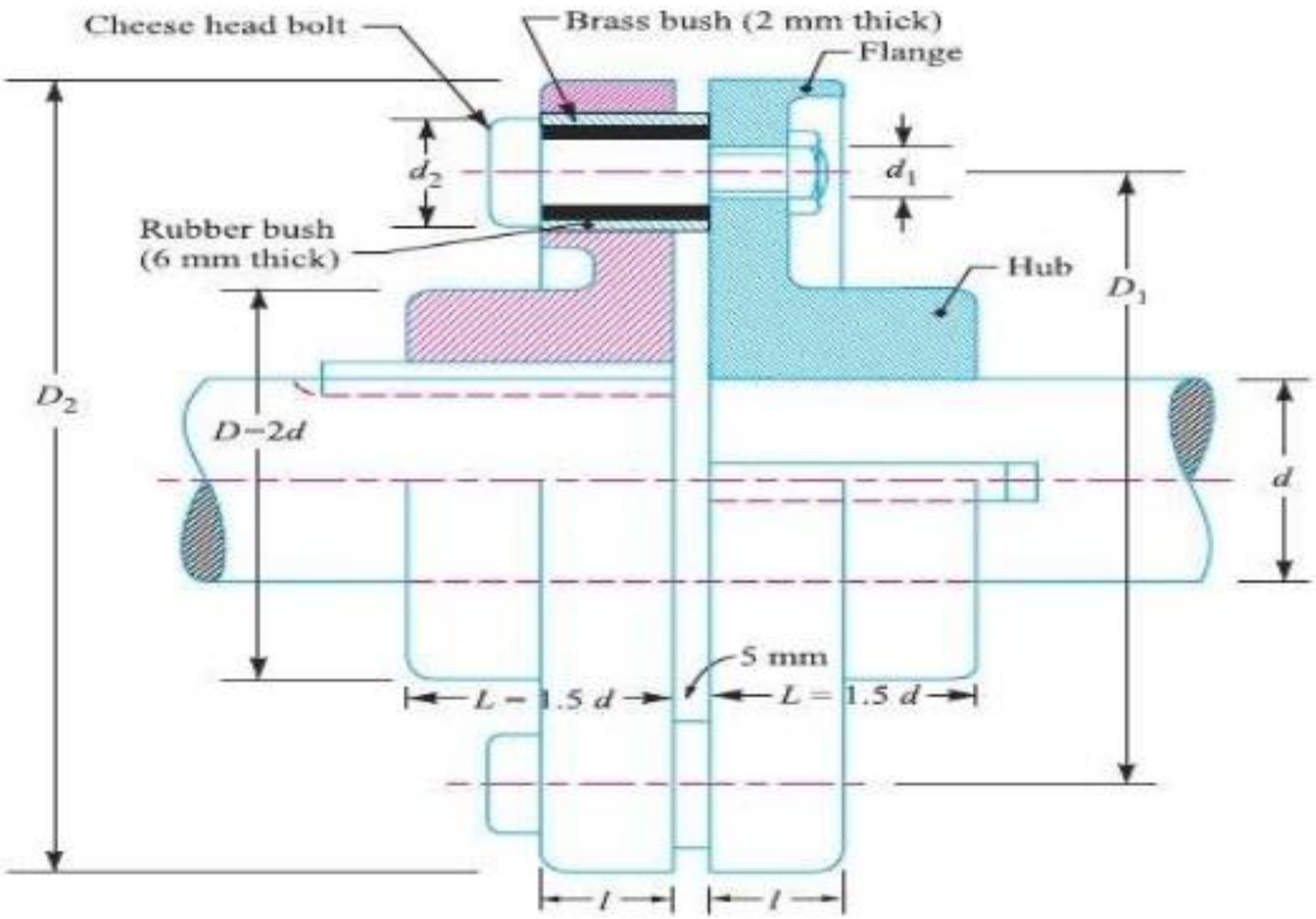


- the protruding bolts and nuts are protected by flanges on the two halves of the coupling, in order to avoid danger to the workman

$$(t_p) = 0.25d$$

The design of unprotective type is same process of protective type

Bushed-pin Flexible Coupling



a modification of the rigid type of flange coupling.

- The coupling bolts are known as pins. The rubber or leather bushes are used over the pins.
- The two halves of the coupling are dissimilar in construction.
- A clearance of 5 mm is left between the face of the two halves of the coupling.

- the **proportions** of the rigid type flange coupling
- the bearing pressure on the rubber or leather bushes and it should not exceed 0.5 N/mm^2

Pin and bush design

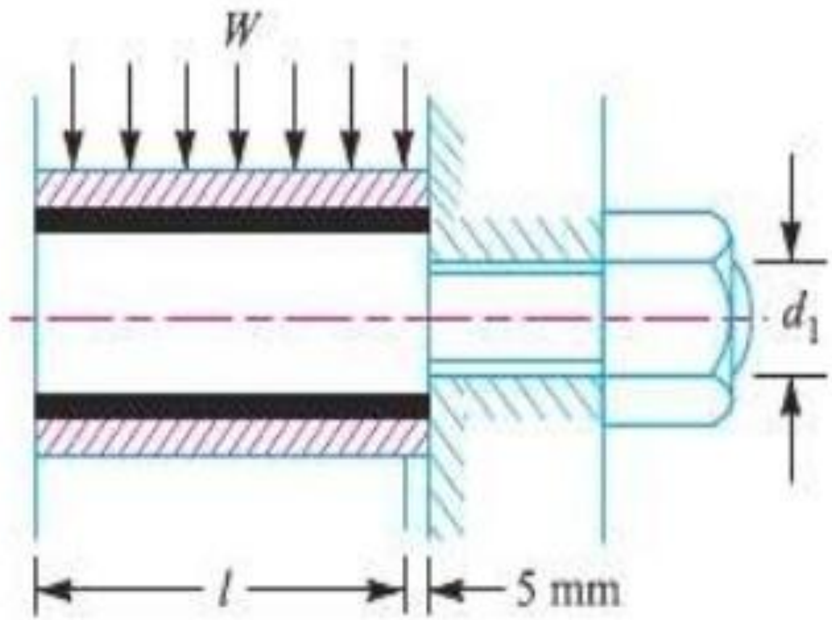
- l=Length of bush in the flange,
- d_2=Diameter of bush,
- p_b=Bearing pressure on the bush or pin,
- n=Number of pins,
- D_1=Diameter of pitch circle of the pins

Pin and bush design

- bearing load acting on each pin,
- $W = p_b \times d_2 \times l$
- $\therefore$Total bearing load on the bush or pins
- $W \times n = p_b \times d_2 \times l \times n$
- torque transmitted by the coupling=

$$T = W \times n \times (D_1/2)$$

$$T = p_b \times d_2 \times l \times n \times (D_1/2)$$


W
d_1
l
5 mm

- Direct shear stress due to pure torsion in the coupling halve
- $\tau = W / [(\pi/4)(d_1^2)]$
- maximum bending moment on the pin
- $M = W(l/2 + 5mm)$
- bending stress

$$\sigma = M / Z$$

$$= W(l/2 + 5mm) / (\pi/32)(d_1^3)$$

- Maximum principal stress

$$= 1/2[\sigma + (\sigma + 4\tau^2)^{1/2}]$$

- maximum shear stress on the pin

$$= 1/2(\sigma + 4\tau^2)^{1/2}$$

- The value of maximum principal stress varies from 28 to <u>42 MPa</u>