Coupling and its Types

Function of Coupling

- Due to sagging problem of shaft, length of continuous shaft is not kept more than 10 meters
- To join two rotating shafts permanently, Couplings are used.
- Function of coupling is to join shafts permanently.

Requirement of good Coupling

- It should transmit the full power from one shaft to another.
- It should keep the shafts in perfect alignment.
- It should absorb the slight misalignment that may be present between the driver and drive shaft.
- It should be easy to connect and disconnect.
- It should have no projecting parts.

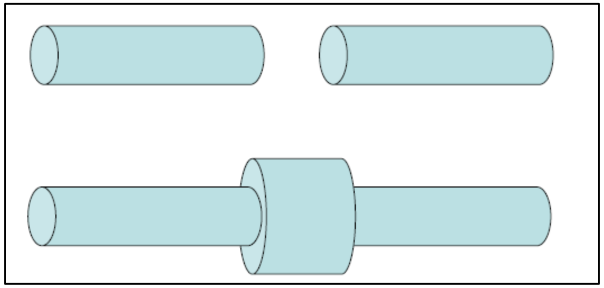
Basic Types of Coupling

1. Rigid Coupling- Cannot tolerate misalignment between the axes, Do not absorbs shocks, Simple & inexpensive

2. Flexible coupling – Elements like bush or disk is used, which tolerate 0.5 degrees of angular misalignment, Absorbs shocks and vibrations, Costlier than Rigid coupling

Rigid Couplings

1. Muff Coupling
2. Clamp Coupling or split muff coupling
3. Rigid Flange Coupling



Muff Coupling

Split Muff Coupling

Flange Coupling

Design of Muff Coupling

1. Calculate Diameter of Solid Shaft (d):

$$(\tau_{allowable})_{shaft} = \frac{16T}{\pi d^3}$$

2. Dimension of the sleeve, by empirical relation:

D= (2d+13) mm, L= 3.5d

D – Diameter of Sleeve

L – Length of Sleeve

d – diameter of shaft

3. Check shear stress induced in the sleeve by using following formula:

$$\tau_{Sleeve} = \frac{16T \times D}{\pi(D^4 - d^4)}$$

If, $\tau_{Sleeve} < (\tau_{allowable})_{sleeve}$ then design is safe

Else, Design is not safe

4. Determine standard cross section of the key from the table (in next slide):

Length of key = $l = \frac{L}{2}$

5. Check Shear and compressive stress in key, it must be less than allowable stresses:

$$\tau = \frac{2T}{dbl}; \sigma_c = \frac{4T}{dhl}$$

Design of Key

Length of Key, $l = \frac{L}{2}$

For rectangular key:

$$w \; \boldsymbol{or} \; b = \frac{d}{4}, \quad h = \frac{d}{6}$$

For square key:

$$w \; \boldsymbol{or} \; b = \frac{d}{4}, \quad h = \frac{d}{4}$$

SI metric sizes

Nominal shaft diameter		Key dimensions	
Over (mm)	to-including (mm)	Width, W (mm)	Height, H (mm)
6	8	2	2
8	10	3	3
10	12	4	4
12	17	5	5
17	22	6	6
22	30	8	7
30	38	10	8
38	44	12	8
44	50	14	9
50	58	16	10
58	65	18	11
65	75	20	12
75	85	22	14
85	95	25	14
95	110	28	16
110	130	32	18

Muff coupling Problem 1 :

Design a muff coupling to connect 2 steel shafts transmitting 25kW power at 360 rpm. The shafts and keys are made of plain carbon steel 30C8 (S_{yt} = S_{yc} = 400 N/mm^2). The sleeve is made of grey cast iron FG 200 (S_{ut}= 200 N/mm^2). The factor of safety for the shafts and key is 4. For the sleeve, the factor of safety is 6 based on ultimate strength.

Solution to Problem 1

1.Diameter of Shaft, d= 40.73 mm

2. Diameter of Sleeve, D = 103 mm

3. Length of Sleeve, L = 157.5 mm

4. $\tau_{Sleeve} = 3.02 \frac{N}{mm^2} < 16.67 \frac{N}{mm^2}$

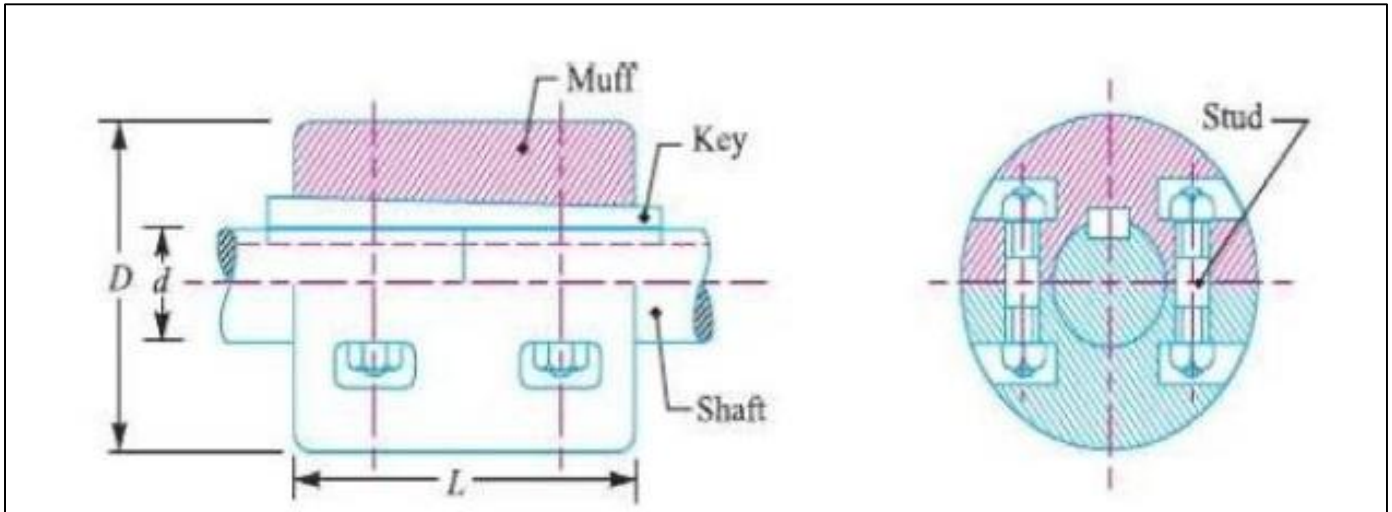
5. Length of Key, l = 80 mm

6. $\tau_{key} = 26.32 \frac{N}{mm^2} < 50 \frac{N}{mm^2}$

7. $\sigma_{c\_key} = 81.87 \frac{N}{mm^2} < 100 \frac{N}{mm^2}$

Clamp Coupling or split muff coupling or compression coupling

- Coupling sleeve in clamp coupling is made up of two halves that are clamped together with bolts.
- Number of bolts may be =4,8 etc. (multiples of four)
- Bolts are placed in the recesses formed in the sleeve halves.



Torque transmission by Clamp Coupling

- In clamp coupling Torque is transmitted by

1] Friction between sleeve halves & shaft

2] Shear resistance of keys

While in muff coupling Torque is transmitted by : Shear resistance of key only

Design of Clamp Coupling

- **For Sleeve halves,**

D= outer Diameter of sleeve halves (mm)

L = length of sleeve (mm)

d= Diameter of shaft (mm)

1) D = 2.5 d

2) L= 3.5 d

Design of Clamp Coupling

For clamping bolt,

P_1 = Clamping force on each bolt

d_1 = core diameter of clamping bolt

σ_t = Permissible tensile stress

1) $P_1 = \frac{\pi}{4} d_1{}^2 \sigma_t$

2) d_1 ***= (0.2 d + 10) mm ; d<55 mm***

3) d_1 ***= (0.15 d + 15) mm ; d>55 mm***

Suppose, N= coupling force on each shaft due to bolt

n= total number of bolts

4) $N = P_1 \frac{n}{2}$

Frictional Torque

- As there is friction between sleeve halves (having bolts which applies P1 force) & shaft

Torque, T = $\mu\, N \frac{d}{2} + \mu\, N \frac{d}{2}$ = $\mu\, N d$

$$T = \frac{\mu\, d\, n\, P_1}{2}$$

Split muff Coupling Problem 2

It is required to design a split muff coupling to transmit 50 kW power at 120 rpm. The shafts, key and coupling bolts are made of plain carbon steel 30C8 (S_{yt} = 400 N/mm^2). The yield strength in compression is 150% of the tensile strength. The factor of safety for the shafts, key and bolts is 5. The number of clamping bolts is 8. The co-efficient of friction between sleeve halves and shaft is 0.3.

Solution to Problem 2

1. Diameter of shaft, d = 79.72 mm or 80 mm

2. Diameter of Sleeve, D = 200 mm

3. Length of Sleeve, L = 280 mm

4. Diameter of bolt, d1 = 26 mm

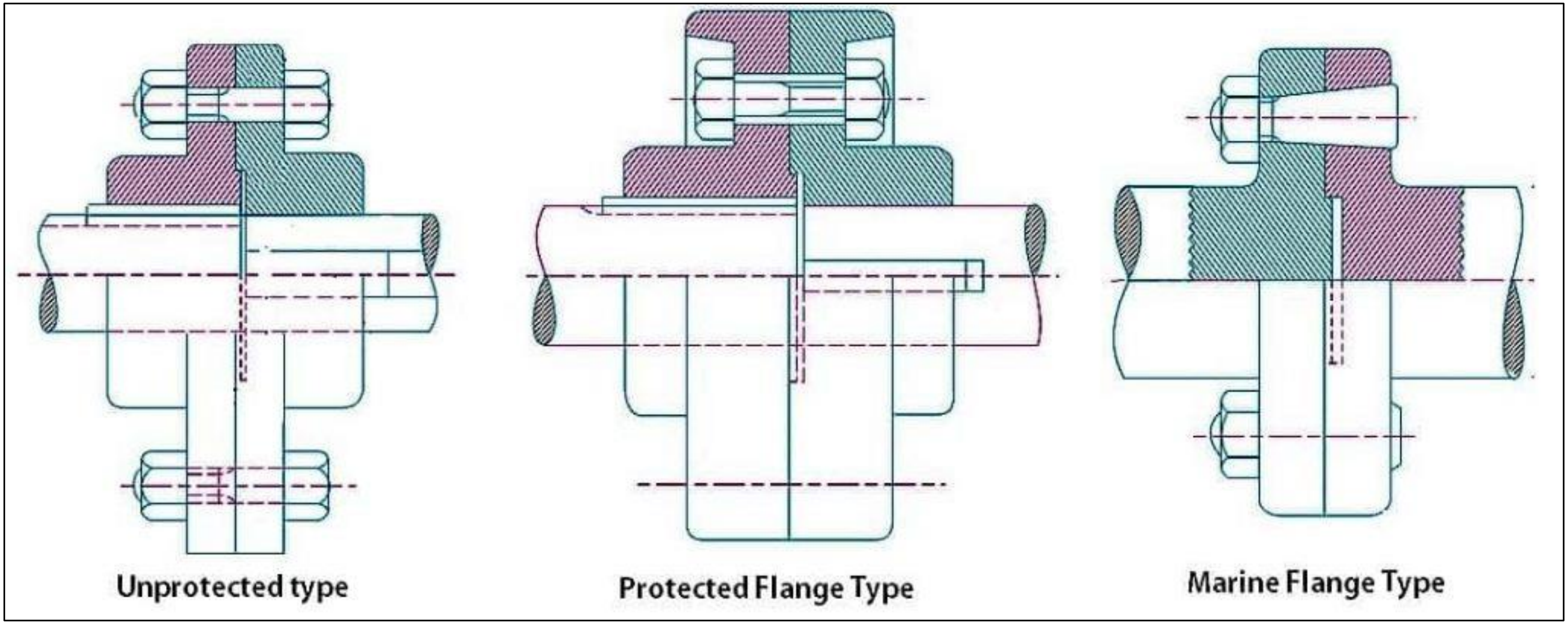
5. Length of key, l =140 mm

6. $\tau_{key} = 32.3 \frac{N}{mm^2} < 40 \frac{N}{mm^2}$

7. $\sigma_{c\_key} = 101.5 \frac{N}{mm^2} < 120 \frac{N}{mm^2}$

Design of Flange Coupling

- Types of flange coupling- Protected type , Marine type and Unprotected type



Design of Protected Type Flange Coupling

1. Outside diameter of hub, $d_h = 2d$
2. Length of Hub or Length of key,
   $l_h = 1.5\ d$
3. Pitch circle diameter of Bolt, D=3d
4. Thickness of flanges, t= 0.5 d
5. Thickness of protecting rim, t_1=0.25 d
6. Diameter of spigot and recess, $d_r = 1.5\ d$

7. Outside diameter of flange, $D_o = 4d + t_1$

d=shaft diameter in mm

Design of Bolts in Protected Flange Coupling

Case 1 Bolts fitted in reamed and ground holes	**Case 2 Bolts fitted in large clearance hole**
1. Shear force in each bolt due to rotation of shaft, $\tau = \frac{P}{\frac{\pi}{4}d_1^2}$ 2. Total torque due to 'N' bolts, T = P x $\frac{D}{2}$ x N Torque '**T**' will be same torque transmitted by shaft.	Total torque transmitted, T = $\mu P_i N R_f$ μ = co-efficient of friction between flanges P_i = Initial tension in each bolt $N = \text{number of bolts}$ $R_f = \frac{2\,(R_o^3 - R_i^3)}{3(R_o^2 - R_i^2)}$ $R_o = outer\ radius\ of\ flange = \frac{D_o}{2}$ $R_i = Radius\ of\ recess = \frac{d_r}{2}$

Design of Protected Flange coupling

1. Calculate Diameter of Solid Shaft (d):

$(\tau_{allowable})_{shaft} = \frac{16T}{\pi d^3}$

2. Dimension of the sleeve, by empirical relation:

Calculate all 7 dimensions shown in previous slide no. 18

3. Check shear stress induced in the hub by using following formula:

$\tau_{hub} = \frac{16T \times d_h}{\pi(d_h^4 - d^4)}$

If, $\tau_{hub} < (\tau_{allowable})_{hub}$ then design is safe

Else, Design is not safe

4. Calculate the diameter of bolt, d1:

a) Using Case 1 equation:

T = P x $\frac{D}{2}$ x N

b) Using Case 2 equation:

T = $\mu P_i N R_f$ → Find P_i → Find diameter of bolt (d_1), Using $P_i = \frac{\pi}{4} d_1^2 \sigma_t$,

σ_t = Permissible tensile strength of bolt material

Problem 3 based on Flange coupling

A rigid coupling is used to transmit 20 kW power at 720 rpm. There are four bolts and the pitch circle diameter of the bolts is 125 mm. The bolts are made of steel 45C8 ($S_{yt} = 380 \frac{N}{mm^2}$) and factor of safety is 3. Assume Shear strength , ($S_{sy} = 0.577\, S_{yt}$) and determine the diameter of the bolts.

Case is reamed and ground holes. [CASE 1]

Solution to problem 3

1. Find Torque transmitted, Power = $\frac{2\pi NT}{60}$
2. Find Allowable shear stress in bolts, $\tau_{all} = \frac{S_{sy}}{FOS}$
3. Find load P transmitted due to torque , T= P x $\frac{D}{2}$x N
4. Using equation of shear stress for bolt, find diameter of bolts, $\tau_{all} = \frac{P}{\frac{\pi}{4}d_1^2}$