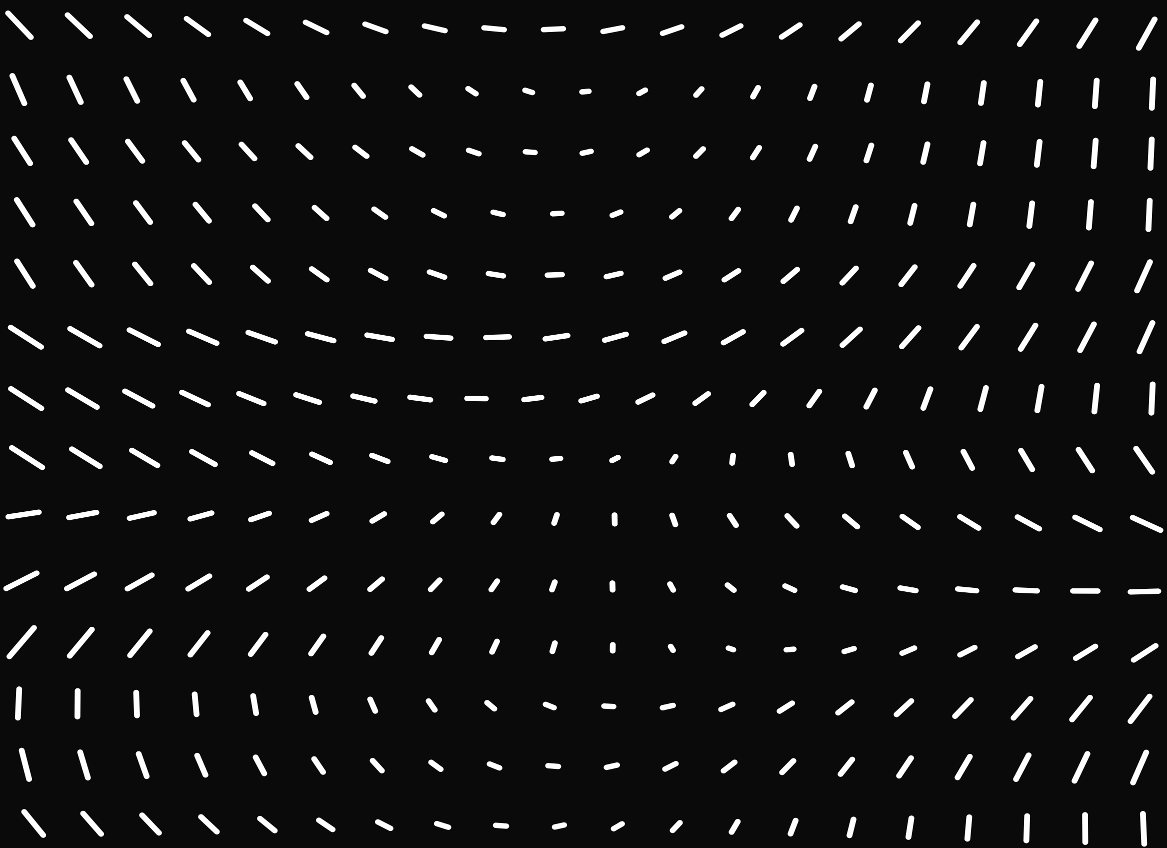


Knuckle Joint :-

Tensile stress = σ_t

Shear stress = τ

Compressive stress = σ_c

Q. A Knuckle joint required to with stand a tensile load of 25 KN.
Design the joint, if the permissible stress are —
Tensile stress = 56 MPa σ_t
Shear stress = 46 mPa τ
Compressive stress = 70 mPa σ_c

A. Given :-

$F = 25 \times 10^3$ N
$\sigma_t = 56$ N/mm^2
$\tau = 46$ N/mm^2
$\sigma_c = 70$ N/mm^2

i) Tensile strength of rod
$F = \frac{\pi}{4} d^2 \sigma_t$

ii) Usual properties of knuckle joint
$d_1 = d$
$d_2 = 2d$
$d_3 = 1.5d$
$t = 1.25d$
$t_1 = 0.75d$
$t_2 = 0.5d$

iii) Load carrying capacity on the basis of shearing stress of knuckle pin
$F = 2\frac{\pi}{4} d_1^2 \tau$
(If it's less, design is safe)

iv) Checking

Single eye = σ_t $F = (d_2 - d_1) t \sigma_t$
τ $F = (d_2 - d_1) t \tau$
σ_c $F = d_1 t \sigma_c$

Double eye = σ_t $F = (d_2 - d_1) 2t \sigma_t$
τ $F = (d_2 - d_1) 2t \tau$
σ_c $F = d_1 2t \sigma_c$

Cotter Joint

Q. Design a cotter joint to support a load varying from 6 KN in tension to 6 KN in compression.
The material used is carbon steel for which the following allowable stresses may be used
The load is applied statically –

Tensile stress (f_t) = 60 N/mm² σ_t

Shear stress (f_s) = 40 N/mm² τ

Crushing stress (f_c) = 100 N/mm² σ_c

A. Given :-

$$F = 6 \times 10^3 \text{ N}$$
$$\sigma_t = 60 \text{ N/mm}^2$$
$$\tau = 40 \text{ N/mm}^2$$
$$\sigma_c = 100 \text{ N/mm}^2$$

i) Tensile strength of solid rod

$$F = \frac{\pi}{4} d^2 \sigma_t$$

ii) Tensile strength of spigot through cotter hole

$$F = \left(\frac{\pi}{4} d_2^2 - \frac{d_2^2}{4} \right) \sigma_t$$

$$t = \frac{d_2}{4}$$

iii) Crushing strength of cotter joint

$$F = d_2 t \sigma_c$$

not less = not safe

For safe values :-

$$F = d_2 t \sigma_c \qquad \left(t = \frac{d_2}{4}\right)$$

$$F = \frac{d_2^2}{4} \sigma_c$$

$$t = \frac{d_2}{4}$$

iv) Tensile strength socket through cotter hole

$$F = \left[\frac{\pi}{4}(d_1^2 - d_2^2) - (d_1 - d_2)t\right]\sigma_t$$

v) Crushing strength of spigot collar

$$F = \frac{\pi}{4}(d_3^2 - d_2^2)\sigma_c$$

vi) Shearing strength of spigot collar

$$F = \pi d_2 t_1 \tau$$

vii) Shearing strength of spigot rod

$$F = 2 a d_2 \tau$$

viii) Crushing strength of socket collar

$$F = (d_4 - d_2) t \sigma_c$$

ix) Shearing strength of socket collar

$$F = 2c\,(d_4 - d_2)\,\tau$$

x) Shearing strength of cotter pin

$$F = 2bt\tau$$

Design of Shaft

Stress in Shaft :-

- → Shear stress due to torque
- → bending stresses
- → Combined stresses due to torque and bending

Shaft design on the basis of :-

- → strength
- → rigidity and stiffness

Design of shaft on the basis of strength

There may be following cases :

- → Shaft subjected to torque only
- → shaft subjected to bending moment only
- → shaft subjected to combined torque and bending moment.
- → shaft subjected to axial loading.

Case - 1 : Shaft subjected to twisting moment only

Then diameter of shaft may be obtained using torsion equation

$$\frac{T}{J} = \frac{\tau}{r}$$

where, T = twisting moment or torque
J = Polar moment of inertia
τ = Torsional shear stress
r = $d/2$

We know

$$J = \frac{\pi}{32} d^4 \quad \text{(solid)}$$

$$J = \frac{\pi}{32} \left(d_o^4 - d_i^4 \right) \quad \text{(hollow)}$$

$$\therefore \boxed{T = \frac{\pi}{16} \tau \times d^3}$$

we know, power transmitted

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

where, T = Torque or twisting moment

N = rpm

Case 2 : Shaft subjected to bending moment only

The bending equation is given by,

$$\frac{M}{I} = \frac{\sigma_b}{y}$$

where, M = bending moment

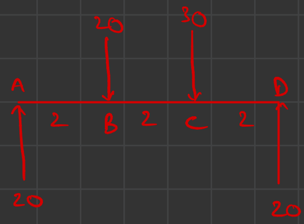
I = M.I. $= \frac{\pi}{64} d^4$

σ_b = bending stresses

$y = d/2$

$$\boxed{M = \frac{\pi}{32} \times \sigma_b \times d^3}$$

Bending moment :-



Bending moment @ B $\Rightarrow$ $20 \times 2 = 40$ N

Bending moment @ C $\Rightarrow$ $20 \times 2 = 40$ N ($\because$ forces are less at right)

Case - 3 : Shaft subjected to combined twisting and bending moment

i) Equivalent Twisting moment

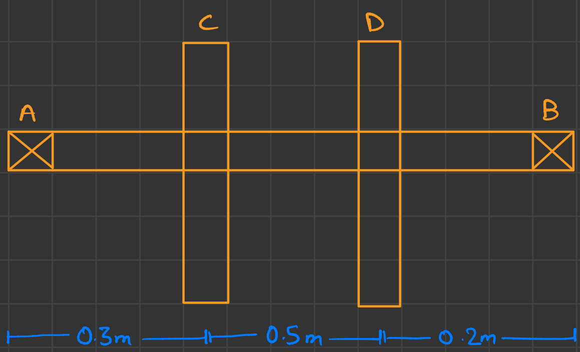
$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \tau \times d^3$$

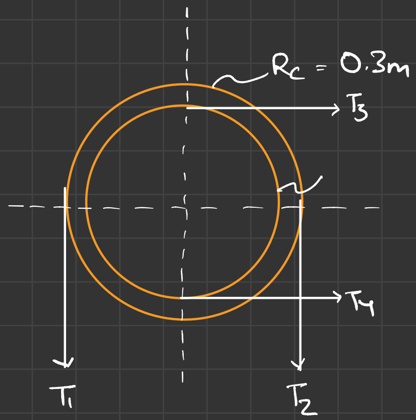
ii) Equivalent bending moment

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = \frac{\pi}{32} \times \sigma_b \times d^3$$

Q. A shaft is supported by 2 bearings at A and B. Two pulleys are mounted at C and D. Pulley C drives directly with the help of belt having maximum tension of 3.2 KN. Another pulley D is driven with the help of electric motor and belt which is placed horizontally. The angle of contact for both the pulley is 180°. Determine the suitable diameter for solid shaft if the allowing working stress of 63 MPa in tension and 42 MPa in shear. Assume that torque on one pulley is equal to that on other pulley.

$N/mm^2 = mPa = 10^6 N/m^2$





A :-

$$T_1 = 3.2 \times 10^3 \text{ N}$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu \theta$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = 0.4 \times \pi$$

$$\frac{T_1}{T_2} = 1.727$$

$$T_2 = 1.852 \times 10^3 \text{ N}$$

$$T = (T_1 - T_2) R_c$$

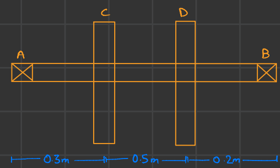
$$\boxed{T = 402 \text{ Nm} = T_D}$$

Since, $W_C = T_1 + T_2 = 5.08 \times 10^3$ N

Since, $\Sigma y = 0$

$W_C - R_{AV} - R_{BV} = 0$

$W_C = R_{AV} + R_{BV}$

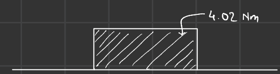


$\Sigma M_B = 0$

$R_{AV} \times 1 - W_C \times 0.7 = 0$

$R_{AV} = 5.08 \times 10^3 \times 0.7$

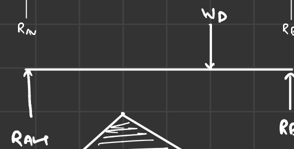
$R_{AV} = 3556$ N



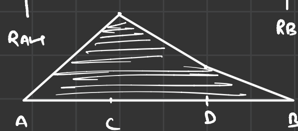
Torque Diagram

Vertical Load Diagram

$R_{BV} = 1524$N



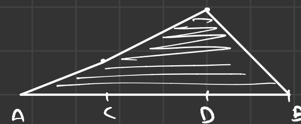
Horizontal Load diagram



BM /VL

Since, $T_D = (T_3 - T_4) \times R_D$

$T_3 - T_4 = \dfrac{402}{0.2}$



BM/HL

$T_3 - T_4 = 2010$

$2.3 \log\left(\dfrac{T_3}{T_4}\right) = \mu\theta$

$\dfrac{T_3}{T_4} = 1.7$

$1.7 T_4 - T_4 = 2010$

$T_4 = 2871.42$

$T_3 = 4881.42$

$W_D = 7752.84$

$\Sigma M = 0$

$R_{AH} - 1 \times W_D \times 0.8 = 0$

$R_{AH} = 6202.272$

$W_D - R_{AH} - R_{BH} = 0$

$R_{BH} = 1550.56$

Bending moment calculations.

i) Vertical Loading

BM @ A = 0

BM @ B = 0

BM @ C = $R_{AV} \times 0.3 = 1066.8$

BM @ D = $R_{BV} \times 0.2 = 457.2$

ii) Horizontal Loading

BM @ A = 0

BM @ B = 0

BM @ C = $R_{AH} \times 0.3 = 679.75$

BM @ D = $R_{BH} \times 0.2 = 1586.02$

Resultant bending moment :-

$$@ C = \sqrt{1066.8^2 + 679.75^2} = 1264.95$$

$$@ D = \sqrt{457.2^2 + 1586.02^2} = 1650.60$$

$$\boxed{\text{Maximum BM} = M = 1650.60\ N}$$

$$\boxed{T_e = \sqrt{M^2 + T^2} = 1698.84}$$

$$\boxed{M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = 1674.72 \ N}$$

$$T_e = \frac{\pi}{16} \times \tau \times d^3$$

$$d = \left(\frac{T_e \times 16}{\pi \times \tau}\right)^{1/3}$$

$$d = 0.059 \ M = 59.05 \ mm$$

$$M_e = \frac{\pi}{32} \times \sigma_b \times d^3$$

$$d = \left(\frac{M_e \times 32}{\pi \times \sigma_b}\right)^{1/3}$$

$$d = 0.064 \ M = 64.69 \ mm$$

$\therefore$ Larger value $\Rightarrow$ $\boxed{d = 64.69 \ mm}$

COUPLING

Q Design a sleeve coupling which is transmitting 35 KW @ 250 rpm. The allowabale shear stress and crushing stress are 30 mPa and 70 mPa respectively. The material for sleeve is Cast iron for which shear stress may be assumed 10 mPa.

A. Let d = Diameter of shaft
D = Outer diameter of sleeve
L = Length of sleeve $(3.5d)$
l = length of key $\left(\frac{3.5d}{2}\right)$

Design of shaft

Torque transmitted by shaft

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

$$= 1337 \text{ Nm}$$

$$T = 1337 \times 10^3 \text{ Nmm}$$

Design of sleeve

$$D = 2d + 13$$

$$T = \frac{\pi}{16} \times \tau_s \times d^3 \qquad (\tau_s = 30 \text{ mPa})$$

$$d = 62 \text{ mm}$$

$$\therefore D = 137 \text{ mm}$$

$$L = 3.5d = 217 \text{ mm}$$

Let us check induced shear stress in Cast Iron

$$T = \frac{\pi}{16} \times \tau_c \times \left(\frac{D^4 - d^4}{D}\right)$$

$$\tau_c = 2.7 \ N mm^2$$

It is less than given value 10 Nmm^2.
$\therefore$ Design is safe.

Design for key

Let t = thickness
w = width (Assume $t = w$)
l = length of key $= \frac{L}{2} = 108.5$

Consider shearing stress in key.

$$T = l \times w \times \tau_s \times \frac{d}{2}$$

$$w = 14 \ mm$$

$$t = w = 14 \ mm$$

Let us check crushing stress in key.

$$\therefore T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2}$$

$$\sigma_c = 56.78 \ Nmm^2 < \text{Given } (70 \ mPa)$$

$\therefore$ Design is safe

Q. Design a flange coupling to transmit 20 KW @ 1000 rpm from electric motor to compressor. The service factor may be 1.21. The following permissible stresses may be used as following.
i) shear stress for shaft, bolt and key = 40 mPa
ii) crushing stress for bolt and key = 80 mPa
iii) shear stress for cast iron material (flange & hub) = 8 mPa

A. Let d = Diameter of shaft
D = Outer diameter of hub = $2d$
d_1 = Outer diameter of bolt
D_1 = Diameter of bolt
n = number of bolts
t_f = Thickness of flange
L = Length of hub = $1.5d$ = l

Design of Hub

$$T = \frac{P \times 60}{2\pi N} \qquad (N = rpm)$$

$$T = 192 \times 10^3 \text{ Nmm}$$

$$T = \frac{\pi}{16} \times \tau_s \times d^3$$

$$\boxed{d = 30 \text{ mm}}$$

$$\boxed{D = 60 \text{ mm}}$$

$$\boxed{L = 45 \text{ mm}}$$

Let us check induced shear stress in hub

$$T = \frac{\pi}{16} \times \tau_c \times \left(\frac{D^4 - d^4}{D}\right)$$

$$\tau_c = 4.82 \ Nmm^2 < \text{Given } (8 \ mPa)$$

$\therefore$ Design is safe

Design for key

Considering shear stress

$$T = l \times w \times \frac{d}{2} \times \tau_s$$

$$w = 7.2 \ mm$$
$$t = 7.2 \ mm$$
$$l = 45 \ mm$$

Checking crushing stress

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2}$$

$$\sigma_c = 79.02 < \text{Given } (80 \ mPa)$$

Design for Flange

$$T = \frac{\pi D^2}{2} \times \tau_c \times t_f$$

$$t_f = 4.5 \ mm$$

Design for bolt

$$D_1 = 3d$$

$$D_1 = 90\ mm$$

$$n = \left(\frac{d}{10}\right) = \left(\frac{30}{10}\right) = 3\ mm$$

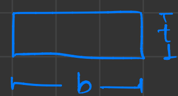
$$T = \frac{\pi}{4} \times d_1^2 \times \tau_b \times n \times \frac{D_1}{2}$$

$$d_1 = 6.72$$

Belt Drives

Q. A flat belt is required to transmit 40 KW from a pulley of 1.5 metre effective diameter running at 400 rpm. The angle of contact is 160°. The coefficient of friction b/w belt and pulley surface is 0.25. Determine taking centrifugal tension into account width of belt required. It is given that the belt thickness is 10 mm. Density of its material is 1200 kg/m³ and the related permissible working stress is 2.1 mPa.

A. Let width of belt = b



mass / length = Area × length × density

$$= b \times t \times L \times \rho$$

$$= b \times 0.01 \times 1 \times 1200$$

$$m = 12b$$

W.K.T. $T_c = mv^2$

$$= 12b \times \left[\pi \times 1.5 \times \frac{400}{60}\right]^2$$

$$v = \frac{\pi d N}{60}$$

$$T_c = 11843\, b$$

$$v = 31.41$$

Maximum Tension,

$$T = T_1 + T_c \longrightarrow (1)$$

∴ Power Transmitted,

$$P = (T_1 - T_2) \times v$$

$$\frac{40\times10^3}{V} = T_1 - T_2$$

$$\frac{40\times10^3}{31.41} = T_1 - T_2$$

$$T_1 - T_2 = 1273.47$$

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta$$

$$2.3\log\frac{T_1}{T_2} = 0.25\times160\times\frac{\pi}{180}$$

$$\frac{T_1}{T_2} = 1.35$$

$$T_1 = 1.35\times T_2$$

$$T_2 = 3638.48 \approx 3638.5\ N$$

$$T_1 = 4911.95 \approx 4912\ N$$

Since, $T = \sigma\times A$

$$T = 2.1\times10^6 \times b\times0.01$$

$$T = 21000\times b$$

From (i),

$$21000b = 4912 + 11843b$$

$$9157b = 4912$$

$$\boxed{b = 0.53\ m}$$

TEE

Cotter (20), Knuckle (14), Coupling (14), Shaft (20), Gear (20), Belt (14)

Shear stress = τ
Tensile stress = σ_t
Crushing stress = σ_c

Sleeve Coupling :-

i) Design of shaft $T = \dfrac{P \times 60}{2\pi N}$

ii) Design of sleeve $D = 2d + 13$

$T = \dfrac{\pi}{16} \tau d^3$

check : $T = \dfrac{\pi}{16} \tau \left(\dfrac{D^4 - d^4}{D} \right)$

iii) Design of key $T = l w \tau \dfrac{d}{2}$

check : $T = l \dfrac{t}{2} \sigma_c \dfrac{d}{2}$

d = dia of shaft
D = Outer dia of sleeve
L = length of sleeve = $3.5d$
l = length of key = $\dfrac{L}{2}$

Flange Coupling :-

i) Design of hub $T = \dfrac{P \times 60}{2\pi N}$, $T = \dfrac{\pi}{16} \tau d^3$

check : $T = \dfrac{\pi}{16} \tau \left(\dfrac{D^4 - d^4}{D} \right)$

ii) Design of key $T = l w \tau \dfrac{d}{2}$

check : $T = l \dfrac{t}{2} \sigma_c \dfrac{d}{2}$

iii) Design of flange $T = \dfrac{\pi D^2}{2} \tau t_f$

iv) Design of bolts $T = \dfrac{\pi}{4} n \tau d_1^2 \dfrac{D_1}{2}$

d = dia of shaft
D = outer dia of hub = $2d$
d_1 = outer dia of bolt
D_1 = dia of bolt = $3d$
n = no. of bolt = $d/10$
t_f = thickness of flange
L = length of hub = $l = 1.5d$

Belt drives :-

mass = area × length × density

$$T_c = mv^2$$

$$v = \frac{\pi D N}{60}$$

$$T = T_1 + T_c$$

$$P = (T_1 - T_2) v$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu \theta$$

$$T = \sigma A$$

Shaft Pulley :-

T_1, T_2, $T = T_d = (T_1 - T_2) R_c$, $W_c = T_1 + T_2$

$\Sigma y = 0$: $W_c = R_{AV} + R_{BV}$, $\Sigma M = 0$: $R_{AV} \times 1 - W_c \times 0.7 = 0$

$T_d = (T_3 - T_4) R_d$, $2.3 \log\left(\frac{T_3}{T_4}\right) = \mu \theta$, T_3, T_4, $W_D = T_3 + T_4$

$\Sigma y = 0$ $W_D = R_{AH} + R_{BH}$, $\Sigma M = 0$: $R_{AH} \times 1 - W_D \times 0.8 = 0$

BM calc :- i) VL ii) HL, Resultant BM = M

$T_e = \sqrt{M^2 + T^2}$, $M_e = \frac{1}{2}\left[M + T_e\right]$

$T_e = \frac{\pi}{16} \tau d^3$, $M_e = \frac{\pi}{32} \sigma d^3$

$d =$ ______

Shaft Gear :-

$\alpha =$ $P =$

$T =$ $N =$

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

$$F_t = \frac{2T}{D} \qquad W_c = \frac{F_t}{\cos\alpha}$$

$$R_A = R_B = \frac{W_c}{2}$$

$$M = \frac{W_c L}{4}$$

Sleeve Coupling

Q. Given :-

$P = 35 \times 10^3$ W
$N = 250$ rpm
$\tau = 30$ mPa
$\sigma_c = 70$ mPa

d = diameter of shaft
D = Outer diameter of sleeve
L = length of sleeve = 3.5 d
l = length of key = $\frac{L}{2}$

Design of shaft

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

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

Torque transmitted by shaft,

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

$$T = 1337 \text{ Nm} = 1337 \times 10^3 \text{ Nmm}$$

Design of sleeve

$T = \frac{\pi}{16} \tau_s d^3$

$$D = 2d + 13$$

$$T = \frac{\pi}{16} \times \tau_s \times d^3$$

$$d = 62 \text{ mm}$$

$$D = 137 \text{ mm}$$

$$L = 3.5d = 217 \text{ mm}$$

Check stress in cast iron

$$T = \frac{\pi}{16} \tau \times \left(\frac{D^4 - d^4}{D} \right)$$

$T = \frac{\pi}{16} \tau \left(\frac{D^4 - d^4}{D} \right)$

$$\tau = 2.7 \text{ N mm}^2$$

$<$ $\therefore$ safe

Design for key

t = thickness

w = width (Assume $t = w$)

l = length of key $= \frac{L}{2} = 108.5$

Considering shear stress in key,

$$T = l w \tau \times \frac{d}{2}$$

$T = l w \tau \times \frac{d}{2}$

$$w = 14 \text{ mm}$$

$$t = 14 \text{ mm}$$

Check crushing stress in key,

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2}$$

$T = l \frac{t}{2} \sigma_c \frac{d}{2}$

$$\sigma_c = 56.78$$

$<$ given

$\therefore$ safe

Sleeve Coupling

i) d = diameter of shaft
D = Outer diameter of sleeve
L = length of sleeve = $3.5d$
l = length of key = $\frac{L}{2}$

d = diameter of shaft
D = Outer diameter of sleeve
L = length of sleeve = $3.5d$
l = length of key = $\frac{L}{2}$

d = diameter of shaft
D = Outer diameter of sleeve
L = length of sleeve = $3.5d$
l = length of key = $\frac{L}{2}$

i) Design of shaft

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

$$T = \_\_\_\_$$

ii) Design of sleeve

$$D = 2d + 13$$

$$L = 3.5d$$

$$T = \frac{\pi}{16} \tau d^3$$

$$d = \_\_\_\_$$

$D =$ ______

$L =$ ______

checking induced shear stress in cast iron

$$T = \frac{\pi}{16} \tau \left(\frac{D^4 - d^4}{D} \right)$$

$\tau =$ ______

iii) Design of key

$t = w$, $l = \frac{L}{2}$

$$T = l w \tau \frac{d}{2}$$

$w =$ ______

$t = w =$ ______

checking crushing stress in key

$$T = l \frac{t}{2} \sigma_c \frac{d}{2}$$

$d =$ dia of shaft
$D =$ outer dia of sleeve
$L =$ length of sleeve $= 3.5d$
$l =$ length of key $= \frac{L}{2}$

i) design of shaft

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

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

$T =$ ______

ii) design of sleeve

$D = 2d + 13$

$L = 3.5\, d$

$$T = \frac{\pi}{16} \tau d^3$$

$d =$ ____ $D =$ ___ $L =$ ____

checking induced shear stress in Cast iron

$$T = \frac{\pi}{16} \tau \left(\frac{D^4 - d^4}{D} \right)$$

$\tau =$ ______

iii) Design of Key

$t = w$

$l = \frac{L}{2}$

$$T = l w \tau \frac{d}{2}$$

$w =$ ___ $= t$

checking induced crushing stress

$$T = l \frac{t}{2} \sigma_c \frac{d}{2}$$

Flange Coupling

Q. $P = 20\ KW$
$N = 1000\ rpm$
$\tau = 40\ mPa = 40\ Nmm^2$
$\sigma_c = 80\ mPa = 80\ Nmm^2$

Let d = dia of sleeve
D = outer dia of hub $= 2d$
d_1 = outer dia of bolt
D_1 = diameter of bolt $= 3d$
n = no. of bolts
t_f = thickness of flange
L = length of hub $= 1.5d = l$

d = dia of shaft
D = Outer dia of hub $= 2d$
d_1 = Outer dia of bolt
D_1 = dia of bolt $= 3d$
n = no. of bolts
t_f = thickness of flange
L = Length of hub flange $= 1.5d = l$

d = dia of shaft
D = Outer dia of hub $= 2d$
d_1 = Outer dia of bolt
D_1 = dia of bolt $= 3d$
n = no. of bolt
t_f = thickness of flange
L = length of hub $= l = 1.5d$

i) design of hub

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

$$T = \_\_\_\_\_\_$$

$$T = \frac{\pi}{16} \tau d^3$$

$$d = \_\_\_\_\_\_$$

$$D = 2d = \_\_\_\_\_\_$$

$$L = 1.5d = \_\_\_\_\_\_$$

check induced τ in hub

$$T = \frac{\pi}{16} \tau \left(\frac{D^4 - d^4}{D}\right)$$

$$\tau <$$

Design of key

$$T = l w \tau \frac{d}{2}$$

$$w = t = \_\_\_\_\_\_$$

check σ_c in key

$$T = l \frac{t}{2} \sigma_c \frac{d}{2}$$

$$\sigma_c = \_\_\_\_\_\_$$

iii) design of flange

$$T = \frac{\pi D^2}{2} \tau t_f$$

$$T = \frac{\pi D^2}{2} \tau t_f$$

$$t_f = \_\_\_\_\_\_$$

iv) Design of bolts

$$D_1 = 3d$$

$$D_1 = \_\_\_\_\_\_$$

$$n = \left(\frac{d}{10}\right) = \_\_\_\_\_\_$$

$$T = \frac{\pi}{4} d_1^2 \tau n \frac{D_1}{2}$$

$$T = \frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2}$$

$$d_1 = \_\_\_\_\_\_$$

---

d = dia of shaft

D = Outer dia of hub = $2d$

d_1 = Outer dia of bolt

D_1 = dia of bolt = $3d$

n = no. of bolt

t_f = thickness of flange

L = length of hub = $1.5d$

d = dia of shaft

D = Outer dia of hub = $2d$

d_1 = Outer dia of bolt

D_1 = dia of bolts = $3d$

n = no. of bolts

t_f = thickness of flange

L = length of hub = $1.5d$

i) design of hub

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

T = ________

$$T = \frac{\pi}{16} \tau d^3$$

d = ________

$D = 2d$ = ________

$L = 1.5d$ = ________

Check induced τ for hub

$$T = \frac{\pi}{16} \tau \left(\frac{D^4 - d^4}{D} \right)$$

τ = ________

ii) Design of key

$t = w$

$l = 1.5d = L$

$$T = l w \tau \frac{d}{2}$$

$$w = t = \_\_\_\_\_\_\_\_$$

check σ_c for key

$$T = l \frac{t}{2} \sigma_c \frac{d}{2}$$

$$\sigma_c = \_\_\_\_\_\_\_\_$$

iii) design of flange

$$T = \frac{\pi D^2}{2} \tau t_f$$

$$t_f = \_\_\_\_\_\_\_\_$$

iv) design of bolt

$$n = \frac{d}{10}$$

$$D_1 = 3d$$

$$T = \frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2}$$

$$T = \frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2}$$

$$T = \frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2}$$

$$\frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2} \qquad \frac{\pi}{4} n \tau d_1^2 \frac{D_1}{2}$$

Belt drive

Q. $P = 40 \times 10^3$ W

$D = 1.5$ m

$\theta = 160°$

$\mu = 0.25$

$t = 10$ mm

$\rho = 1200$ kg/m^3

mass = area × length × density

$T_c = mv^2$

$v = \frac{\pi DN}{60}$

Let b = width of belt

mass = Area × length × density

$m = b \times t \times L \times \rho$

$= b \times 0.01 \times 1 \times 1200$

$m = 12b$

WKT, $T_c = mv^2$

$v = \frac{\pi d N}{60}$

$T_c = \_\_\_\_ b$

Max tension,

$T = T_1 + T_c \longrightarrow (1)$

Power, $P = (T_1 - T_2) V$

$T_1 - T_2 = \_\_\_\_$

$2.3 \log \frac{T_1}{T_2} = \mu \theta$

$T_1 = \_\_\_\_ T_2$

$T_1 = \_\_\_\_\_\_$

$T_2 = \_\_\_\_\_\_$

$$T = \sigma A$$
$$= 2.1 \times 10^6 \times b \times 0.01$$
$$T = 21000b$$

$$T = T_1 + T_c$$

$b = \_\_\_\_\_\_$

Let b = width of belt

mass = Area × length × density
$$m = b \times t \times L \times \rho$$
$$m = \_\_\_ b$$

$$T_c = mv^2$$

$$v = \frac{\pi D N}{60}$$

$$T_c = m\left(\frac{\pi D N}{60}\right)^2$$

Max Torque,
$$T = T_1 + T_c$$

Power = $P = (T_1 - T_2) v$

$T_1 - T_2 = \_\_\_\_\_\_$

$$2.3 \log \frac{T_1}{T_2} = \mu \theta$$

$$T_1 = \_\_\_ T_2$$

$$T_1 = \_\_\_\_\_\_ , \quad T_2 = \_\_\_\_\_\_$$

$$T = \sigma A$$
$$= 2.1 \times 10^6 \times b \times 0.01$$
$$T = 21000\, b$$

$$T = T_1 + T_c$$

Q. b = width of belt

mass = Area × length × density

$$m = b \times t \times L \times \rho$$
$$m = \_\_\_\_\_\_ b$$

WKT, $T_c = mv^2$

$$v = \frac{\pi D N}{60}$$

$$T_c = \_\_\_\_\_\_$$

Max Torque, $T = T_1 + T_c$

Power, $P = (T_1 - T_2)\, V$

$$T_1 - T_2 = \_\_\_\_\_\_$$

$$2.3 \log \frac{T_1}{T_2} = \mu \theta$$

$$T_1 = \_\_\_ T_2$$
$$T_1 = \_\_\_\_\_\_$$
$$T_2 = \_\_\_\_\_\_$$

$$T = \sigma \times A$$
$$= 2.1 \times 10^6 \times b \times t$$

Shaft :-

Q. $T_1 = 3.2 \times 10^3$ N

$\theta = 180°$

$\sigma_t = 63$ mPa

$\tau = 42$ mPa

$T_1 = 3.2 \times 10^3$ N

$$2.3 \log \frac{T_1}{T_2} = \mu \theta$$

$$\frac{T_1}{T_2} = \_\_\_\_$$

$$T_2 = \_\_\_\_\_\_$$

$$T_D = (T_1 - T_2) R_C$$

$$T_D = \_\_\_\_\_$$

$$W_C = T_1 + T_2 = 5.08 \times 10^3 \text{ N}$$

$$\Sigma y = 0$$

$$W_C - R_{AV} - R_{BV} = 0$$

$$W_C = R_{AV} + R_{BV}$$

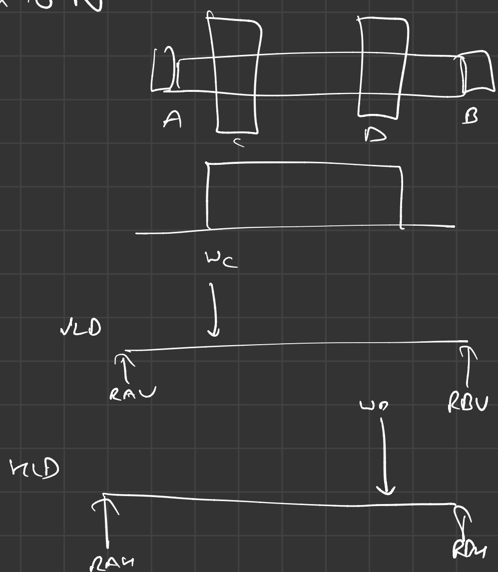
$$\Sigma M_B = 0$$

$$R_{AV} \times 1 - W_C \times 0.7 = 0$$

$$R_{AV} = \_\_\_\_\_$$

$$W_C = R_{AV} + R_{BV}$$

$$R_{BV} = \_\_\_\_\_\_$$



$T_D = (T_3 - T_4) R_D$

$T_3 - T_4 =$ ______

$2.3 \log\left(\frac{T_3}{T_4}\right) = \mu\theta$

$T_3 =$ ____ $T_4 =$ ______

$W_D = T_3 + T_4$

$\Sigma M = 0$

$R_{AH} \times 1 - W_D \times 0.8 = 0$

$R_{AH} =$ ______

$W_D = R_{AH} + R_{BH}$

$R_{BH} =$ ______

BM Calc :-

i) VL

BM @ A $= 0$

BM @ B $= 0$

BM @ C $= R_{AV} \times 0.3 \rightarrow$ 1

BM @ D $= R_{BV} \times 0.2 \rightarrow$ 2

ii) HL

BM @ A $= 0$

BM @ B $= 0$

BM @ C $= R_{AH} \times 0.3 \rightarrow$ 3

BM @ D $= R_{BH} \times 0.2 \rightarrow$ 4

Resultant BM

@ C $= \sqrt{(1)^2 + (3)^2}$

@ D $= \sqrt{(2)^2 + (4)^2}$

Max BM = M = ______

$T_e = \sqrt{M^2 + T^2}$

$M_e = \frac{1}{2}\left[M + \sqrt{M^2+T^2}\right] =$ ______

$T_e = \frac{\pi}{16} \times \tau \times d^3$

$d =$ ______

$M_e = \frac{\pi}{32} \sigma d^3$

$d =$ ______

Larger value $\therefore d =$ ______

Q. $T_1 =$ ______

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta$$

$\frac{T_1}{T_2} =$ ______

$T_2 =$ ______

$T_d = (T_1 - T_2) R_c$

$W_c = T_1 + T_2$

$\Sigma y = 0$

$W_c - R_{AV} - R_{BV} = 0$

$W_c = R_{AV} + R_{BV}$

$\Sigma M = 0$

$R_{AV} \times 1 - W_c \times 0.7 = 0$

$R_{AV} =$ ______

$R_{BV} =$ ______

$T_d = (T_3 - T_4) R_d$

$T_3 - T_4 =$ ______

$$2.3 \log\left(\frac{T_3}{T_4}\right) = \mu\theta$$

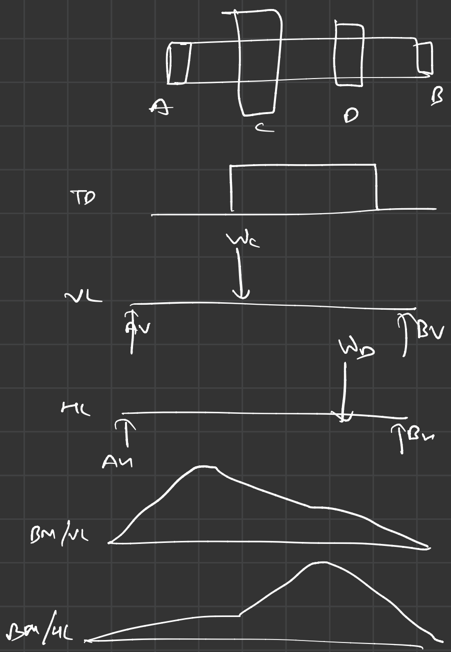
$T_3 =$ ______

$T_4 =$ ______

$W_D = T_3 + T_4$

$\Sigma y = 0$

$W_D = R_{AH} + R_{BH}$



$\Sigma M = 0$

$R_{AH} \times 1 - W_D \times 0.8 = 0$

$R_{AH} =$ ______

$R_{BH} =$ ______

BM Calc

i) VL

BM @ A = 0

BM @ B = 0

BM @ C = $R_{AV} \times 0.3$

BM @ D = $R_{BV} \times 0.2$

ii) HL

BM @ A = 0

BM @ B = 0

BM @ C = $R_{AH} \times 0.3$

BM @ D = $R_{BH} \times 0.2$

Resultant BM, @ C = $\sqrt{(1)^2 + (3)^2}$

@ D = $\sqrt{(2)^2 + (4)^2}$

BM = M = ______

$T_e = \sqrt{M^2 + T^2}$

$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$

$T_e = \frac{\pi}{16} \tau d^3$

$M_e = \frac{\pi}{32} \sigma_c d^3$

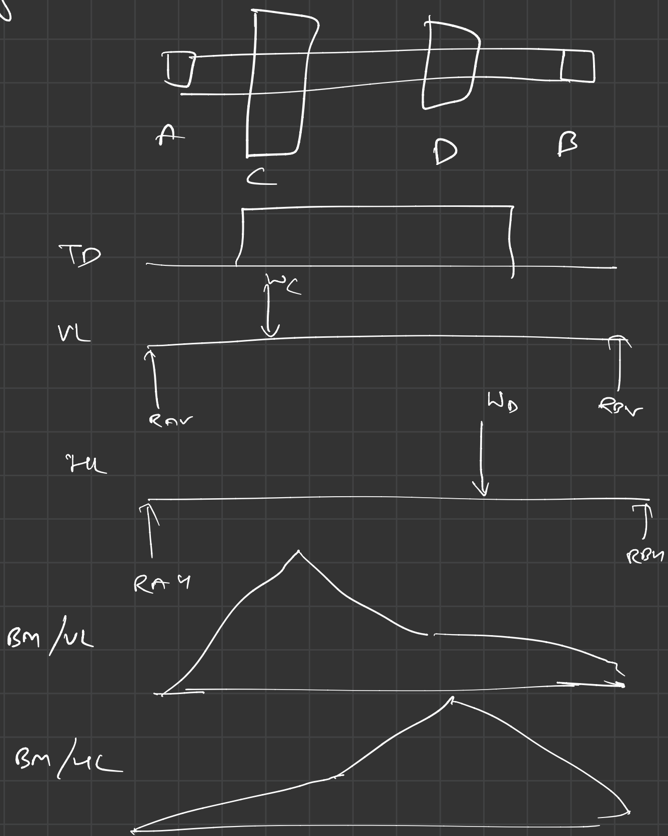
$d =$ ______

$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$

$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$

$M_e = \frac{\pi}{32} \sigma_c d^3$

Q Shaft



$T_1 =$ ________

$$2.3 \log \frac{T_1}{T_2} = \mu\theta$$

$\frac{T_1}{T_2} =$ ________

$T_2 =$ ________

$$T_d = (T_1 - T_2) R_c = T$$

$$W_C = T_1 + T_2$$

$$\Sigma y = 0$$

$$W_C - R_{AV} - R_{BV} = 0$$

$$W_C = R_{AV} + R_{BV}$$

$$\Sigma M = 0$$

$$R_{AV} \times 1 - W_C \times 0.7 = 0$$

$$R_{AV} = \_\_\_\_$$

$$R_{BV} = \_\_\_\_$$

$$T_D = (T_3 - T_4) R_D$$

$$2.3 \log \frac{T_3}{T_4} = \mu \theta$$

$$T_3 = \_\_\_\_$$

$$T_4 = \_\_\_\_$$

$$W_D = T_3 + T_4$$

$$\Sigma y = 0$$

$$W_D = R_{BH} + R_{AH}$$

$$\Sigma M = 0$$

$$R_{AH} \times 1 - W_D \times 0.8 = 0$$

$$R_{AH} = \_\_\_\_$$

$$R_{BH} = \_\_\_\_$$

<u>BM calc</u>

i) VL

BM @ A = 0

B = 0

C = 0.3 × R_{AV}

D = 0.2 × R_{BV}

ii) HL

BM @ A = 0

$B = 6$

$C = RAu \times 0.3$

$D = RBu \times 0.2$

Resultant $BM = \_\_\_\_\_\_\_\_ = M$

$$T_e = \sqrt{M^2 + T^2}$$

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$T_e = \frac{\pi}{16} \tau d^3$$

$$M_e = \frac{\pi}{32} \sigma_c d^3$$

$d = \_\_\_\_\_\_\_\_$

Shaft gear :-

Q. $\alpha =$ ____
$T =$ ____
$N =$ ____
$P =$ ____

$$F_t = \frac{2T}{D}$$

$$W_c = \frac{F_t}{\cos\alpha}$$

$$M = \frac{W_c L}{4}$$

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

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

W_c = Normal load acting on gear

$$R_A = R_B = \frac{W_c}{2}$$

F_t = Tangential force

$$F_t = \frac{2T}{D} \qquad W_c = \frac{F_t}{\cos\alpha}$$

$$R_A = R_B = \frac{W_c}{2} = \text{\_\_\_\_}$$

$$M = \frac{W_c L}{4}$$

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \tau d^3$$

$$M_e = \frac{1}{2}\left[M + T_e\right] = \frac{\pi}{32} \sigma d^3$$

Knuckle Joint

Q. $F = 25 \times 10^3 \, N$

i) Tensile Strength of rod

$$F = \frac{\pi}{4} d^2 \sigma_t \qquad F = \frac{\pi}{4} d^2 \sigma_t$$

$d =$

ii) Usual properties of knuckle joint

$$\begin{aligned} d_1 &= d & d_1 &= d \\ d_2 &= 2d & d_2 &= 2d \\ d_3 &= 1.5d & d_3 &= 1.5d \\ t &= 1.25d & t &= 1.25d \\ t_1 &= 0.75d & t_1 &= 0.75d \\ t_2 &= 0.5d & t_2 &= 0.5d \end{aligned}$$

iii) Load carrying capacity on the basis of shearing stress of knuckle pin

$$F = 2 \frac{\pi}{4} d_1^2 \tau$$

iv) Checking

Single eye :-

$$\begin{aligned} \sigma_t &: F = (d_2 - d_1) t \sigma_t \\ \tau &: F = (d_2 - d_1) t \tau \\ \sigma_c &: F = d_1 t \sigma_c \end{aligned}$$

Double eye :-

σ_t : $F = (d_2 - d_1) 2t\, \sigma_t$

τ : $F = (d_2 - d_1) 2t\, \tau$

σ_c : $F = d_1 2t\, \sigma_c$

Q. Knuckle joint

Given : F = ______

τ = ______

σ_t = ______

σ_c = ______

i) Tensile strength of rod

$$F = \frac{\pi}{4} d^2 \sigma_t \quad , d = \_\_\_\_$$

ii) Basic properties of knuckle joint

$d_1 = d$

$d_2 = 2d$

$d_3 = 1.5d$

$t = 1.25d$

$t_1 = 0.75d$

$t_2 = 0.5d$

iii) Load carrying capacity on the basis of shear stress of knuckle pin

$$F = \frac{\pi}{4} d_1^2 \tau$$

τ = ______

iv) Checking :-

Single eye :-

σ_t : $F = (d_2 - d_1)\, t\, \sigma_t$

τ : $F = (d_2 - d_1)\, t\, \tau$

σ_c : $F = d_1 t \sigma_c$

Double eye :-

σ_t : $F = (d_2 - d_1)\, 2t\, \sigma_t$

τ : $F = (d_2 - d_1)\, 2t\, \tau$

σ_c : $F = d_1\, 2t\, \sigma_c$

Q. Knuckle joint

$F =$ ________

$\sigma_t =$ ________

$\tau =$ ________

$\sigma_c =$ ________

i) Tensile strength of rod

$$F = \frac{\pi}{4} d^2 \sigma_t$$

$d =$ ________

ii) Basic properties of knuckle joint

$d_1 = d$

$d_2 = 2d$

$d_3 = 1.5\, d$

$t = 1.25\, d$

$t_1 = 0.75\, d$

$t_2 = 0.5\, d$

iii) Load carrying capacity on the basis of shearing stress of knuckle pin

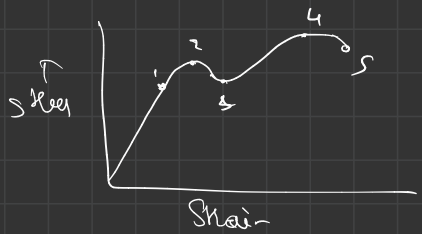
$$F = \frac{\pi}{4} d_1^2 \tau$$

$\tau =$ ______

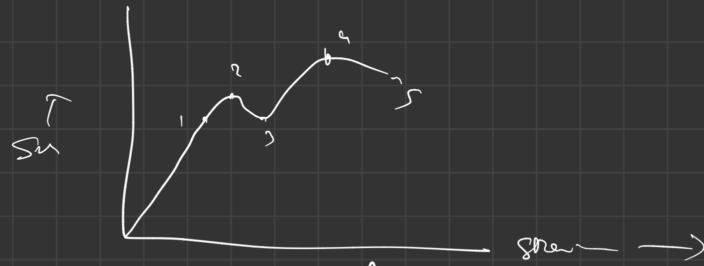
iv) Checking

single eye :- σ_t : $F = (d_2 - d_1) t \sigma_t$
τ : $F = (d_2 - d_1) t \tau$
σ_c : $F = d_1 t \sigma_c$

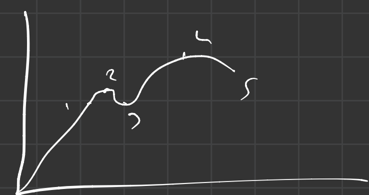
double eye :- σ_t : $F = (d_2 - d_1) 2t \sigma_t$
τ : $F = (d_2 - d_1) 2t \tau$
σ_c : $F = d_1 2t \sigma_c$



1 = proportional limit
2 = elastic limit
3 = yield point
4 = ultimate stress point
5 = fracture



1 = proportional
2 = elastic
3 = yield
4 = ultimate stress
5 = fracture



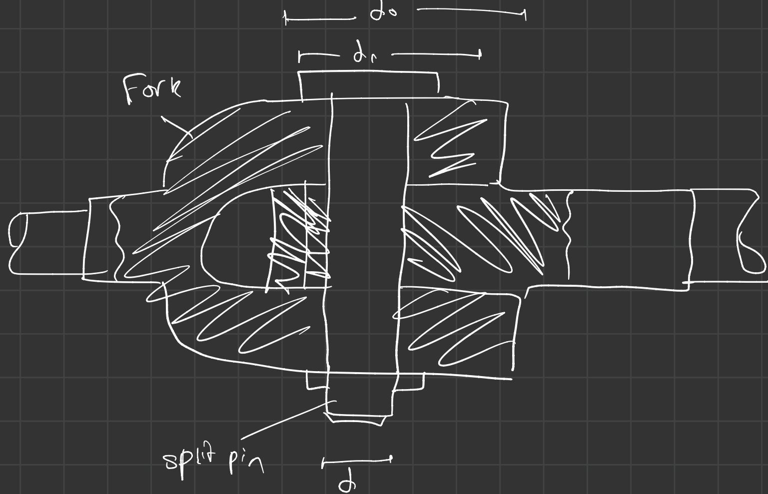
1 = proportional
2 = elastic
3 = yield
4 = ultimate
5 = fracture

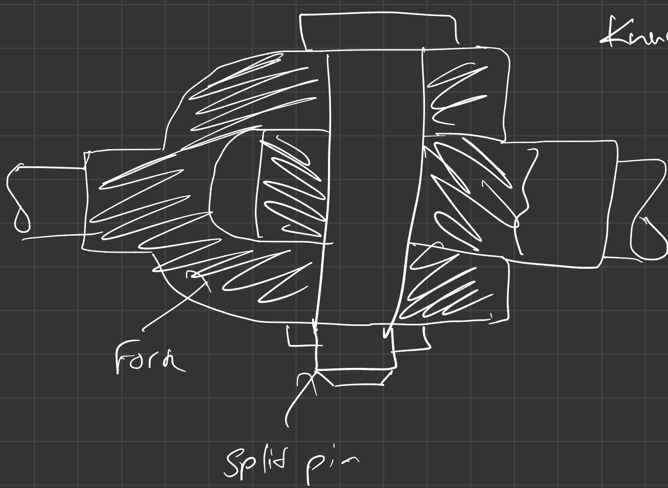
Co-linear shaft	Linear shaft
→ Rigid coupling	Flexible
→ sleeve or muff	→ Bush pin type
→ split muff coupling	→ Old ham coupling
→ Flange coupling	→ Universal coupling

Types of coupling

Co-linear shaft	Non co-linear shaft
Rigid coupling	flexible
Sleeve or Muff	Bush pin type
Flange coupling	Universal
Split muff coupling	Old ham coupling

Knuckle Joint





Knuckle joint