VTU question paper Dec 2017/Jan 2018 Solutions

Sem : V

Faculty : RPR

subject : DME I

subject code : 15ME54

Module 1

1(a) Define standards and codes

Ans: code is a set of specifications for the analysis, design, manufacture and construction of anything. The purpose of code is to achieve a specified degree of safety, effeciency and quality.

Standard is a set of specifications for parts, materials or processes intended to achieve uniformity, effeciency and desired quality.

b) A circular rod of diameter 50mm is subjected to loads as shown in fig. Q1(b). Determine the nature and magnitude of stresses at the critical points.

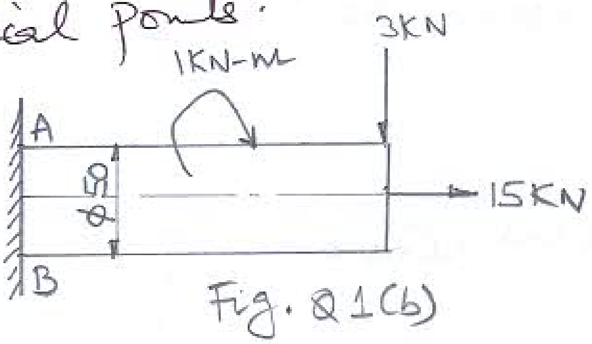


Fig. Q1(b)

Ans: data

$d = 50\,mm$.

to find stresses at A & B.

Direct tensile stress (σ_t) $= \dfrac{15\times10^3}{\left(\dfrac{\pi\times50^2}{4}\right)} = 7.64\ N/mm^2$

Bending stress (σ_b) $= \dfrac{M_b}{Z_b} = \dfrac{3\times10^3\times250}{\left(\dfrac{\pi\times50^3}{32}\right)}$

$= 61.11\ N/mm^2$

(tensile at A and compr. at B).

Torsional shear stress (τ) $= \dfrac{M_t}{Z_t} = \dfrac{1\times10^3}{\left(\dfrac{\pi\times50^3}{16}\right)}$

$= 40.74\ N/mm^2$

Stresses at A

Combined normal stress (σ) $= \sigma_t + \sigma_b$

$= 7.64 + 61.11$

$= 68.75\ N/mm^2$

Max. principal stress (σ_1) $= \dfrac{\sigma}{2} + \sqrt{\left(\dfrac{\sigma}{2}\right)^2 + \tau^2}$

$= 87.68\ N/mm^2$ (T)

Min. principal stress (σ_2) $= \dfrac{\sigma}{2} - \sqrt{\left(\dfrac{\sigma}{2}\right)^2 + \tau^2}$

$= -18.93\ N/mm^2$ (c).

Max. shear stress (τ_{max}) $= \sqrt{\left(\dfrac{\sigma}{2}\right)^2 + \tau^2}$

$= 53.22\ N/mm^2$.

Stresses at B

Combined normal stress $(\sigma) = \sigma_t + \sigma_b$

$= 7.64 - 61.11$

$= -53.47\,N/mm^2$.

Max. principal stress $(\sigma_1) = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$

$= 21.99\,N/mm^2\ (T)$

Min. principal stress $(\sigma_2) = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$

$= -75.46\,N/mm^2\ (C)$.

Max. shear stress $(\tau_{max}) = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$

$= 48.72\,N/mm^2$.

2(a) Briefly explain the ~~stages~~ Phases of design process (Shiegley's)

Ans:

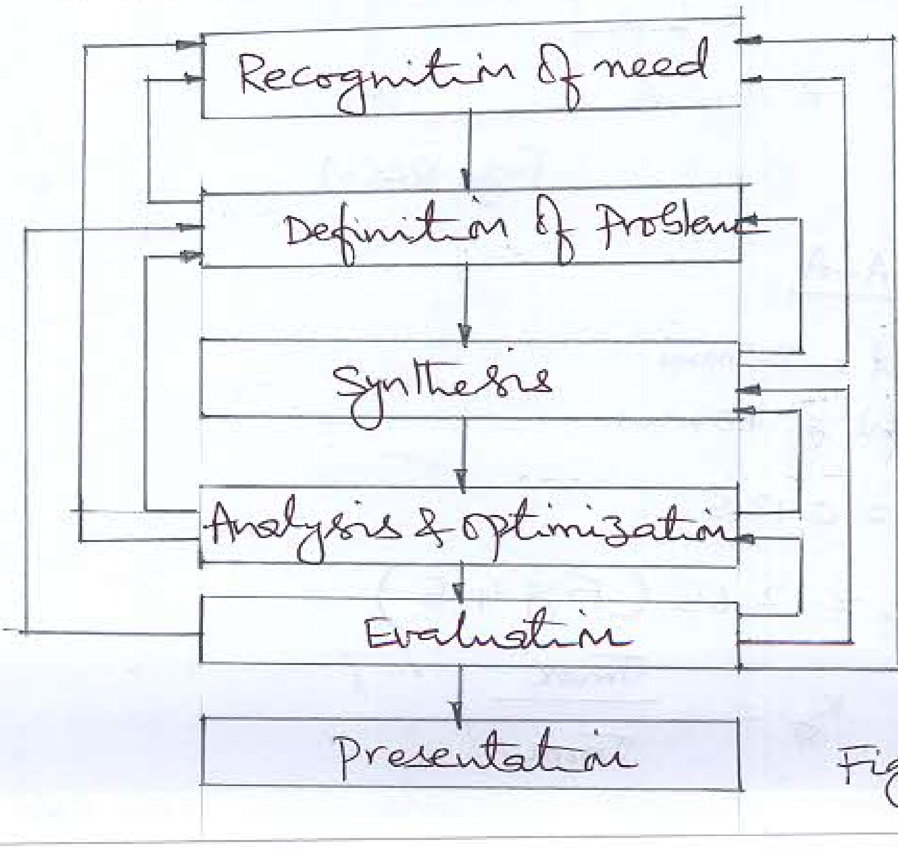


Fig 2(a)

The phases of design process (Shigley's) is represented in Fig. 2(a). The design process begins with recognition of need. After many iterations, the process ends with the presentation of plans for satisfying the need.

2(b) A flat bar shown in fig 2(b) is subjected to an axial load of 100 kN. Assuming that the stress in the bar is limited to 200 N/mm^2, determine the thickness of bar.

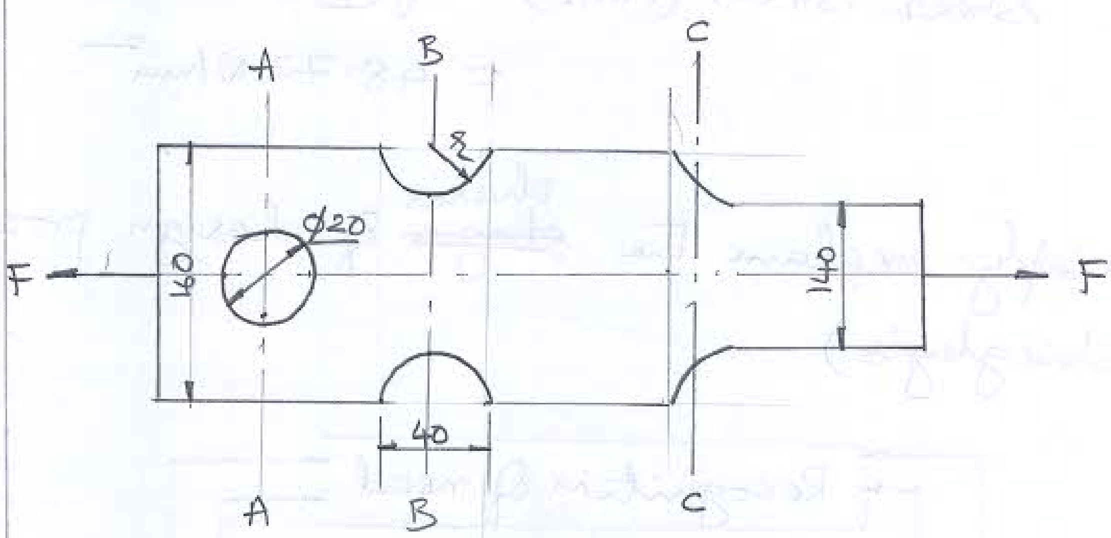


Fig. Q2(b)

Sec A–A

$d = 20\,mm$
$w = 160\,mm$

$\frac{d}{w} = 0.125$

$\therefore K_t = 2.65$ (Fig 4.5)

Now $K_t = \frac{\sigma_{max}}{\sigma_{nom}}$

$$\therefore \quad 2.65 = \frac{200}{\sigma_{nom}}$$

$$\Rightarrow \sigma_{nom} = 75.47\ N/mm^2.$$

$$\text{But } \sigma_{nom} = \frac{F}{(w-d)h}$$

$$\text{ie} \quad 75.47 = \frac{100 \times 10^3}{(160-20)h}$$

$$\Rightarrow h = 9.46\ mm.$$

Sec B-B

$D = 160\ mm$

$d = 160 - 40 = 120\ mm.$

$r = 20\ mm.$

$$\therefore \frac{r}{d} = \frac{20}{120} = 0.167$$

$$\frac{D}{d} = \frac{160}{120} = 1.33.$$

$$\therefore K_\sigma = 2.1 \text{ (Fig 4.22A)}.$$

$$\text{Now } K_\sigma = \frac{\sigma_{max}}{\sigma_{nom}}.$$

$$2.1 = \frac{200}{\sigma_{nom}}$$

$$\Rightarrow \sigma_{nom} = 95.23\ N/mm^2$$

$$\text{But } \sigma_{nom} = \frac{F}{hd} = \frac{100 \times 10^3}{h \times 120}$$

$$\Rightarrow h = 8.75\ mm.$$

Sec C-C

here $r = 10\ mm$, $d = 140\ mm$, $D = 160\ mm$.

$$\frac{r}{d} = \frac{10}{140} = 0.0714$$

$$\frac{D}{d} = \frac{160}{140} = 1.142.$$

From Fig 4.24, $K_t = 1.88$.

Now $K_t = \frac{\sigma_{max}}{\sigma_{nom}}$

$$1.88 = \frac{200}{\sigma_{nom}}$$

$$\Rightarrow \sigma_{nom} = 106.38\ N/mm^2$$

but $\sigma_{nom} = \frac{F}{A} = \frac{F}{hd} = \frac{100\times10^3}{h\times140}$

$$\Rightarrow h = 6.71mm.$$

Selecting the higher value of all the three values,

$$h = 9.46\ mm$$

Module-2

3(a) A cantilever beam of span 800mm has a rectangular cross section of depth 200mm. The free end of the beam is subjected to a transverse load of 1KN that drops on to it from a height of 40mm. Selecting C40 steel ($\sigma_y = 328.6$ MPa) and FOS = 3 determine the width of rect. section.

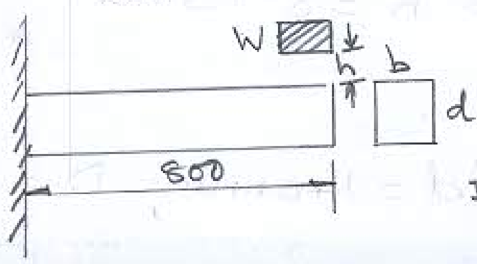


Fig. Q. 3(a)

Ans: data

$l = 800\,mm$

$d = 200\,mm$

$W = 1\,KN$

$h = 40\,mm$

$$\sigma_{bi} = \frac{\sigma_y}{FS} = \frac{328.6}{3} = 109.53\ N/mm^2$$

to find

$b = ?$

$$\sigma_{bi} = (\sigma_b)_{st}\left[1 + \sqrt{1 + \frac{2h}{\delta_{st}}}\right] \quad \text{— (1)}$$

$$\text{where } (\sigma_b)_{st} = \frac{M_b}{Z_b} = \frac{Fl}{\left(\frac{bd^2}{6}\right)} \begin{matrix}(T\,2.8)\\(T\,2.7)\end{matrix}$$

$$= \frac{6 \times Fl}{bd^2}$$

$$= \frac{6 \times 1 \times 10^3 \times 800}{b \times 200^2}$$

$$= \left(\frac{120}{b}\right) N/mm^2$$

$$\delta_{st} = \frac{Fl^3}{3EI} \quad \frac{(T\,2.8)}{P\,2.34}$$

$$= \frac{1 \times 10^3 \times 800^3 \times 12}{3 \times 206.8 \times 10^3 \times b \times 200^3}$$

$$= \left(\frac{1.24}{b}\right) mm$$

Sub in (1),
$$109.53 = \frac{120}{b}\left[1 + \sqrt{1 + \frac{2 \times 40 b}{1.24}}\right]$$

$$\therefore 1+\sqrt{1+64.51b} = 0.912b.$$

$$\sqrt{1+64.51b} = (0.912b-1)$$

Squaring on both sides,

$$1+64.51b = 0.831b^2 - 1.824b + 1$$

$$\Rightarrow 0.831b^2 - 66.33b = 0.$$

$$\Rightarrow b = 79.82 \text{ mm say } 80 \text{ mm}.$$

3(b) A rectangular cross section bar 200 mm long is subjected to an impact by a load of 1KN that falls onto it from a height of 10mm from rest. Determine the c/s dimension of rectangular bar, if the allow. stress of the material of the bar is 125 N/mm^2. Assume the thickness & depth is twice the width. Also find deformation due to impact.

Ans: data

$l = 200$ mm, $W = 1$KN, $h = 10$mm, $\sigma' = 125$ N/mm^2

$d = 2b$

to find

1) d & b

2) δ_{max}.

We know $\sigma' = \sigma \left[1 + \sqrt{1 + \frac{2hAE}{Wl}} \right]$

$$125 = \frac{1000}{A} \left[1 + \sqrt{1 + \frac{2 \times 10 \times A \times 206.8 \times 10^3}{1000 \times 200}} \right]$$

ie $0.125\,A = 1 + \sqrt{1 + 20.68A}$

$\Rightarrow A = 1339.52\,mm^2$

Now $A = b \times d$

$1339.52 = b \times 2b$

$\Rightarrow b = 25.87\,mm$. Say $26\,mm$.

$\therefore d = 52\,mm$.

Now using Hooke's law

$$\frac{\sigma'}{\epsilon'} = E.$$

$$\frac{\sigma'}{\left(\frac{\delta_{max}}{l}\right)} = E.$$

$$\frac{125}{\left(\frac{\delta_{max}}{200}\right)} = 206.8 \times 10^3$$

$\Rightarrow \delta_{max} = 0.1209\,mm$.

(PTO)

4 A round rod of diameter 1.2d is reduced to a diameter 'd' with a fillet radius of 0.1d. This stepped rod is to sustain a twisting moment that fluctuates between 2.5 KN-m to 1.5 KN-m together with a bending moment of 1 KN-m to -1 KN-m. The rod is made of carbon steel C40 ($\sigma_y = 328.6$ MPa, $\sigma_u = 620$ MPa). Determine suitable value for 'd'. (10)

Ans: data

$D = 1.2d$

$d = d.$

$r = 0.1d.$

$(M_t)_{max} = 2.5 \times 10^6$ N-mm.

$(M_t)_{min} = 1.5 \times 10^6$ N-mm.

$(M_b)_{max} = 1 \times 10^6$ N-mm.

$(M_b)_{min} = -1 \times 10^6$ N-mm.

$\sigma_y = 328.6$ N/mm^2.

$\sigma_u = 620$ N/mm^2

to find

$d = ?$

consider twisting moment

Equivalent shear stress (τ') $= \dfrac{K_{\tau}\, \tau_a\, \tau_y}{\sigma_{-1} \cdot K_e \cdot K_{sr} \cdot K_{sz}} + \tau_m$ —(1)

K_{τ}

$$\frac{r}{d} = \frac{0.1d}{d} = 0.1.$$

$$\frac{D}{d} = \frac{1.2d}{d} = 1.2.$$

$\therefore K_t = 1.34$ (Fig. 4-19 A / P 4.18).

assuming $q_{-1} = 1$, $K_{-t} = K_t = 1.34$.

$\underline{\tau_y}$

Assume $\tau_y = 0.5 \sigma_y$

$= 0.5 \times 328.6$

$= 164.3 \ N/mm^2$.

$\underline{\sigma_{-1}}$

For steel, $\sigma_{-1} = 0.5 \sigma_u$.

$= 0.5 \times 620$

$= 310 \ N/mm^2$.

$\underline{K_l, K_{sr} \ \& \ K_{sz}}$

For torsion, $K_l = 0.6$

For $\sigma_u = 620 \ N/mm^2$ & for rough finished surface,

$K_{sr} = 0.9$ (Fig 5.3 / P 5.8)

assume $K_{sz} = 0.85$.

$\underline{\tau_a \ \& \ \tau_m}$

$$(M_b)_a = \frac{(M_t)_{max} - (M_t)_{min}}{2}$$

$= 0.5 \times 10^6$ ~~N/mm~~ N-mm.

$$(M_t)_m = \frac{(2.5 + 1.5) 10^6}{2}$$

$= 2 \times 10^6$ N-mm.

Now, $$\tau_a = \frac{(M_t)_a}{Z_t} = \frac{0.5\times10^6}{\left(\frac{\pi d^3}{16}\right)}$$

$$= \left(\frac{2.54\times10^6}{d^3}\right) N/mm^2$$

$$\tau_m = \frac{(M_t)_m}{Z_t} = \left(\frac{10.18\times10^6}{d^3}\right) N/mm^2.$$

Sub in (1)

$$\tau' = \frac{1.34\times2.54\times10^6\times164.3}{310\times0.6\times0.9\times0.85\times d^3} + \frac{10.18\times10^6}{d^3}$$

$$= \left(\frac{14.11\times10^6}{d^3}\right) N/mm^2$$

2) Bending moment

The equivalent bending stress

$$\sigma_b' = \frac{K_{-\sigma}\,\sigma_a\,\sigma_y}{\sigma_{-1}\cdot K_e\cdot K_{sr}\cdot K_{sz}} + \sigma_m \quad \text{—— (2)}$$

$K_{-\sigma}$

Refer Fig. 4.21A / P4.20

$\frac{r}{d} = 0.1$

$\frac{D}{d} = 1.2$

$\therefore K_\sigma = 1.62.$

assuming $q_{-1} = 1$, $K_{-\sigma} = K_\sigma = 1.62.$

K_l, K_{sr}, K_{sz}

For bending,

$$K_l = 1.0$$

$$K_{sr} = 0.85 \text{ (Fig 5.3)}$$

$$K_{sz} = 0.85$$

σ_a & σ_m

$$(M_b)_a = \frac{(1\times10^6) + (1\times10^6)}{2} = 1\times10^6 \text{ N-mm.}$$

$$(M_b)_m = 0.$$

$$\sigma_a = \frac{(M_b)_a}{Z_b} = \frac{1\times10^6 \times 32}{\pi d^3} = \left(\frac{10.18\times10^6}{d^3}\right) \text{N/mm}^2$$

$$\sigma_m = 0.$$

Sub in (2)

$$\sigma_b' = \frac{1.62 \times 10.18\times10^6 \times 328.6}{320 \times d^3 \times 1 \times 0.85 \times 0.82}$$

$$= \left(\frac{25.08\times10^6}{d^3}\right) \text{N/mm}^2.$$

Now, max. shear stress

$$\tau_{max} = \sqrt{\left(\frac{\sigma'}{2}\right)^2 + \tau'^2} = \frac{\tau_y}{n}.$$

$$\sqrt{\left(\frac{25.08\times10^6}{2d^3}\right)^2 + \left(\frac{14.11\times10^6}{d^3}\right)^2} = 82.15$$

$$\Rightarrow d = 61.25 \text{ mm say } 62 \text{ mm.}$$

5. A solid steel shaft running at 600 RPM is supported on bearings 600 mm apart. The shaft receives 40 KW through a 400 mm diameter pulley weighing 400 N located 300 mm to the right of left bearing by a vertical flat belt drive. The power is transmitted from the shaft through another pulley of diameter 600 mm weighing 600 N located 200 mm to the right of right bearing. The belt drives are at right angles to each other and the ratio of belt tensions is 3. Determine the size of shaft necessary, if the allow. shear stress in the shaft material is 40 MPa and the loads are steady. (14).

Ans: data

$n = 600$ RPM

$N = 40$ KW

$d_{PB} = 400$ mm

$W_{PB} = 400$ N

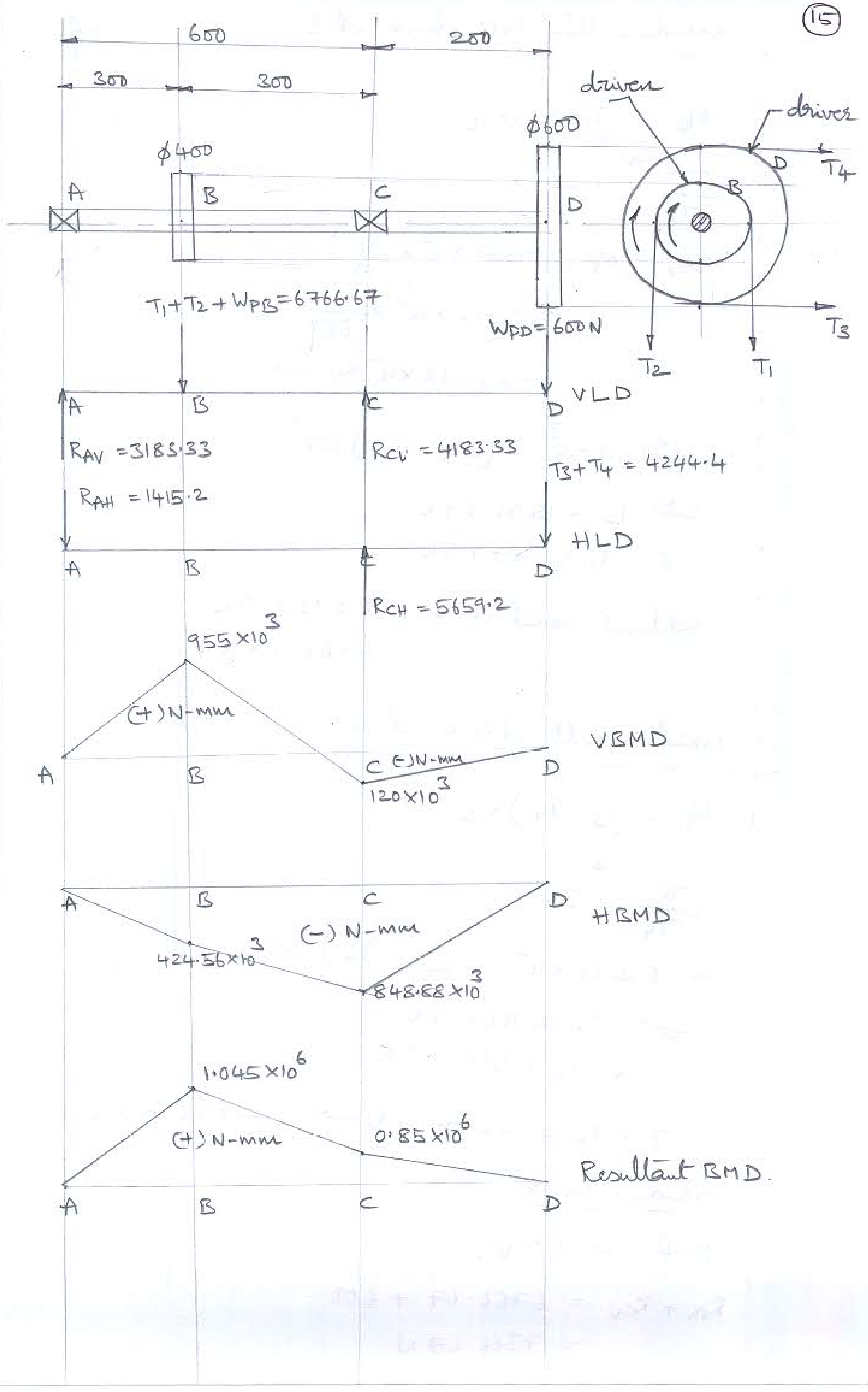
$d_{PD} = 600$ mm

$W_{PB} = 600$ N.

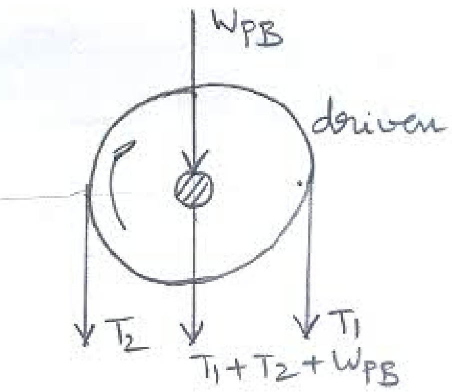
$\frac{T_1}{T_2} = 3$ & $\frac{T_3}{T_4} = 3$.

$\tau_{ed} = 40\ N/mm^2$

to find $D = ?$


600
200
300
300
driven
driver
ϕ600
ϕ400
A
B
C
D
T4
T3
T2
T1
T1+T2+WPB=6766.67
WPD=600N
VLD
RAV =3183.33
RCV =4183.33
T3+T4 = 4244.4
RAH =1415.2
HLD
RCH = 5659.2
955×10^3
(+)N-mm
VBMD
C (–)N-mm
120×10^3
HBMD
(–) N-mm
424.56×10^3
848.88×10^3
1.045×10^6
(+) N-mm
0.85×10^6
Resultant BMD.

Consider the belt drive at B



$$M_t = (T_1 - T_2)R_{PB}$$
&
$$\frac{T_1}{T_2} = 3.$$

Now, $M_t = 9550 \times 10^3 \times \frac{N}{n}$

$$= 9550 \times 10^3 \times \frac{40}{600}$$

$$= 636.66 \times 10^3 \text{ N-mm.}$$

$$\therefore 636.66 \times 10^3 = (3T_2 - T_2)200$$

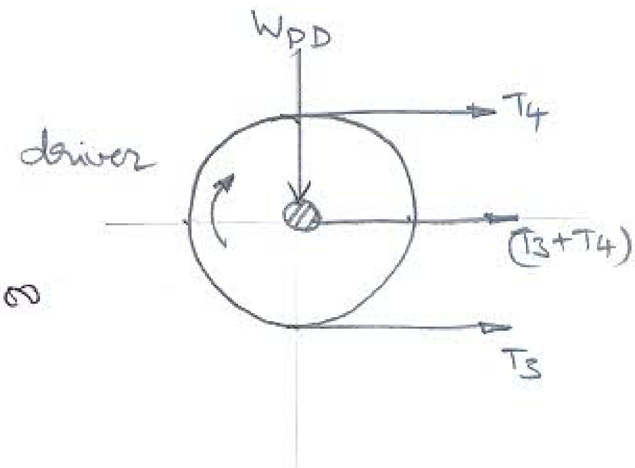
$$\Rightarrow T_2 = 1591.67 \text{ N}$$

$$\therefore T_1 = 4775 \text{ N.}$$

$\therefore$ vertical load at B $= T_1 + T_2 + W_{PB}$

$$= 6766.67 \text{ N} \downarrow$$

Consider belt drive at D



$$M_t = (T_3 - T_4)R_{PD}$$
&
$$\frac{T_3}{T_4} = 3.$$

Now $636.66 \times 10^3 = (3T_4 - T_4)300$

$$\Rightarrow T_4 = 1061.1 \text{ N}$$

$$\& \; T_3 = 3183.3 \text{ N.}$$

$\therefore T_3 + T_4 = 4244.4 \text{ N} \rightarrow$ (looking from left)

Consider VLD

to find R_{AV} & R_{CV},

$$R_{AV} + R_{CV} = 6766.67 + 600$$

$$= 7366.67 \text{ N.}$$

taking moments about A,

$(6766.67 \times 300) + (600 \times 800) = R_{CV} \times 600$

$\Rightarrow R_{CV} = 4183.33 N$

$\Rightarrow R_{AV} = 3183.33 N$.

VBMD

$(M_b)_{AV} = 0$

$(M_b)_{BV} = (3183.33 \times 300) = 955 \times 10^3$ N-mm.

$(M_b)_{CV} = -600 \times 200 = -120 \times 10^3$ N-mm.

$(M_b)_{DV} = 0$.

consider HLD

$R_{AH} + R_{CH} = 4244 N$

taking moments about A,

$R_{CH} \times 600 = 4244.4 \times 800$

$\Rightarrow R_{CH} = 5659.2 N$

& $R_{AH} = -1415.2 N$

HBMD

$(M_b)_{AH} = 0$

$(M_b)_{BH} = -424.58 \times 10^3$ N-mm

$(M_b)_{CH} = -848.88 \times 10^3$ N-mm

$(M_b)_{DH} = 0$.

Resultant BMD

$(M_b)_A = 0$.

$(M_b)_B = \sqrt{(955 \times 10^3)^2 + (424.58 \times 10^3)^2}$

$= 1.045 \times 10^6$ N-mm.

$$(M_b)_C = \sqrt{(-120\times10^3)^2 + (-848.88\times10^3)^2}$$
$$= 857.31\times10^3 \text{ N-mm}.$$
$$= 0.85\times10^6 \text{ N-mm}.$$

$$(M_b)_D = 0.$$

$$\therefore (M_b)_{max} = (M_b)_B = 1.045\times10^6 \text{ N-mm}.$$

$$M_t = 9550\times10^3 \times \frac{N}{n}$$
$$= 636.66\times10^3 \text{ N-mm}.$$

$$\therefore D = \left[\frac{16}{\pi \tau_{ed}}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right]^{\frac{1}{3}}$$

$$= \left[\frac{16}{\pi\times40}\sqrt{(1.5\times1.045\times10^6)^2 + (1.0\times636.66\times10^3)^2}\right]^{\frac{1}{3}}$$

$$= 59.94 \text{ mm}.$$

Select diameter of shaft $D = 60$ mm.

Q6 Design a flange coupling to connect the shafts of a motor and a centrifugal pump for the following specifications. pump output = 3000 L/min, Total head = 20m, pump speed = 600 rpm, pump effeciency = 70%, Select C40 steel ($\sigma_y = 328.6$ MPa) for shaft and C35 steel ($\sigma_y = 304$ MPa) for bolts with a F.S of 2. Use allowable shear stress for C.I flange as 15 N/mm².

Ans: data

$Q = 3000$ L/min $= \frac{3000\times10^{-3}}{60} = 0.05$ m³/sec.

$H = 20$ m, $n = 600$ rpm. $\eta = 0.7$, $FS = 2$, $\tau_f = 15$ N/mm²

Shaft material C40 ($\sigma_y = 328.6$ N/mm²)

Bolt material (C35) $\sigma_y = 304\ N/mm^2$.

Yield shear stress for shaft material $\tau_y = 0.5\sigma_y$

$= 164.3\ N/mm^2$

ums all. shear stress for shaft material

$$\tau_s = \frac{\tau_y}{FS} = \frac{164.3}{2} = 82.15\ N/mm^2\ (\tau_{d2})$$

Similarly allows shear stress for key material $= 82.15\ N/mm^2$

(assuming the same C40 steel for key)

Assuming allows crushing stress in key material as

$$\sigma_b' = 2 \times \tau_{d2} = 2 \times 82.15 = 164.3\ N/mm^2.$$

For bolt material, $\tau_y = \frac{\sigma_y}{2} = \frac{304}{2} = 152\ N/mm^2$.

$\therefore$ Allow. shear stress for bolt material $\tau_b = \frac{\tau_y}{FS}$

$$= \frac{152}{2} = 76\ N/mm^2.$$

1. power transmitted (N)

$$N = \frac{\rho g Q \cdot H}{\eta} = \frac{1000 \times 9.81 \times 0.05 \times 20}{0.7} = 14014.28\ W$$

$$= 14014\ KW.$$

2. Torque transmitted by the coupling (M_t)

$$M_t = 9550 \times 10^3 \times \frac{N}{n}$$

$$= 9550 \times 10^3 \times \frac{14.014}{600} = 223060.71\ N\text{-}mm$$

3. diameter of shaft (d)

$$M_t = \frac{\pi d^3}{16} \eta_K \tau_s \quad 19.2 / P19.3$$

Assuming the Keyway factor (η_k) = 0.75,

Torque transmitted (M_t) $= \frac{\pi d^3}{16} \eta \tau_s$

$$223060.71 = \frac{\pi \times d^3}{16} \times 0.75 \times 82.15$$

$$\Rightarrow d = 26.41 \text{mm}.$$

Select $d = 30$mm (T 14.6).

4. Bolt circle diameter (D_1)

$D_1 = 2d + 50$ 19.12b / P19.4

$= (2 \times 30) + 50$

$= 110$ mm.

5. Design of hub

a) Hub diameter (D_2) $= 1.5d + 25$ 19.13b / P19.4

$= 70$mm.

b) length of hub (l) $= 1.25d + 18.75$ 19.14d / P19.4

$= 56.25$mm.

6. Design of flange

a) outer dia. of flange $D = 2.5d + 75$ (19.14b)

$= 150$mm

b) thickness of flange (t) $= 0.5d$

$= 15$mm.

check for flange design:

Torque based on shearing of flange

$$M_t = (\pi D_2 t)\, \tau_f \times \frac{D_2}{2} \quad (19.6)$$

$$223060.71 = (\pi \times 70 \times 15)(\tau_f)_{ind} \times \frac{70}{2}$$

$$\therefore (\tau_f)_{ind} = 1.932 \ N/mm^2.$$

Since the induced sheer stress is less than the allow. sheer stress value of $15 N/mm^2$, the design of flange is safe.

7. Design of bolts

(a) No. of bolts $(i) = 0.02d + 3$ 19.1b /P19.3

$= 3.6$ say 4.

b) diameter of bolt (d_1)

Torque transmitted through bolts $(M_t) = i \cdot \left(\frac{\pi d_1^4}{4}\right)\tau_b \times \frac{D_1}{2}$ (19.4)

ie $223060.71 = 4 \times \frac{\pi \times d_1^2}{4} \times 76 \times \left(\frac{110}{2}\right)$

$\Rightarrow d_1 = 4.12 mm.$

Select $d_1 = 5 mm$ (T 18.7)

ie M5 X0.5 bolt is selected.

$\therefore$ std. core diameter $(d_1) = 4.386565 mm.$

std. nominal diameter $(d) = 5 mm.$

Check for design of bolt

Torque transmitted by all bolts $(M_t) = i\, d_1 t (\sigma_c)_b \frac{D_1}{2}$ (19.5)

$\therefore (\sigma_c)_b$ induced $= \dfrac{2M_t}{i d_1 t D_1} = \dfrac{2 \times 223060.71}{4 \times 4.386 \times 15 \times 110}$

$= 15.41 \, N/mm^2$

where as $(\sigma_c)_b$ allow. $= 2\tau_b = 2 \times 76 = 152 \, N/mm^2$

Since the induced crushing stress is less than the allowable value, the design of bolts is safe.

8. Design of Key

Selecting taper sunk key with 1:100 taper,

from T 17.4, for d = 30 mm,

width of key (b) = 8 mm and

thickness of key (h) = 7 mm.

Now from table 17.5, for b = 8 mm & h = 7 mm,

length of key (l) = 63 mm.

Check for the key:

width of the key $b = \dfrac{2M_t}{\tau_{d2} \cdot l \cdot d}$ (19.50)

$8 = \dfrac{2 \times 223060.71}{\tau_{d2} \times 63 \times 30}$

$\Rightarrow (\tau_{d2})_{ind} = 29.5 \, N/mm^2$

$< 82.15 \, N/mm^2$

thickness of key $h = \dfrac{4M_t}{\sigma_b' \cdot l \cdot d}$ (19.51)

$$7 = \frac{4 \times 223060.71}{\sigma_b' \times 63 \times 30}$$

$$\Rightarrow (\sigma_b')_{ind} = 67.44\ N/mm^2$$
$$< 164.3\ N/mm^2.$$

Since the induced shear & crushing stresses ~~the~~ are less than the allow. values, the design of key is safe.

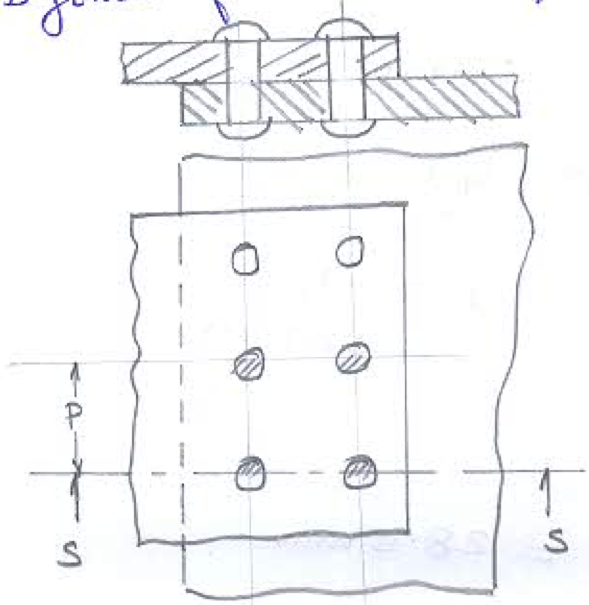
7(a) A double riveted lap joint is to be made between 9mm plates. If the safe working stresses in tension, crushing and shear are 80, 120 and 60 N/mm² respectively, design the riveted joint

Ans:- <u>data</u>

$h = 9mm$, $\sigma_\theta = 80\ N/mm^2$, $\sigma_c = 120\ N/mm^2$

$\tau = 60\ N/mm^2$.

<u>1. Type of joint</u> : Assuming chain riveting, select type b joint from T13.14/P13.11.



$i_1 = 2$
$i_2 = 0.$

2. diameter of rivet (d) & rivet hole (d_h)

Since $h \geq 8$ mm, using Unwin's formula,

$$d = 6\sqrt{h} \text{ to } 6.3\sqrt{h}$$
$$= 6\sqrt{9} \text{ to } 6.3\sqrt{9}$$
$$= 18 \text{ mm to } 18.9 \text{ mm}$$

From T 13.2, select $d = 18$ mm.

$\therefore$ $d_h = 19$ mm.

3. pitch (P)

$$P = \frac{(2i_2 + i_1)\pi d^2 \tau}{4 h \sigma_\theta} + d_h \quad (13.30)$$

$= 66.25$ mm.

Also, for type 'b' joint,

$$P = 2.62h + 40 \quad (T\,13.14)$$
$$= 63.58 \text{ mm}$$

choosing the lower value of the above two,

Select $P = 64$ mm.

4. transverse pitch (P_t)

From T 13.14, $P_t = 2d_h$
$= 38$ mm.

5. margin (m)

$m = 1.5 d_h = 28.5$ mm.

6. Effeciency of joint (η)

a) Tensile strength of solid plate $= p h \sigma_\theta$ (13.20)

$= 46{,}080$ N.

b) Tensile strength of perforated plate along outer gage line $= (p - d_h) h \sigma_\theta$. (13.21)

$= 32{,}400$ N.

c) Resistance to shear in all rivets in one pitch length $= (2i_2 + i_1) \frac{\pi d^2}{4} \tau$ (13.22)

$= 34{,}023$ N.

d) Resistance to crushing of all rivets in one pitch length $= (i_2 h + i_1 h_2) d \sigma_c$. (13.23)

$= 41{,}040$ N.

$\therefore$ Effeciency of joint (η) $= \dfrac{\text{Min. of of } b, c \,\&\, d}{a}$

$= \dfrac{32{,}400}{46{,}080}$

$= 70.31\%$

7(b) Determine the diameter of rivet for the joint shown in fig. Q7(b). The allow. stress in the rivet is 100 N/mm^2.

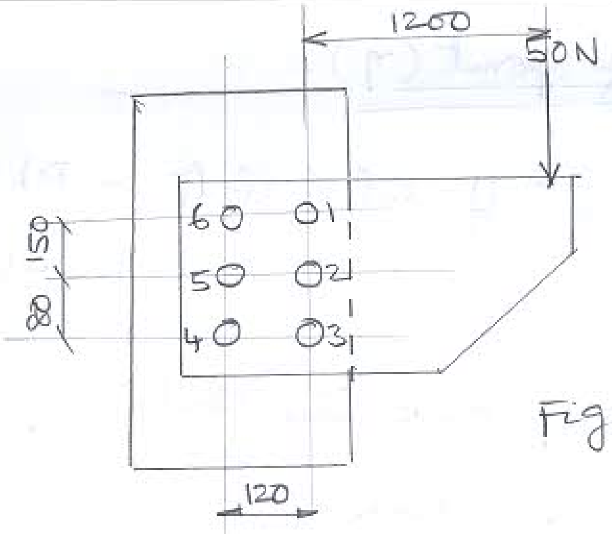


Fig. Q7(b)

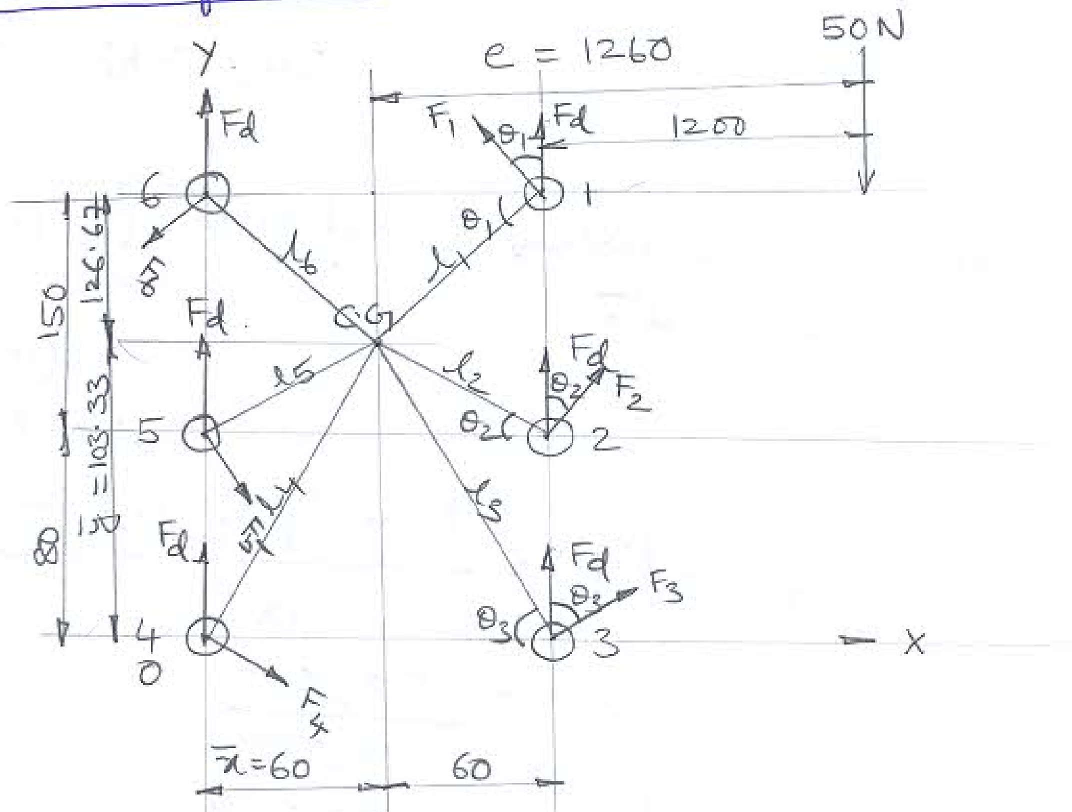
Ans: data

$\tau = 100\ N/mm^2$

to find

$d = ?$

1. C.G. of rivet formation



$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4 + x_5 + x_6}{6}$$

$$= \frac{120 + 120 + 120 + 0 + 0 + 0}{6}$$

$$= 60\,mm.$$

$$\bar{y} = \frac{y_1 + y_2 + y_3 + y_4 + y_5 + y_6}{6}$$

$$= \frac{230 + 80 + 0 + 0 + 80 + 230}{6}$$

$$= 103.33 \text{ mm}.$$

3. direct shear load on each rivet (F_d)

$$F_d = \frac{F}{i} = \frac{50,000}{6} = 8333.33 \text{ N}.$$

4. secondary shear loads (F_1, F_2, F_3 ----) on each rivet

$$l_1 = \sqrt{(126.67)^2 + 60^2} = 140.66 \text{ mm}$$
$$= l_6.$$

$$l_2 = \sqrt{(23.33)^2 + 60^2} = 64.37 \text{ mm}$$
$$= l_5$$

$$l_3 = \sqrt{103.33^2 + 60^2}$$
$$= 119.48 \text{ mm}$$
$$= l_4.$$

$$\cos\theta_1 = \frac{60}{l_1} = \frac{60}{140.16} = 0.428$$

$$\cos\theta_2 = \frac{60}{64.37} = 0.932$$

$$\cos\theta_3 = \frac{60}{119.48} = 0.5.$$

$$\therefore F_1 = \frac{F e l_1}{\Sigma l_i^2} = 115986.6 \text{ N}.$$

$$F_2 = \frac{F_1 . l_2}{l_1} = 53276.38 \text{ N}.$$

$$F_3 = \frac{F_1 . l_3}{l_1} = 98873.3 \text{ N}.$$

5. Resultant loads

The rivets 1, 2, 3 are heavily loaded.

$$\therefore F_{R1} = \sqrt{F_d^2 + F_1^2 + 2F_d F_1 \cos\theta},$$

$$= 119790.26\,N.$$

$$F_{R2} = \sqrt{F_d^2 + F_2^2 + 2F_d F_2 \cos\theta_2}$$

$$= \sqrt{(8333.33)^2 + (53276.38)^2 + (2 \times 8333.33 \times 53276.38 \times 0.932)}$$

$$= 61{,}117.72\,N.$$

$$F_{R3} = \sqrt{F_d^2 + F_3^2 + 2F_d F_3 \cos\theta_3}.$$

$$= \sqrt{(8333.33)^2 + (98873.3)^2 + (2 \times 8333.33 \times 98873.3 \times 0.5)}$$

$$= 1{,}03{,}292.38\,N.$$

$$\therefore (F_R)_{max} = 119790.26\,N.$$

6. dia. of rivet (d)

$$(F_R)_{max} = \frac{\pi d^2}{4} \times \tau.$$

$$119790.26 = \frac{\pi d^2}{4} \times 100.$$

$$\Rightarrow d = 39.05\,mm.$$

Select $d = 42\,mm$ (T 13.2).

8(a) A 16mm thick plate is welded to a vertical support by two fillet welds as shown in fig. Q8(a). Determine the size of weld, if the permissible shear stress for the weld material is 75MPa.

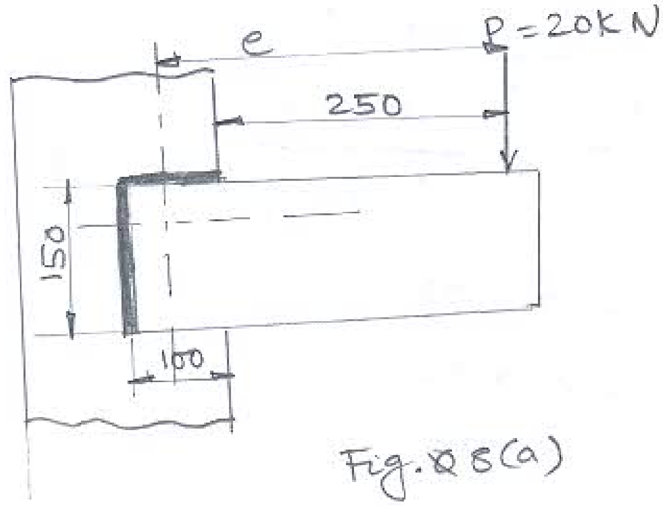


Fig. Q8(a)

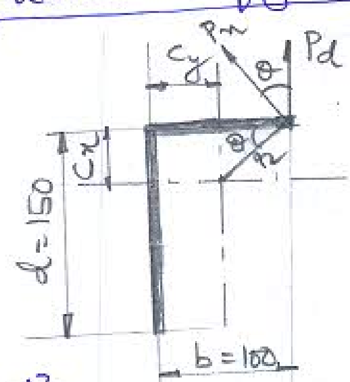
Ans: **data**

$\tau = 75\ N/mm^2$, $P = 20\ KN$

to find

$\omega = ?$

1. C.G of weld configuration



$$c_x = \frac{d^2}{2(b+d)} = 45mm$$

$$c_y = \frac{b^2}{2(b+d)} = 20mm$$

2. direct shear stress (τ_d)

$$\tau_d = \frac{P}{0.707\omega l} \quad \text{where } l = 150 + 100 = 250mm.$$

$$\tau_d = \frac{20 \times 10^3}{0.707 \times \omega \times 250}$$

$$= \left(\frac{113.154}{\omega} \right) N/mm^2$$

3. Secondary shear stress (τ_n)

$$\tau_n = \frac{M_t \times r}{J} = \frac{(P.e) \times r}{J_\omega \times 0.707\omega}$$

here $e = 250 + (100 - c_y)$

$= 250 + 80$

$= 330 \text{ mm}.$

$$r = \sqrt{c_x^2 + 80^2}$$

$$= \sqrt{45^2 + 80^2}$$

$= 91.78 \text{ mm}.$

$$J_\omega = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)}$$ T12.3 / P.12.10.

$$= \frac{(100+150)^4 - 6(100^2)(150^2)}{12(100+150)}$$

$= 852.08 \times 10^3 \text{ mm}^3.$

$$\therefore \tau_n = \frac{20 \times 10^3 \times 330 \times 91.78}{852.08 \times 10^3 \times 0.707\omega}$$

$$= \left(\frac{1005.52}{\omega} \right) N/mm^2.$$

4. Resultant shear stress (τ_{max})

$$\tau_{max} = \sqrt{\tau_d^2 + \tau_n^2 + 2\tau_d \tau_n \cos\theta}.$$

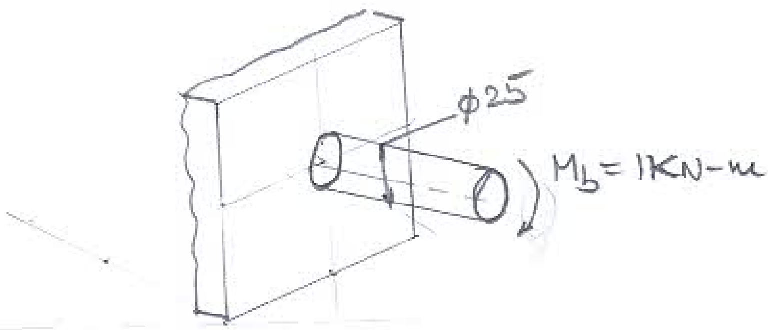
here $\cos\theta = \frac{80}{r} = \frac{80}{91.78} = 0.871$

$\therefore \tau_{max} = \sqrt{\left(\frac{113.154}{w}\right)^2 + \left(\frac{1005.52}{w}\right)^2 + 2\left(\frac{113.154}{w}\right)\left(\frac{1005.52}{w}\right) \times 0.871}$

But $\tau_{max} = 75\ N/mm^2$

$\therefore w =$ ~~23 mm~~ 14.73 mm say 15 mm.

8(b) Determine the allowable stress in the joint shown in fig. 8(b), if size of the weld is 10mm.



data

$M_b = 1\ KN\text{-}m$
$= 1 \times 10^6\ N\text{-}mm$.

$w = 10\ mm$.

to find

$\sigma = ?$

From T 12-1 / P 12-8,
for the configuration shown above,

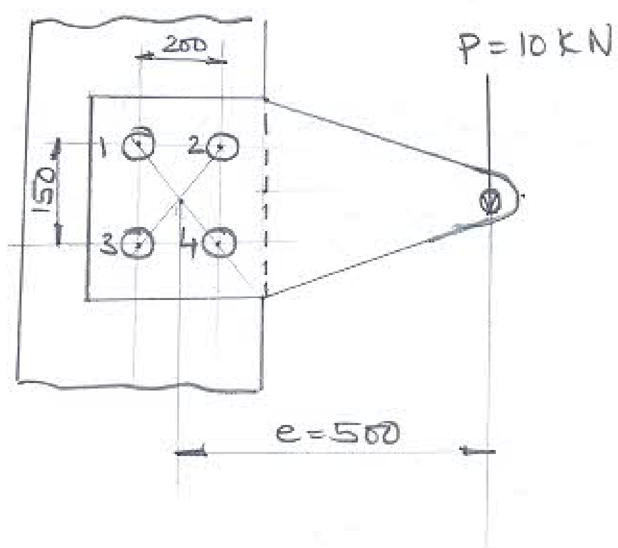
$$\sigma = \frac{5.66 M_b}{h D^2 \pi}$$

here $h = w = 10\ mm$.
$D = 25\ mm$.

$$\therefore \sigma = \frac{5.66 \times 1 \times 10^6}{10 \times 25^2 \times \pi}$$

$= 288.26\ N/mm^2$.

9(a) The structure in fig. 9(a) is subjected to an eccentric load P = 10 KN with an eccentricity of 500 mm. All bolts are identical and made of carbon steel having yield strength in tension as 400 MPa and F.S = 2.5. Det. the size of bolt. (32)



Ans: data

$P = 10\,KN$.

$e = 500\,mm$.

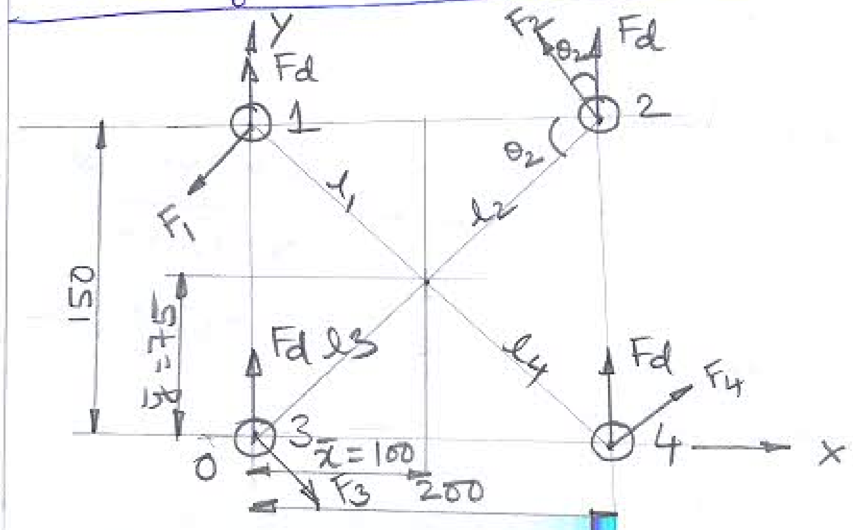
$\sigma_y = 400\,N/mm^2$

$FS = 2.5$.

to find

$d = ?$

1. C.G. of bolt configuration



$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4}{4}$$

$$= \cancel{150}\ \frac{0 + 200 + 200 + 0}{4}$$

$$= 100 \text{ mm}$$

$$\bar{y} = \frac{y_1 + y_2 + y_3 + y_4}{4}$$

$$= \frac{150 + 150 + 0 + 0}{4}$$

$$= 75 \text{ mm}$$

2. Direct shear load (F_d) on each rivet

$$F_d = \frac{F}{i} = \frac{10 \times 10^3}{4} = 2.5 \text{ kN}$$

3. Sec. shear load ($F_1, F_2 - - -$) on each rivet

$$l_1 = l_2 = l_3 = l_4 = \sqrt{100^2 + 75^2}$$

$$= 125 \text{ mm}$$

$$F_1 = F_2 = F_3 = F_4 = \frac{F e l_1}{\Sigma l_i^2} = \frac{10 \times 10^3 \times 500 \times 125}{4 \times 125^2}$$

$$= 10{,}000 \text{ N}$$

4. Resultant load (F_R)

The rivets 2 and 3 will be heavily loaded as

θ_2 and θ_3 are minimum.

Since $\cancel{F_2 = F_3}$ $F_2 = F_3$ & $\theta_2 = \theta_3$

$$F_{R2} = F_{R3} = \sqrt{F_d^2 + F_2^2 + 2 F_d F_2 \cos\theta_2}$$

$$\cos\theta_2 = \frac{100}{l_2} = \frac{100}{125} = 0.8.$$

$$\therefore (F_R)_{max} = \sqrt{(2500)^2 + (10{,}000)^2 + (2 \times 2500 \times 10{,}000 \times 0.8)}$$
$$= 12.09 \times 10^3 \text{ N}.$$

5. Size of the bolt (d)

$$\text{Allow. normal Stress } (\sigma) = \frac{\sigma_y}{FS} = \frac{400}{2.5} = 160 \text{ N/mm}^2$$

$$\therefore \text{Allow Shear stress } \tau = 0.5\,\sigma$$
$$= 80 \text{ N/mm}^2$$

$$\text{Now } (F_R)_{max} = \frac{\pi d_1^2}{4} \times \tau$$

where d_1 = core dia. of bolt

$$12.09 \times 10^3 = \frac{\pi d_1^2}{4} \times 80$$
$$\Rightarrow d_1 = 13.87 \text{ mm}.$$

For coarse threads, major dia $(d) = \frac{d_1}{0.84}$
$$= 16.52 \text{ mm}$$

Selecting std. diameter $d = 18$ mm.

$\therefore$ Select M18 bolt.

9(b) A bracket is fixed to wall by 4 bolts and loaded as shown in Fig. 9(b). Calculate the size of bolts, if the load is 10 KN and allowable shear stress in the bolt material is 40 MPa.

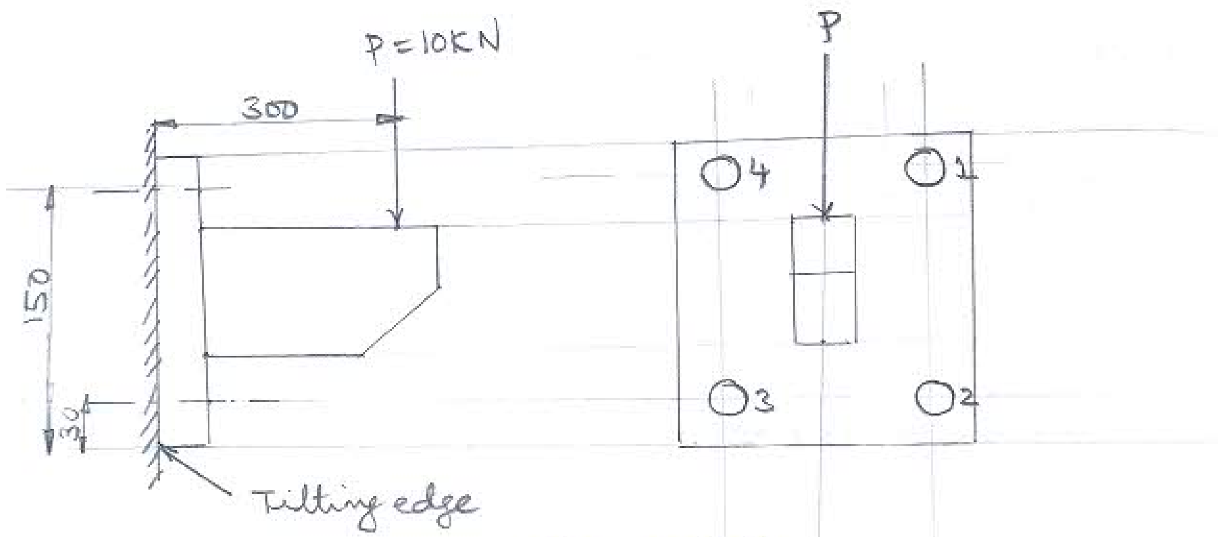


Fig. Q9(b)

Ans: data

$F = P = 10\,KN$
$= 10 \times 10^3\,N$

$e = 300\,mm$

$\tau = 40\,N/mm^2$

$l_1 = l_4 = 150\,mm$

$l_2 = l_3 = 30\,mm$

$i = 4$

to find

$d = ?$

1. Direct shear stress (τ_d)

Direct shear load $(F_d) = \dfrac{F}{i} = \dfrac{10 \times 10^3}{4} = 2.5 \times 10^3\,N.$

$\therefore$ direct shear stress $\tau_d = \dfrac{F_d}{\left(\frac{\pi d_1^2}{4}\right)} = \dfrac{2.5 \times 10^3}{\left(\frac{\pi d_1^2}{4}\right)}$

$= \left(\dfrac{3183}{d_1^2}\right) N/mm^2$

2. Normal stress (σ) ~~Secondary shear stress (τ_n)~~

As the bolts 1 & 4 are farthest from the tilting edge, they are subjected to max. normal stress due to the tilting moment.

$$F_1 = F_4 = \frac{F e l_1}{\Sigma l_i^2} = \frac{10\times10^3 \times 300 \times 150}{2(150^2) + 2(30^2)}$$

$$= 9615.38 \text{ N}.$$

$\therefore$ Normal stress $\sigma = \dfrac{F_1}{\left(\frac{\pi d_1^2}{4}\right)} = \dfrac{9615.38\times4}{\pi d_1^2}$

$$= \left(\frac{12.24\times10^3}{d_1^2}\right) \text{N/mm}^2$$

3. <u>Size of bolt (d)</u>

Now $\tau_{max} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau_d^2}$

$$40 = \sqrt{\left(\frac{12.24\times10^3}{2d_1^2}\right)^2 + \left(\frac{3183}{d_1^2}\right)^2}$$

$\Rightarrow d_1 = 13.13$ mm.

$\therefore$ core diameter of bolt $(d_1) = 13.13$ mm.

$\therefore$ Major dia. of bolt for coarse threads $= \dfrac{13.13}{0.84}$

$= 15.63$ mm.

Selecting std. dia, $d = 16$ mm.

$\therefore$ Select M18 bolt.

10 Design a screw jack with a lift of 300 mm to lift a load of 50 KN. Select C40 steel ($\sigma_y = 328.6$ MPa) for the screw and soft phosphor bronze ($\sigma_{ut} = 345$ MPa and $\sigma_y = 138$ MPa) for nut.

Ans: data

$W = 50$ KN
$= 50 \times 10^3$ N.

lift $= 300$ mm.

$\sigma_{ys} = 328.6$ N/mm^2

$\sigma_{un} = 345$ N/mm^2

$\sigma_{yn} = 138$ N/mm^2

to design
1) screw 2) Nut 3) lever (Tommy bar).

Allowable stresses

i) Allow. tensile/compr. stress in the screw $\Big\}\ \sigma_s = \dfrac{\sigma_{ys}}{F.S.}$

Assume $F.S = 3.$

$\therefore \sigma_s = \dfrac{328.6}{3} = 109.53$ N/mm^2

ii) Allow. shear stress in the screw $\Big\}\ \tau_s = \dfrac{\sigma_s}{2} = \dfrac{109.53}{2} = 54.76$ N/mm^2

iii) Allow. tensile/compr. stress in the nut $\sigma_n = \dfrac{\sigma_{un}}{FS}$

Assume a $F.S = 6$ based on σ_u.

Allws. compr. stress $\therefore (\sigma_c)_n = \frac{345}{6}$

$= 57.5\ N/mm^2$.

$$(\sigma_t)_n = \frac{\sigma_{yn}}{F.S}$$

Assume a F.S = 3 based on yield strength

Allws. tensile stress $\therefore (\sigma_t)_n = \frac{138}{3} = 46\ N/mm^2$.

$\therefore$ allws. shear stress $(\tau)_n = \frac{46}{2} = 23\ N/mm^2$.

1. design of screw

The screw is subjected to joint action of compression, twisting moment and bending. Initially the core diameter of screw is determined on the basis of compression only. Assuming 25% overload,

$$W_{des} = 1.25 \times W$$
$$= 1.25 \times 50$$
$$= 62.5\ KN.$$

Now $$(\sigma_c)_s = \frac{W_{des}}{\left(\frac{\pi d_1^2}{4}\right)}$$

$$109.53 = \frac{62.5 \times 10^3 \times 4}{\pi d_1^2}$$

$$\Rightarrow d_1 = 26.96\ mm.$$

Selecting single start square thread,

From T 18·8 / P 18·20,

For normal series, std value for

core diameter $(d_1) = 30\,mm$.

Major diameter $(d) = 36\,mm$.

pitch $(P) = 6\,mm$.

$\therefore$ Pitch dia. of screw $(d_2) = \dfrac{d + d_1}{2} = \dfrac{36 + 30}{2}$

$= 33\,mm$.

Check for design of screw

The screw friction torque

$$M_{ts} = W\left[\frac{d_2}{2}\left(\frac{\tan\alpha + \mu}{1 - \mu\tan\alpha}\right)\right]$$

$$\tan\alpha = \frac{l}{\pi d_2}$$

where $l = i \times P$

$= 1 \times 6$

$= 6\,mm$.

$$\therefore \tan\alpha = \frac{6}{(\pi \times 33)} = 0.057.$$

For heavy machine oil, $\mu = 0.14$ (T18·4 / P18·8)

$$M_{ts} = 50 \times 10^3 \left[\frac{33}{2}\left(\frac{0.057 + 0.14}{1 - (0.14 \times 0.057)}\right)\right]$$

$= 163.83 \times 10^3\ N\text{-}mm$.

Now $\tau = \dfrac{M_{ts}}{\left(\dfrac{\pi d_1^3}{16}\right)}$

$\tau \; \cancel{54.76} = \dfrac{163.83 \times 10^3 \times 16}{\pi \times 30^3}$

$\cancel{\Rightarrow d_1 =}$ $\tau = 30.90\ N/mm^2$.

Also, direct compr. stress $(\sigma_c) = \dfrac{W}{\left(\dfrac{\pi d_1^2}{4}\right)}$

$= \dfrac{50 \times 10^3 \times 4}{\pi \times 30^2}$

$= 70.73\ N/mm^2$

$\therefore$ Max. principal stress $(\sigma_{max}) = \dfrac{\sigma_c}{2} + \sqrt{\left(\dfrac{\sigma_c}{2}\right)^2 + \tau^2}$

$= 82.32\ N/mm^2$

$< 109.53\ N/mm^2$

(allow. stress)

Max. Shear Stress $(\tau_{max}) = \sqrt{\left(\dfrac{\sigma_c}{2}\right)^2 + \tau^2}$

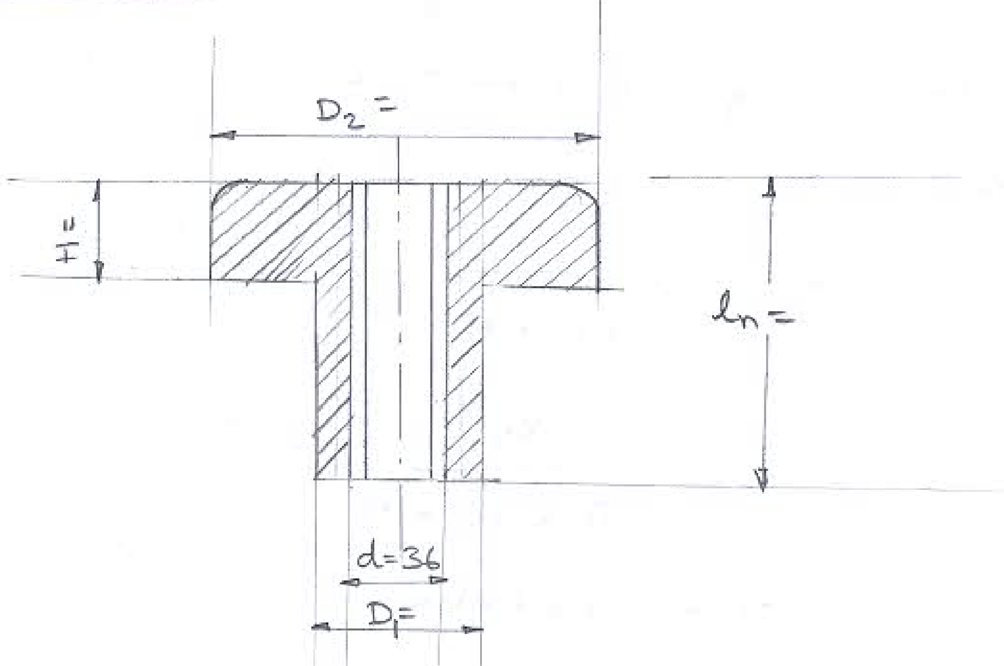
$= \sqrt{\left(\dfrac{70.73}{2}\right)^2 + (30.90)^2}$

$= 46.96\ N/mm^2$

$< 54.76\ N/mm^2$

$\therefore$ Design of screw is safe.

Design of nut



No of threads in the nut $i' = \dfrac{4W}{\sigma_b' \pi (d^2 - d_1^2)}$.

From T 18.6 / P 18.15, for screw Jack with

Steel screw & Bronze nut,

σ_b' varies from $10.8\ N/mm^2$ to $17.2\ N/mm^2$.

Select $\sigma_b' = 14\ N/mm^2$ in our case.

$$\therefore i' = \frac{4 \times 50 \times 10^3}{14 \times \pi (36^2 - 30^2)}$$

$$= 11.48$$

$$\approx 12.$$

The outer dia. of the body of nut is taken as twice the nominal dia. of thread.

$$\therefore D_1 = 2 \times 36$$

$$= 72\ mm.$$

The thickness (H) of nut can be determined by considering the transverse shear at the head of nut.

$$\tau_n = \frac{W}{\pi D_1 \times H}$$

$$23 = \frac{50 \times 10^3}{\pi \times 72 \times H}$$

$$\Rightarrow H = 9.61 \text{ mm}$$

$$\simeq 10 \text{ mm}.$$

The outer dia. of the head of the nut is determined by considering the compression of head.

$$(\sigma_c)_n = \frac{W}{\frac{\pi}{4}(D_2^2 - D_1^2)}$$

$$46 = \frac{50 \times 10^3 \times 4}{\pi (D_2^2 - 72^2)}$$

$$\Rightarrow D_2 = 81.04 \text{ mm}.$$

Check for stresses in the threads of screw & nut :

Shear stress in the threads of screw $\Big\}$ $\tau_s = \dfrac{W}{(\pi d_1 t) \times i}$

here $t = \frac{P}{2} = \frac{6}{2} = 3$ mm.

& $d_1 = 30$ mm.

$$\therefore \tau_{s} = \frac{50 \times 10^3}{(\pi \times 30 \times 3) \times 12}$$

$$= 14.73 \, N/mm^2$$

$$< 54.76 \, N/mm^2$$

Sheer stress in the threads of nut

$$\tau_{tn} = \frac{W}{(\pi d t) \times i'}$$

$$= \frac{50 \times 10^3}{(\pi \times 36 \times 3 \times 12)}$$

$$= 12.28 \, N/mm^2$$

$$< 23 \, N/mm^2$$

$\therefore$ The design of threads both for screw & nut are safe.