

## Machine Tool Elements (lever & wire rope)

1. A hand lever of a brake is 0.8 m long from the center of gravity of the spindle to the point of application of the pull of 300 N. The effective overhang from the nearest bearing is 100 mm. If the permissible stress in tensile shear and crushing is not to exceed 66 N/mm<sup>2</sup>. Design the spindle key and lever. Assume the arm of the lever rectangular having width twice of the thickness.

sol Given data

force applied at the handle  $F = 300 \text{ N}$

effective length of the lever  $L = 0.8 \text{ m} = 800 \text{ mm}$

effective overhang distance  $l = 100 \text{ mm}$

allowable tensile stress  
shear stress  
crushing stress } = 66 \text{ N/mm}^2

→ Dia of shaft inside the lever

$$\begin{aligned} d &= \left[ \frac{16T}{\pi \tau} \right]^{1/3} \\ &= \left( \frac{16 \times F \times L}{\pi \times 66} \right)^{1/3} \\ &= \left( \frac{16 \times (300 \times 800)}{\pi \times 66} \right)^{1/3} = 27 \text{ mm} \end{aligned}$$

→ dia of shaft inside the bearing

$$\begin{aligned} d_1 &= \left( \frac{16 T_e}{\pi \tau} \right)^{1/3} \\ &= \left( \frac{16 \times \sqrt{M^2 + T^2}}{\pi \times \tau} \right)^{1/3} \\ &= \left( \frac{16 \times \sqrt{(300 \times 100)^2 + (300 \times 800)^2}}{\pi \times 66} \right)^{1/3} \\ &= 27 \text{ mm} \end{aligned}$$

→ proportional dimensions of key

$$l_k = h$$

$$w_k = d/4 \\ = 27/4 = 7 \text{ mm}$$

$$t_k = d/6 \\ = 27/6 = 5 \text{ mm}$$

$$\tau = \frac{2T}{l_k \cdot w_k \cdot d}$$

$$l_k = \frac{2 \times (300 \times 800)}{66 \times 7 \times 27} = 38.48 \text{ mm}$$

$$\rightarrow t_1 = 0.3d \\ = 0.3 \times 27 = 8.1 \text{ mm}$$

$$\rightarrow d_s = 1.6 \times d \\ = 1.6 \times 27 = 43.2 \text{ mm}$$

→ Tensile stress

$$\sigma_t = \frac{2FL}{ht_1(d+t_1)} \\ = \frac{2 \times 300 \times 800}{39 \times 8.1 (27 + 8.1)} = 43.28 \text{ N/mm}^2$$

$43.28 < 66 \text{ N/mm}^2$  design is safe

→ Bending stress

$$\sigma_b = \frac{6FL}{tB^2} \quad (\because B = 4t)$$

$$\sigma_b = \frac{6 \times FL}{t \times (4t)^2}$$

$$t^3 = \frac{GFL}{\pi b \times 16}$$

$$t = \sqrt[3]{\frac{6 \times 300 \times 300}{66 \times 16}}$$

$$t = 11.08 \text{ mm}$$

$$B = 4t$$

$$B = 4(11.08) = 44.32 \text{ mm}$$

→ width of the lever

$$b = B/2$$

$$= 44.32/2$$

$$= 22.16 \text{ mm}$$

The length of the handle grip may be taken as 150 mm with outer end of 27 mm diameter and gradually tapered to 25 mm dia at the inner end.

2. Design a foot brake lever from the following data, length of lever from the center of gravity of the spindle to be point of application of load 1m max load on the foot brake 800 N. overhang from the nearest bearing 100 mm. permissible tensile & shear stress 70 N/mm<sup>2</sup>

3d Given data :

Effective length  $L = 1\text{m} = 1000 \text{ mm}$

load on foot brake  $F = 800 \text{ N}$

overhang bearing  $l = 100 \text{ mm}$

permissible tensile & shear = 70 N/mm<sup>2</sup>

→ dia of the shaft

$$d = \left[ \frac{16T}{\pi \tau} \right]^{1/3}$$

$$d = \left[ \frac{16 \times FL}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times (800 \times 1000)}{\pi \times 70} \right]^{1/3} = 38.75 \text{ mm}$$

→ dia of shaft inside the bearing

$$d_1 = \left[ \frac{16T_e}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{M^2 + T^2}}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{80000^2 + 800000^2}}{\pi \times 70} \right]^{1/3}$$

$$= 38.81 \approx 40 \text{ mm}$$

→ proportional dimensions of key

$$l_k = h$$

$$w_k = 1.25d$$

$$w_k = d/4$$

$$= 40/4 = 10 \text{ mm}$$

$$t_k = d/6$$

$$= 40/6 = 6.6 \approx 7 \text{ mm}$$

$$\tau = \frac{2T}{l_k \cdot w_k \cdot d}$$

$$l_k = \frac{2T}{\tau \cdot w_k \cdot d}$$

$$I_k = \frac{3 \times 800 \times 1000}{10 \times 70 \times 39}$$

$$= 59 \text{ mm}$$

$$\rightarrow \sigma_b = \frac{6 FL}{t B^2} \quad (\because B = 4t)$$

$$\sigma_b = \frac{6 FL}{t (4t)^2}$$

$$t^3 = \frac{6 FL}{16 \times \sigma_b}$$

$$t = \sqrt[3]{\frac{6 \times 800 \times 1000}{16 \times 70}}$$

$$t = 16.24 \text{ mm}$$

$$\rightarrow B = 4t$$

$$= 4 \times 16.24 = 65 \text{ mm}$$

$$\rightarrow b = B/2$$

$$= 65/2 = 32.5 \text{ mm}$$

$$\rightarrow t_1 = 0.3d$$

$$= 0.3 \times 40 = 12 \text{ mm}$$

$$\rightarrow \sigma_t = \frac{2 FL}{h t_1 (d + t_1)}$$

$$= \frac{2 \times 800 \times 1000}{59 \times 12 (40 + 12)}$$

$$= 43.45 \text{ N/mm}^2$$

The length of the foot plate may be taken as 50 mm with outer end of 39 mm dia and the thickness of foot lever is 17 mm and the width of the foot lever is handle 33 mm

3. Design a cranked lever for the following dimensions length of the handle 300 mm, length of the lever arm is 400 mm. overhang of the journal 100 mm. The lever is operated by a single person exerting a max force of 400 N at a distance of  $\frac{1}{3}$  length of the handle from its force end. The permissible stress may be taken as 50 N/mm<sup>2</sup> in bending for lever & 40 N/mm<sup>2</sup> in shear for shaft.

sol Given data

length of the handle  $l = 300 \text{ mm}$

length of the over arm  $L = 400 \text{ mm}$

overhang of journal  $x = 100 \text{ mm}$

max force  $F = 400 \text{ N}$

$\sigma_b = 50 \text{ N/mm}^2$

$\tau_s = 40 \text{ N/mm}^2$

→ dia of the shaft handle

$$d = \left[ \frac{64 F l}{3 \pi \sigma_b} \right]^{1/3}$$

$$= \left[ \frac{64 \times 400 \times 300}{3 \times \pi \times 50} \right]^{1/3}$$

$$= 25.35 \text{ mm}$$

→ thickness of web

$$\sigma_b = \frac{7.5 F L}{t B^2} \quad (\because B = 2t)$$

$$\sigma_b = \frac{7.5 F L}{t (2t)^2}$$

$$t^3 = \frac{7.5 FL}{\sigma_b \times 4}$$

$$t = \sqrt[3]{\frac{7.5 \times 400 \times 400}{50 \times 4}}$$

$$t = 18.17 \text{ mm}$$

→ Dia of journal

$$D = \left[ \frac{16 T_e}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times 20,000}{\pi \times 40} \right]^{1/3}$$

$$= 29.42 \text{ mm}$$

4. Design a cranked lever for the following dimensions length of the handle 320 mm, length of the lever arm 450 mm, overhang of the journal 120 mm, the lever operated by a single person exerting a max force of 400 N at a distance of  $\frac{1}{3}$  length of the handle for the free end.  $50 \text{ N/mm}^2$  for lever &  $40 \text{ N/mm}^2$  for shaft

sol Given data :-

$$l = 320 \text{ mm}$$

$$L = 450 \text{ mm}$$

$$x = 120 \text{ mm}$$

$$F = 400 \text{ N}$$

$$\sigma_b = 50 \text{ N/mm}^2$$

$$\tau = 40 \text{ N/mm}^2$$

→ dia of the handle

$$d = \left[ \frac{64 F l}{\pi \times 3 \times \sigma_b} \right]^{1/3}$$

$$= \left[ \frac{64 \times 400 \times 320}{\pi \times 3 \times 50} \right]^{1/3} = 26 \text{ mm}$$

→ thickness of web

$$\sigma_b = \frac{7.5 FL}{t B^2} \quad (\because B = 2t)$$

$$\sigma_b = \frac{7.5 FL}{t \times (2t)^2}$$

$$t^3 = \frac{7.5 FL}{4 \times \sigma_b}$$

$$t = \sqrt[3]{\frac{7.5 \times 400 \times 450}{4 \times 50}}$$

$$t = 18.89 \text{ mm}$$

→ dia of the journal

$$D = \left[ \frac{16 T_e}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{M^2 + T^2}}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times 224003.96}{\pi \times 40} \right]^{1/3}$$

$$= 30.55 \text{ mm}$$

5. select a wire rope for a vertical mine hoist to lift a load of 20 kN from a depth of 500 m. A rope speed of 3 m/s is to be attain in 10 sec

sol

Given data :

$$\text{load } P_r = 20 \times 10^3 \text{ N}$$

$$\text{depth } h = 500 \text{ m}$$

$$\text{speed } v = 3 \text{ m/s}$$

$$\text{time } t = 10 \text{ sec}$$

based on applications

5

6 x 19 is selected

$$dw = 0.07 d$$

$$A = 0.4 d^2$$

$$n = 10$$

$$k_d = 1.5$$

→ design load

$$\begin{aligned} P_d &= P_r \times n \times k_d \\ &= 30 \times 10^3 \times 10 \times 1.5 \\ &= 30 \times 10^4 \text{ N.} \end{aligned}$$

→ Net cross area of rope

$$\begin{aligned} A &= \frac{P_d}{\sigma_u} & (\because \sigma_u = 1600 - 1900) \\ &= \frac{30 \times 10^4}{1800} \\ &= 166.667 \end{aligned}$$

→ dia of the rope

$$d = 1.5 dw \sqrt{i} \quad \text{①}$$

$$A = \frac{\pi}{4} d^2$$

$$d = \sqrt{A/0.4}$$

$$d = \sqrt{166.667/0.4}$$

$$d = 20.41$$

$$d = 22$$

$$w = 18.4$$

$$P = 284$$

} from table 26.6

## Effective load acting on the rope

→ during normal working

$$F = F_t + F_b$$

$$F_t = P_r + (W \times L)$$

$$= 20 \times 10^3 + (18.4 \times 500)$$

$$= 29.200 \text{ KN}$$

$$F_b = A \cdot \frac{d\omega}{D_{\min}} \cdot e'$$

$$= 0.4 \times (22)^2 \times \frac{0.07(22)}{100(22)} \times 0.8 \times 10^5$$

$$= 10.8416 \text{ KN}$$

$$F = 29.200 + 10.8416$$

$$= 40.104 \text{ KN}$$

$$F = P/n$$

$$n = P/F$$

$$= 284 / 40.104 = 7.09$$

$$F \leq P/n$$

$$40.104 \leq P/n \text{ design is safe}$$

→ during acceleration

$$F = F_t + F_b + F_a$$

$$F_a = F_t \cdot a/g \quad (\because v/t)$$

$$F_a = 29.200 \times \left( \frac{3/10}{9.81} \right)$$

$$= 0.89 \text{ KN}$$

$$F = 29.200 + 10.8416 + 0.89$$

$$= 40.934 \text{ KN}$$

$$F = P/n$$

$$n = P/F$$

$$= 284/40.934$$

$$= 6.93$$

$$F \leq P/n$$

$40.934 \leq P/n$  design is safe

→ During starting

$$F = F_{st} + F_b$$

$$F_{st} = 2F_t$$

$$= 2 \times 29.200$$

$$= 58.4 \text{ kN}$$

$$F = 58.4 + 10.8416$$

$$= 69.2416 \text{ kN}$$

$$F = P/n$$

$$n = P/F$$

$$= 284/69.2416$$

$$= 4.1015$$

$$F \leq P/n$$

$69.2416 \leq P/n$  design is safe

6. Select a suitable wire rope by 6x37 group to lift a max load of 10 kN through a height of 60m. The weight of bucket is 2 kN. max lifting speed is 2 m/sec. which is attend in 3 sec the f.o.s is 6

sd Given data

$$\text{total weight} = 10 + 2 = 12 \text{ kN}$$

$$V = 2 \text{ m/s}$$

$$t = 3 \text{ sec}$$

$$h = 60 \text{ m}$$

6x37 group

→ from data book table no 26.1

$$\text{dia wire } d_w = 0.041 d$$

$$\text{Area } A = 0.4 d^2$$

→ from table no. 26.4

$$n = 6$$

$$K_d = 1.6$$

$$\text{Dim}/d = 22-27$$

→ Design load

$$P_d = P \times n \times K_d$$

$$= 12 \times 10^3 \times 6 \times 1.6$$

$$= 115.2 \text{ kN}$$

→ Net cross section

$$A = \frac{P_d}{\sigma_{cu}}$$

$$= \frac{115.2 \times 10^3}{1800} = 64$$

→ dia of rope

$$d = \sqrt{A/0.4}$$

$$= \sqrt{64/0.4} = 12.6 \text{ mm} \approx 14 \text{ mm}$$

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

$$W = 7.4$$

$$P = 113$$

} from table no 26.7

## Effective load acting on the rope :

→ during normal working

$$F = F_t + F_b$$

$$F_t = P + (w \times l)$$

$$= 12 \times 10^3 + (7.4 \times 60)$$

$$= 12.4 \times 10^3 \text{ N}$$

$$= 12.4 \text{ kN}$$

$$F_b = A \cdot \frac{dw}{D_{min}} \cdot E'$$

$$= 64 \times \frac{0.041 (14)}{14 (25)} \times (0.8 \times 10^5)$$

$$= 8.396 \text{ kN}$$

$$F = 12.4 + 8.396$$

$$= 20.7 \text{ kN}$$

$$F = P/n$$

$$n = P/F$$

$$= 113/20.7 = 5.45$$

$$F \leq P/n$$

$$20.7 \leq P/n \text{ design is safe}$$

→ During acceleration of load

$$F = F_t + F_b + F_a$$

$$F_a = F_t (a/g)$$

$$(\because a = v/t)$$

$$= 12.4 \left( \frac{2/3}{9.81} \right)$$

$$= 0.8426 \text{ kN}$$

$$F = 12.4 + 8.396 + 0.8426$$

$$= 21.63 \text{ kN}$$

$$F \leq P/n$$

$$n = P/F$$

$$= 113 / 21.63 = 5.22$$

$$F \leq P/n$$

$$21.63 \leq P/n \text{ design is safe}$$

→ During starting

$$F = F_{st} + F_b$$

$$F_{st} = 2 F_t$$

$$= 2 \times 12.4 = 24.8 \text{ kN}$$

$$F = 24.8 + 8.396$$

$$= 33.196$$

$$F \leq P/n$$

$$n = P/F$$

$$= 113 / 33.196$$

$$= 3.40$$

$$F \leq P/n$$

$$33.196 \leq P/n \text{ design is safe}$$

A foot lever is 1 m from the center of shaft to be point of application of 800 N load. Find the dia of shaft. Dimensions of key. Dimensions of rectangular arm of the foot lever at 60 mm from the center of shaft. Assume width of the arm is 3 times the thickness the allowable tensile stress may be taken as 73 mpa & the allowable shear stress as 70 mpa

Given data

Effective length  $L = 1 \text{ m} = 1000 \text{ mm}$

load on foot brake  $F = 800 \text{ N}$

$l = 60 \text{ mm}$

$B = 4t$

$\sigma_t = 73 \text{ mpa}$

$\tau = 70 \text{ mpa}$

$$\rightarrow \text{dia of shaft } d = \left[ \frac{16T}{\pi \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times (800 \times 1000)}{\pi \times 70} \right]^{1/3} = 38.75 \text{ mm}$$

$\rightarrow$  dia of shaft inside the bearing

$$d_1 = \left[ \frac{16T_e}{\pi \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{M^2 + T^2}}{\pi \times \tau} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{(800 \times 60)^2 + (800 \times 1000)^2}}{\pi \times 70} \right]^{1/3}$$

$$= \left[ \frac{16 \times \sqrt{(48000)^2 + (800000)^2}}{\pi \times 70} \right]^{1/3}$$

$$= 38.77 \approx 40 \text{ mm}$$

→ Proportional dimension of key

$$l_k = h$$

$$w_k = d/4$$
$$= 40/4 = 10 \text{ mm}$$

$$t_k = d/6$$
$$= 40/6 = 6.67 \approx 7 \text{ mm}$$

→  $T = \frac{2T}{l_k \cdot w_k \cdot d}$

$$l_k = \frac{2 \times FL}{T \times w_k \times d}$$

$$l_k = \frac{2 \times (800 \times 1000)}{70 \times 10 \times 40} = 57.14 \text{ mm}$$

→  $\sigma_b = \frac{6FL}{tB^2} \quad (\because B = 3t)$

$$\sigma_b = \frac{6FL}{t(3t)^2}$$

$$t^3 = \frac{6 \times (800 \times 1000)}{73 \times 9}$$

$$t = 19.40 \text{ mm}$$

→  $B = 4t$

$$= 4 \times 19.40 = 58.21 \text{ mm}$$

→  $b = B/2$

$$= 58.21/2 = 29.106 \text{ mm}$$

→  $t_1 = 0.3d$

$$= 0.3 \times 40 = 12 \text{ mm}$$

$$q_t = \frac{2FL}{hl(d+h)}$$

$$= \frac{2 \times (200 \times 1000)}{57.14 \times 12 (40+12)}$$

$$= 44.38 \text{ N/mm}^2$$

The length of the foot plate may be taken as 150 mm with the dia 40 mm and the thickness of the foot lever is 19.40 mm and the width of the foot lever is handle 29.106 mm

### \* Safety valve - lever

Q. A lever loaded safety is 70 mm in dia and is to be design for a boiler to blow off at a pressure of 1 mpa. design a suitable mild steel lever of rectangular cross-section taking the allowable stress at 70 mpa in tension 50 mpa in shear and 25 mpa in bearing pressure. The pin is made of same material as that of the lever. The distance from the fulcrum to weight the lever is 880 mm and the distance b/w the fulcrum pin & pin connected to valve spindle link to the lever is 30 mm

### sol. Given data

dia of safety valve  $\phi = 70 \text{ mm}$

allowable tensile ( $\sigma_t$ ) = 70 N/mm<sup>2</sup>

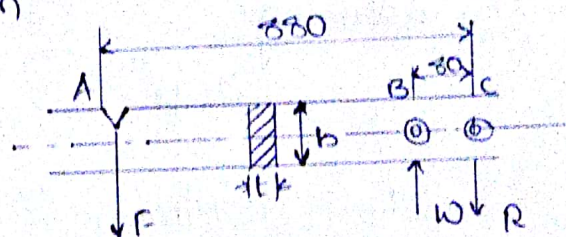
shear ( $\tau$ ) = 50 N/mm<sup>2</sup>

bearing ( $P_b$ ) = 25 N/mm<sup>2</sup>

blow off pressure  $P = 1 \text{ mpa} = 1 \text{ N/mm}^2$

The load applied on the lever at point B

$$W = \frac{\pi}{4} d^2 \cdot P$$



$$W = \frac{\pi}{4} (70)^2 \times 1$$

$$= 3.84 \times 10^3 \text{ N.}$$

for finding dead weight at point A. Take moments at point C

$$F \times 880 + R \times 0 = W \times 80$$

$$F \times 880 = W \times 80$$

$$F = \frac{3.84 \times 10^3 \times 80}{880}$$

$$F = 350 \text{ N}$$

$$R + F = W$$

$$R = W - F$$

$$R = 3.84 \times 10^3 - 350$$

$$R = 3490 \text{ N} \quad (\text{acting downward})$$

dimensions of pin at load point B & fulcrum point C:

$d_b$  = dia of pin at point B

$l_b$  = length of pin at point B

by assuming

$$l_b = 1.25 d_b.$$

$$P_b = 25 \text{ N/mm}^2$$

$$P_b = \frac{W}{l_b \cdot d_b}$$

$$P_b = \frac{W}{d_b \times 1.25 d_b}$$

$$d_b^2 = \frac{3.84 \times 10^3}{25 \times 1.25}$$

$$d_b = 11.08 \text{ mm}$$

$$l_b = 1.25 d_b$$

$$= 1.25 \times 11.08 = 13.85 \approx 14 \text{ mm}$$

Then by following the above procedure the parameters  $l_c$  &  $d_c$  can be determined but since the load applied at point B & C are nearly equal we can take

$$d_c = 11.08 \text{ mm}$$

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

checking the pin of shear strength :-

$$\tau = \frac{W}{2 \times \frac{\pi}{4} d_b^2}$$

$$= \frac{3.84 \times 10^3}{2 \times \frac{\pi}{4} (11.08)^2}$$

$$= 20.20 \text{ N/mm}^2 < 50 \text{ N/mm}^2 \quad \text{design is safe}$$

Dimensions of lever :

The inner dia of the boss = pin dia + (2 x bush thickness)

$$= 11.08 + (2 \times 2) \quad (\because t = 2)$$

$$= 15.08 \text{ mm}$$

outer dia of the boss = 2 x pin dia

$$= 2 \times 11.08$$

$$= 22.08 \text{ mm}$$

$t$  = thickness of lever

$B$  = Width of lever.

$$\rightarrow \sigma_b = \frac{6FL}{tB^2} \quad (\because B = 4t)$$

$$\sigma_b = \frac{6FL}{t(4t)^2}$$

$$t^3 = \frac{6 \times 350 \times 880}{16 \times 70}$$

$$t = 11.81 \text{ mm}$$

$$B = 4t$$

$$= 4 \times 11.81$$

$$= 47.26 \text{ mm}$$

(assuming  $f_b = f_t$ )

9. A lever loaded safety valve is 75 mm in dia and is to be design for a boiler to blow off at a pressure of 1.1 mpa. Design a suitable mild steel lever of rectangular cross section using the following permissible stresses, tensile stress 72 mpa, shear stress 45 mpa, bearing pressure intensity 24 mpa. The pin is also made of mild steel the distance from the fulcrum to the weight of the lever is 900 mm and the distance b/w the fulcrum and pin connected the valve spindle links to the lever is 100 mm

Sol Given data

dia of the safety valve  $D = 75 \text{ mm}$

blow off pressure  $P = 1.1 \text{ mpa}$

tensile stress ( $\sigma_t$ ) = 72 mpa

shear stress ( $\tau$ ) = 45 mpa

bearing pressure ( $P_b$ ) = 24 mpa

length  $L = 900 \text{ mm}$

length b/w B to C = 100 mm

The load applied on the lever at point B

$$W = \pi/4 d^2 \cdot P$$

$$= \frac{\pi}{4} (75)^2 \times 1.1$$

$$= 4659.65 \text{ N}$$

for finding the dead weight at point A. Take moment at point C.

$$F \times 900 = W \times 100$$

$$F = \frac{4859.65 \times 100}{900}$$

$$F = 539.96 \text{ N}$$

$$R + F = W$$

$$R = W - F$$

$$R = 4859.65 - 539.96 = 4319.68 \text{ N}$$

dimensions of pin at load point B & fulcrum point C ∴

$d_b$  = dia of pin at point B

$l_b$  = length of pin at point B

by assuming

$$l_b = 1.25 d_b ; P_b = 24 \text{ mpa}$$

$$P_b = \frac{W}{l_b \cdot d_b}$$

$$P_b = \frac{W}{1.25 d_b \times d_b}$$

$$d_b^2 = \frac{4859.65}{1.25 \times 24}$$

$$d_b = 12.72 \text{ mm} \approx 13 \text{ mm}$$

$$l_b = 1.25 d_b$$

$$= 1.25 \times 13$$

$$= 16 \text{ mm}$$

Then by following the above procedure the parameter  $l_c$  &  $d_c$  can be determined by since load applied at point B & C are nearly equal to

$$d_c = 13 \text{ mm}$$

$$l_c = 16 \text{ mm}$$

checking the pin of shear strength :-

$$\tau = \frac{W}{2 \times \frac{\pi}{4} d b^2}$$
$$= \frac{4659.65}{2 \times \frac{\pi}{4} (13)^2} = 18.30 \text{ N/mm}^2 < 45 \text{ N/mm}^2$$

design is safe

Dimensions of lever :-

$$\begin{aligned} \text{inner dia of box} &= \text{pin dia} + (2 \times \text{bush thickness}) \\ &= 13 + (2 \times 2) \\ &= 17 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{outer dia of box} &= 2 \times \text{pin dia} \\ &= 2 \times 13 = 26 \text{ mm} \end{aligned}$$

$t$  = thickness of lever

$B$  = width of lever

$$\rightarrow \sigma_b = \frac{6FL}{tB^2} \quad (\because B = 4t)$$

$$\sigma_b = \frac{6FL}{t(4t)^2}$$

(assuming  $\sigma_b = \sigma_t$ ).

$$t^3 = \frac{6 \times 539.96 \times 900}{16 \times 72}$$

$$t = 13.62 \text{ mm} \approx 14 \text{ mm}$$

$$\rightarrow B = 4t$$

$$= 4 \times 13.62$$

$$= 54.48 \text{ mm}$$