* Design of Machine Elements: (Lab-3):

* Knuckle Joint:

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→ Calculations:

Axial Tensile force = 25 kN

$$\boxed{P = 25 kN}$$

(*). Assuming factor of safety to be 3.5.

(*) For simplicity, I will be using same material for all 3 parts.

(Plain Carbon Steel)

$S_{yt} = 400 N/mm^2$

① Tensile failure of rods.

$$\sigma_t = \frac{P}{\pi/4 D^2} \Rightarrow \quad \cancel{\sigma_t} = \frac{\sigma_t}{F.O.S} = \sigma_{all}$$

$$\Rightarrow D = \sqrt{\frac{P}{\pi/4 \sigma_t}} = \sqrt{\frac{25 \times 10^3}{\frac{\pi}{4} \times 114.28}}$$

$$(\sigma_{all}) = \frac{400}{3.5} = 114.28 N/mm^2$$

$$\Rightarrow D = \sqrt{\frac{25 \times 10^3}{89.71}} = 16.69 mm$$

$$\boxed{D = 16.69 mm} \quad D_1 = 1.1 \times D$$

$\therefore \boxed{D_1 = 18.359 \text{ mm}}$

② Pin shear failure

$\tau = P/2(\pi/4\, d^2)$ or $\boxed{d = \sqrt{\dfrac{2P}{\pi\tau}}}$

Here $\boxed{d = D}$

$\therefore$ By empirical relation $d = D = 16.69$ mm

$\therefore \boxed{d = 16.69 \text{mm}}$

③ Crushing failure of its eye :

$\sigma_c = \dfrac{P}{bd}$ $\Rightarrow$ $2 \times (114.28) = \dfrac{25 \times 10^3}{20.862 \times d}$

from ①

$2(\sigma_t)_{all}$

from first eqn.

$\boxed{b = 1.25 \times D}$ $\Rightarrow$ $b = 1.25 \times 16.69$

empirical reln

$\Rightarrow \boxed{b = 20.862 \text{mm}}$

$\therefore \boxed{d = \dfrac{25 \times 10^3}{2 \times 114.28 \times 20.862}}$

$\Rightarrow d = \dfrac{25000}{4727.077}$

$\boxed{d = 5.288 \text{ mm}}$

④ Crushing failure of pin in force:

$$(\sigma_c)_{all} = 2(\sigma_t)_{all}$$ ~~from eqn~~

$\downarrow$

114.28 N/mm² (from ①)

$$\sigma_c = \frac{P}{2ad}$$

$a = 0.75 \times D = 0.75 \times 16.69$

$\therefore$ $\boxed{a = 12.517\ mm}$

$$\therefore\ 2 \times 114.28 = \frac{25 \times 10^3}{2 \times 12.517 \times d}$$

$$\Rightarrow\ d = \frac{25 \times 10^3}{2 \times 114.28 \times 2 \times 12.517}$$

$$d = \frac{25000}{5721.7710} = 4.3.69\ mm$$

$\boxed{d = 4.369\ mm}$

⑤ Bending failure

$$\sigma_b = \frac{\frac{P}{2}\left[\frac{b}{4} + \frac{a}{3}\right] d/2}{\frac{\pi}{64} d^4}$$

σ_b for calculation is σ_b allowable

$= (\sigma_t)_{allow} = 114.28\ N/mm^2$

Page No.
Date

$$\therefore (\sigma_t)_{allow} = 114.28 \times 12.5 \times 10^3 \left(\frac{20.86}{4} + \frac{12.517}{3}\right)$$

$$114.28 = \frac{12.5 \times 10^3 \left(\frac{20.86}{4} + \frac{12.517}{3}\right)(2.644)}{\frac{\pi}{64} \times (d^4)}$$

$$\frac{64 \times 12.5 \times 10^3 \times (5.215 + 4.172)(2.644)}{\pi d^4} = 114.28$$

$$\Rightarrow 2115200\,(9.387) = 114.28 \times \pi \times d^4$$
$$= 358.83 \times \underline{d^4}.$$

$$\Rightarrow \cancel{2115} \quad d^4 = 55333.674$$

$$\Rightarrow \boxed{d = 15.337\,mm}$$

$\therefore$ Now on getting ③ values of d we have to select the maximum d value.

$\therefore$ The largest value $\Rightarrow \boxed{d = 16.69\,mm}$

⑥ Tensile failure of eye:

$$\underset{\substack{\downarrow \\ all}}{\sigma_t} = \frac{P}{b(d_o - d)} \Rightarrow 114.28 = \frac{25 \times 10^3}{20.862(d_o - 16.69)}$$

$$\Rightarrow d_o - 16.69 = \frac{25 \times 10^3}{20.862 \times 114.28}$$

$$d_o - 16.69 = \frac{25 \times 10^3}{2386.11} = 10.486$$

Page No.:
Date:

$\therefore$ on calculating $\boxed{d_o = 27.176 \text{ mm}}$

⑦ Shear-failure of eye

$$\tau = \frac{P}{2\left[\frac{b(d_o - d)}{2}\right]}$$

$0.5\sigma_{yt} \Rightarrow \quad \sigma_{yt} = (\sigma_{yt})_{allow} = \frac{114.28 \text{ N/mm}^2}{2}$

$= 57.14 \text{ N/mm}^2$

$$\therefore 57.14 = \frac{25 \times 1000}{20.862(d_o - 16.69)}$$

$$d_o - 16.69 = \frac{25000}{20.862 \times 57.14}$$

$$\boxed{d_o = 37.66 \text{ mm}}$$

⑧ Tensile-failure of fork:

$$\sigma_t = \frac{P}{2a(d_o - d)} \Rightarrow$$

$$114.28 = \frac{25000}{2 \times 12.517 \times (d_o - 16.69)}.$$

$$d_o - 16.69 = \frac{25000}{2 \times 12.517 \times 114.28}$$

$$d_o - 16.69 = \frac{25000}{2860.88}$$

$\Rightarrow$ $d_o - 16.69 = 25.42 \Rightarrow \boxed{d_o = 25.42\,mm}$

⑨ Shear-failure of fork: $\tau = \dfrac{P}{2a(d_o - d)}$

$0.5\,\sigma_{yt}$

$\Rightarrow 57.44\,N/mm^2 = \dfrac{25 \times 10^3}{2 \times 12.517 (d_o - 16.69)}$

$d_o - 16.69 = \dfrac{25 \times 10^3}{2 \times 12.517 \times 57.44}$

$d_o = 16.69 + \dfrac{25000}{1437.95}$

$\boxed{d_o = 34.075\,mm}$

Here we have to select the highest value of do

$\therefore \boxed{d_o = 37.66\,mm}$

$\rightarrow$ $\therefore$ Final dimensions (taking exact values as rounding off might affect other parameters.

Finally.

$\therefore$

$\boxed{d = 16.69\,mm}$ $\boxed{D_1 = 18.359\,mm}$

$d_1 = 1.5 \times 16.69$

$\boxed{D = 16.69\,mm}$ $\boxed{d_o = 37.66\,mm}$

$\boxed{d_1 = 25.035\,mm}$ $\boxed{a = 12.517\,mm}$ $\boxed{b = 20.862\,mm}$