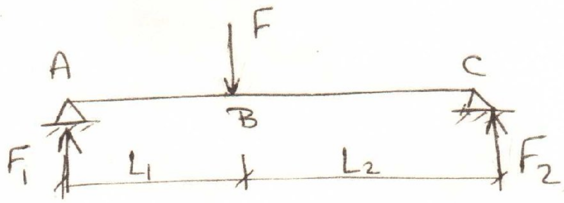
③ Normal due to bending

* N.A هو محور التعادل



* السطح العلوي للكمره تعرض للضغط
* السطح السفلي ~ ~ للشد
* لايجاد قيم ردود الافعال يتم استخدام معادلات الاتزان $\Sigma F = 0 , \Sigma M = 0$

* يتم حساب قيم العزم عند النقطه المطلوب من ناحيه الجانب الايسر

العزم عند النقطه → M

المسافه من N.A إلى النقطه → y

$$\sigma = \frac{My}{I}$$

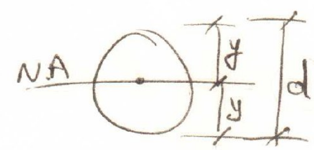
I ← second moment of Area mm^4

* في حاله الكمره الواحده تكون قيم I, y ثابته وتتغير مع تغير M
* يتم رسم العزم عكس اتجاه السهم (مع ذيل السهم)

Beam type

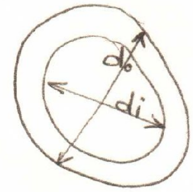
A) circular

$$y = \frac{d}{2} \qquad I = \frac{\pi}{64} d^4$$



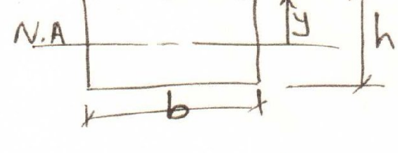
B) hollow cylinder

$$y = \frac{d_o}{2} \qquad I = \frac{\pi}{64}\left(d_o^4 - d_i^4\right)$$

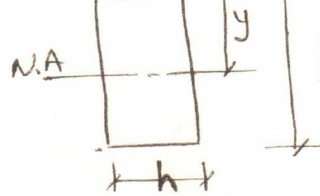


c) rectangular section

$$y = \frac{h}{2} \qquad I = \frac{bh^3}{12}$$



$$y = \frac{b}{2} \qquad I = \frac{hb^3}{12}$$



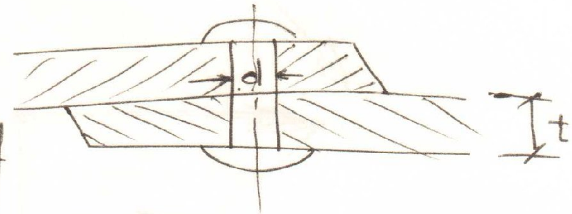
* Bearing stress (crushing stress)

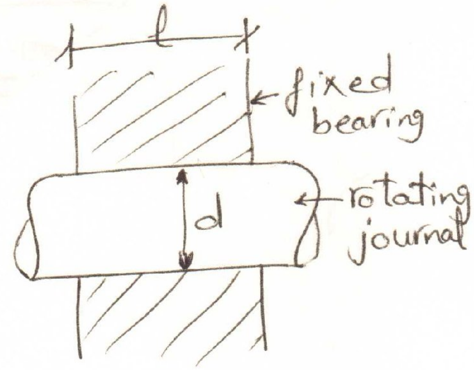
$$\sigma_c = \sigma_b = \frac{P}{d.t.n}$$

P ← force

d.t ← projected area

n ← no. of rivets





$$P_b = \frac{P}{l.d}$$

P_b ← average bearing pressure

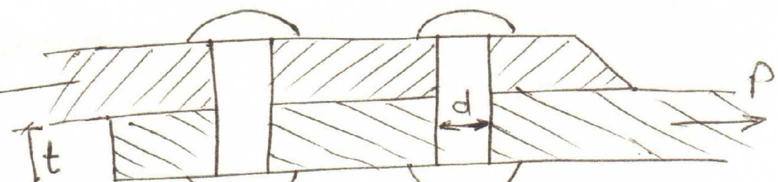
P ← radial load

d ← diameter of journal

l ← length of journal in contact

ex.

two plate 16 mm (t) thickness are joined by double riveted lap joint as shown. Find the crushing stress induced between the plates and the rivet, if the max. tensile load on the joint is 48 KN and the rivet diameter is 25 mm



$$\sigma_c = \frac{P}{d.t.n} = \frac{48*1000}{25*16*2} = 60 \ N/mm^2$$

ex. A journal 25 mm in diameter is supported in sliding bearings has a max. end reaction of 2500 N. Assuming an allowable bearing pressure of 5 N/mm², find the length of the sliding bearing.

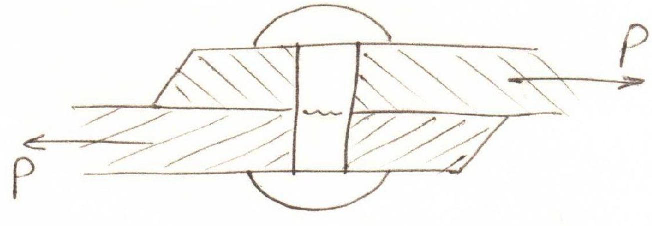
$$P_b = \frac{P}{l.d}$$

$$5 = \frac{2500}{l*25} \Rightarrow l = 20 \ mm$$

* shear stress

① Direct shear

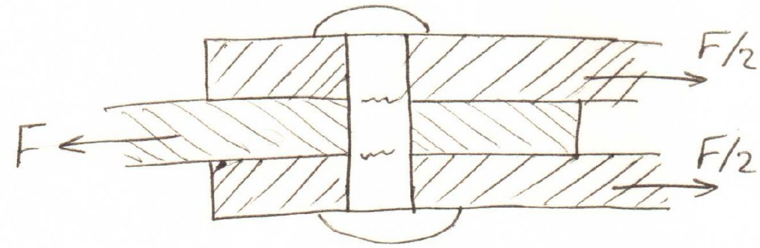
(A) single shear



$$\tau = \frac{\text{Force}}{\text{area of failure}}$$

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

(B) double shear



shear stress ↘

$$\tau = \frac{\text{Force}}{n * A}$$

عدد مساحات الكسر → n

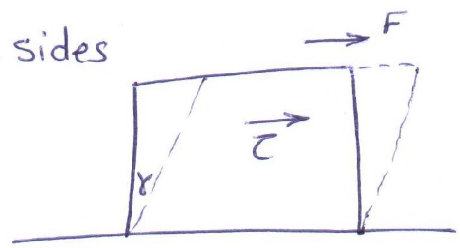
Area → A: $A = \frac{\pi}{4} d^2$

$n = 1$ single shear

$n = 2$ double shear

γ shear strain = change in ⊥ sides of the block

↳ in radians



$\tau \propto \gamma$ in elastic zone

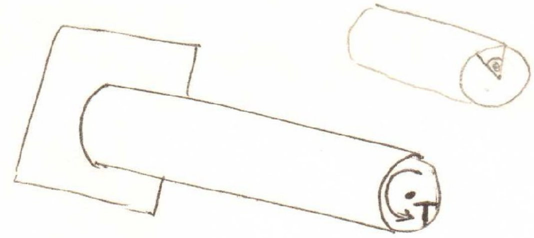
$\tau = G\gamma$ as G: modulus of rigidity (Pa)

$$\boxed{E = 2G(1 + \nu)}$$

ν = Poisson's ratio = 0.3 for most materials

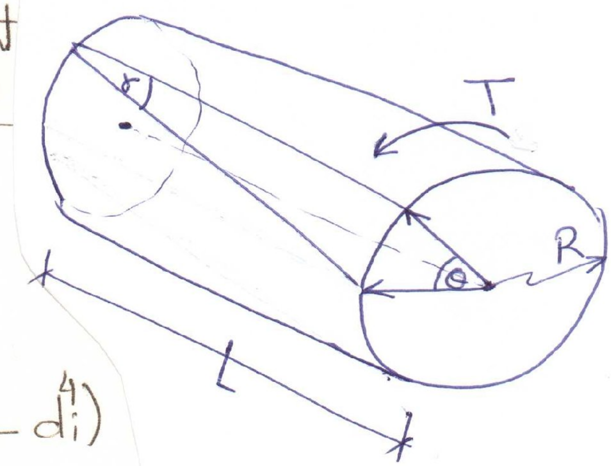
$$\therefore \boxed{E = 2.6\,G}$$

② shear due to torsion



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

- T — Torque (N-mm)
- r — radius (mm)
- τ — shear stress (MPa)
- J — polar moment of Area (mm^4)



Beam type

Ⓐ circular $\quad r = \frac{d}{2} \quad J = \frac{\pi}{32} d^4$

Ⓑ hollow cylinder $\quad r = \frac{d_o}{2}$

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

θ twisting angle $\qquad r\theta = \gamma L$

γ shear strain angle

L total length

R max radius

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$$

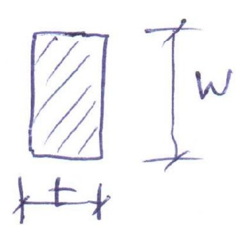
τ shear stress

r radius

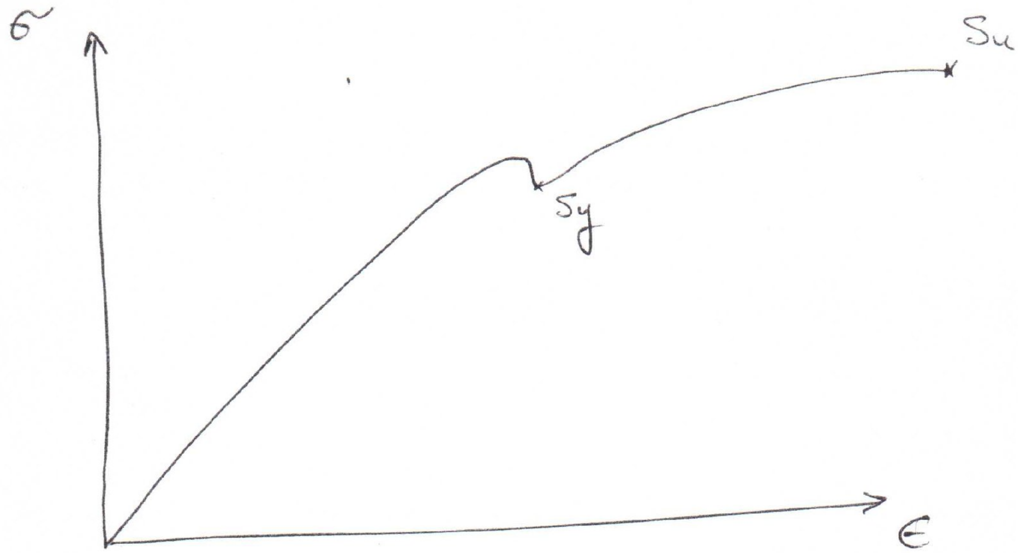
T twisting moment

Ⓒ rectangular

$$\tau_{max} = \frac{T}{w t^2}\left(3 + 1.8\frac{t}{w}\right)$$



yield strength and ultimate strength



S_y : yield strength (MPa) إجهاد الخضوع (إجهاد التشكل)

S_u : ultimate strength (MPa) إجهاد الكسر (أقصى إجهاد يتحمله الجسم)

f.s. : factor of safety معامل الأمان (2 ~ 3)

σ_{all} : maximum allowable stress

$$\boxed{\sigma_{all} = \frac{S_y}{f.s.}}$$

τ_{all} : maximum allowable shear stress

$$\boxed{\tau_{all} = \frac{0.5\, S_y}{f.s.}}$$

Combined stresses

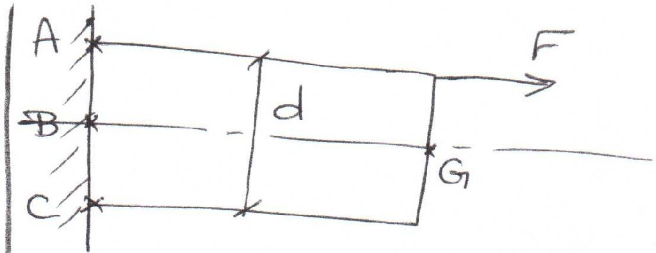
from the same Kind

tension or Comp. + bending

from different Kind

Bending (σ) + torque (τ)

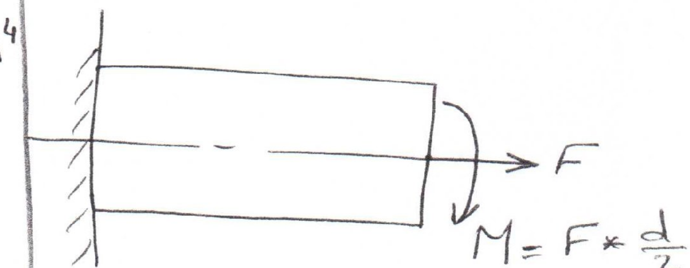
From the same Kind



$$\sigma_{tension} = \frac{F}{A} \quad , A = \frac{\pi}{4}d^2$$

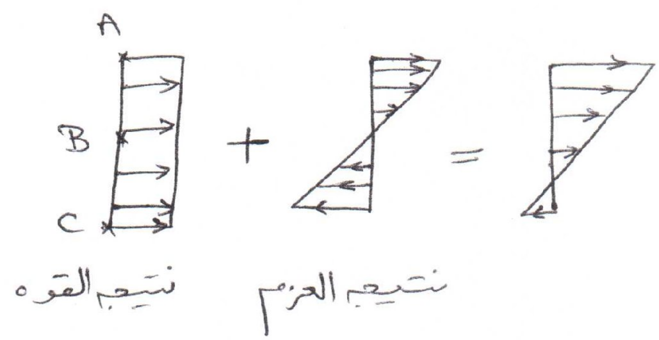
$$\sigma_{bending} = \frac{My}{I} \quad , y = \frac{d}{2}$$

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



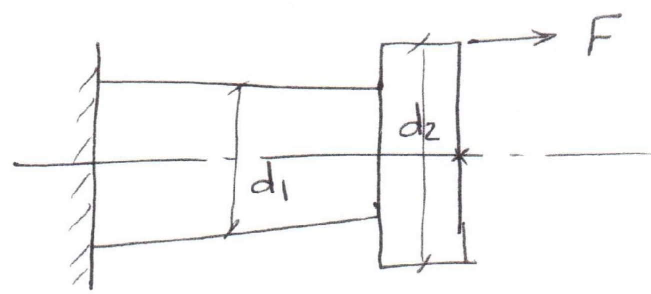
At point A (top surface)

$$\sigma_{max} = \sigma_{tension} + \sigma_{bending}$$



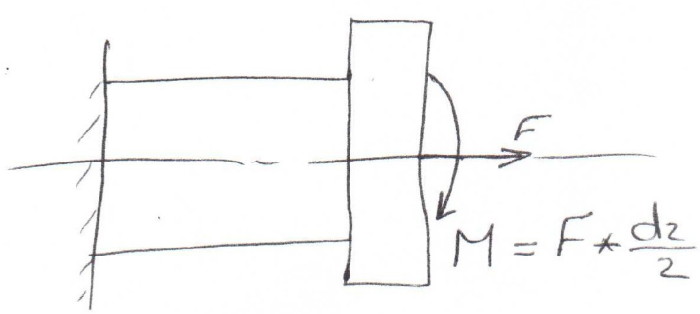
At point C (bottom surface)

$$\sigma_{min} = \sigma_{tension} - \sigma_{bending}$$



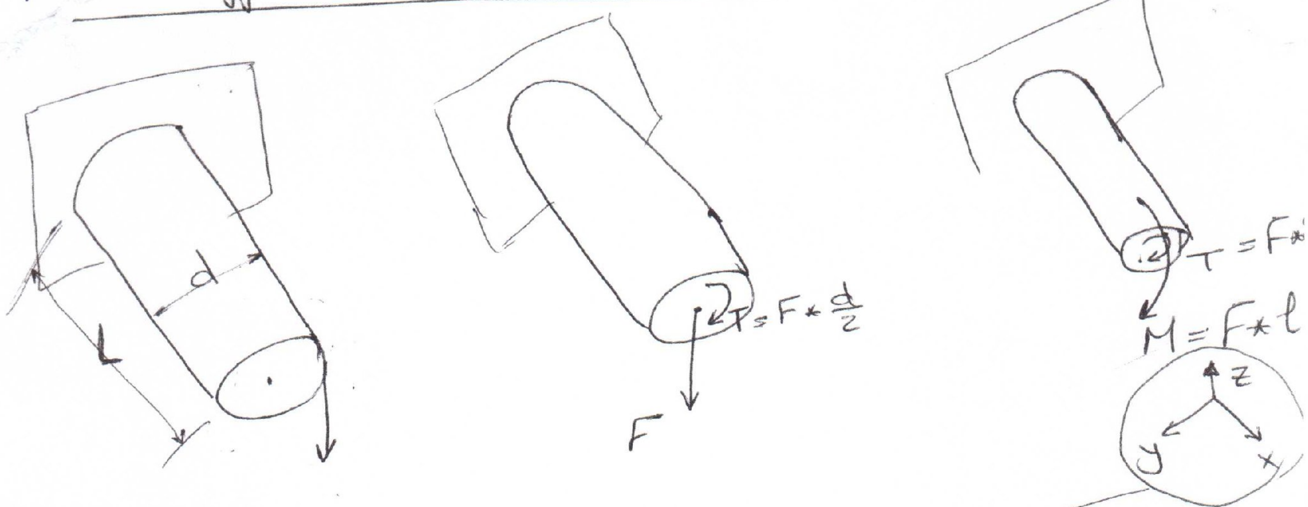
$$\sigma_{tension} = \frac{F}{\frac{\pi}{4}d_1^2}$$

$$\sigma_{bending} = \frac{M * \frac{d_1}{2}}{\frac{\pi}{64}d_1^4}$$



في حالة وجود أكثر من قطر للshaft
يتم استخدام أقل قطر
لأنه الأكثر عرضة للكسر

From different Kind (σ with τ)



هنا M تعمل انثناء
لمحور X وبالتالي

$$\sigma_x = \frac{My}{I}$$

$\&$ $\sigma_y = 0$

$$\sigma_{bending} = \frac{M * y}{I}$$

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

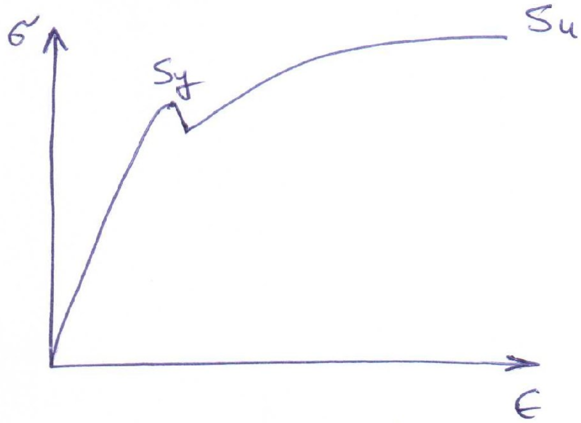
max. & min. Normal stress

$$\sigma_{\substack{max \\ min}} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \leq \frac{S_y}{f.s.}$$

$$\& \quad \tau_{max.} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \leq \frac{0.5\, S_y}{f.s.}$$

Materials

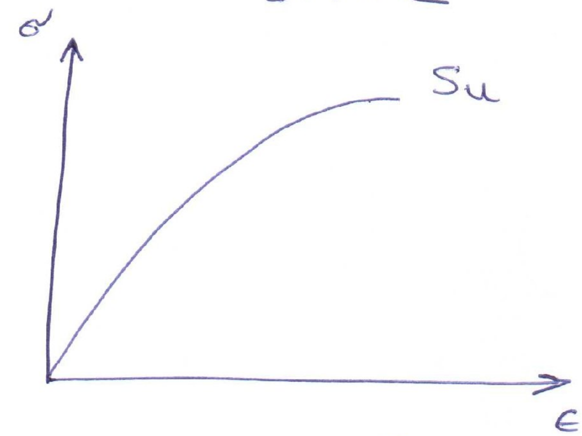
Ductile



$$\sigma_{all} = \frac{S_y}{f.s}$$

$$\tau_{all} = \frac{0.5\,S_y}{f.s}$$

Brittle



$$\sigma_{all} = \frac{S_u}{f.S.}$$

$$\tau_{all} = \frac{0.5\,S_u}{f.S.}$$

---

* factor of safety >1

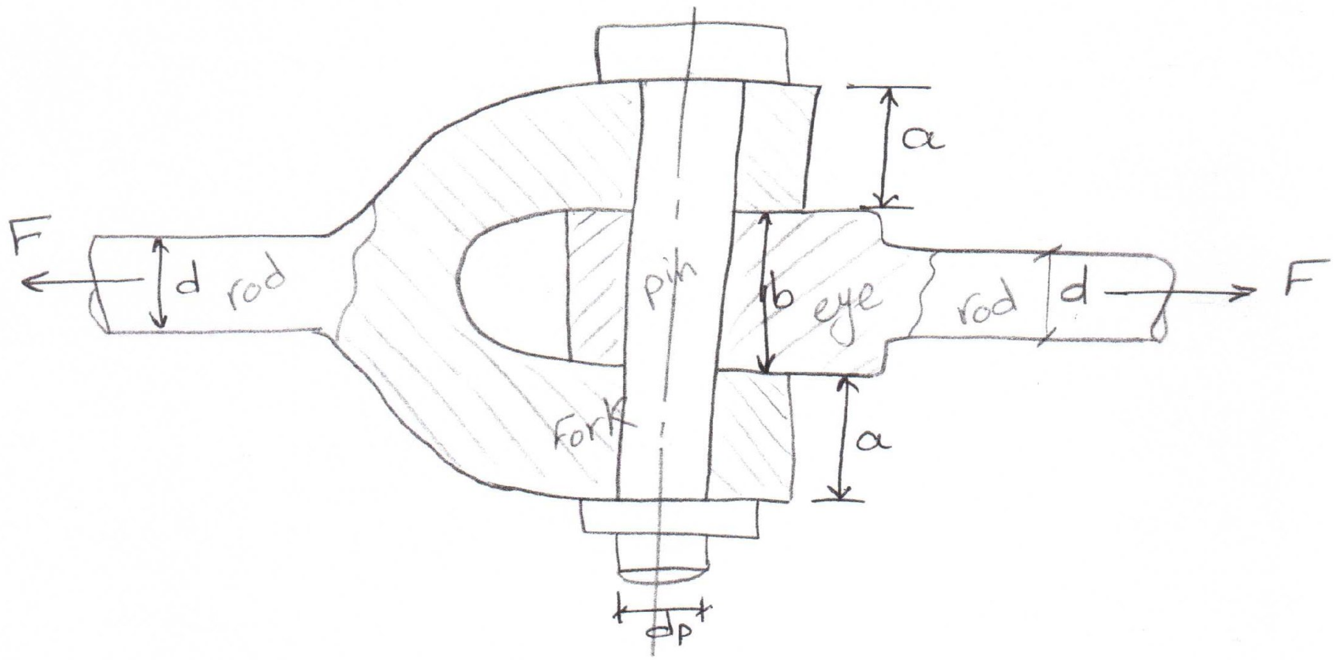
It depends on the Judgement of the designer.
It should depends on the following Consideration:-
It should depends on the following Consideration:-

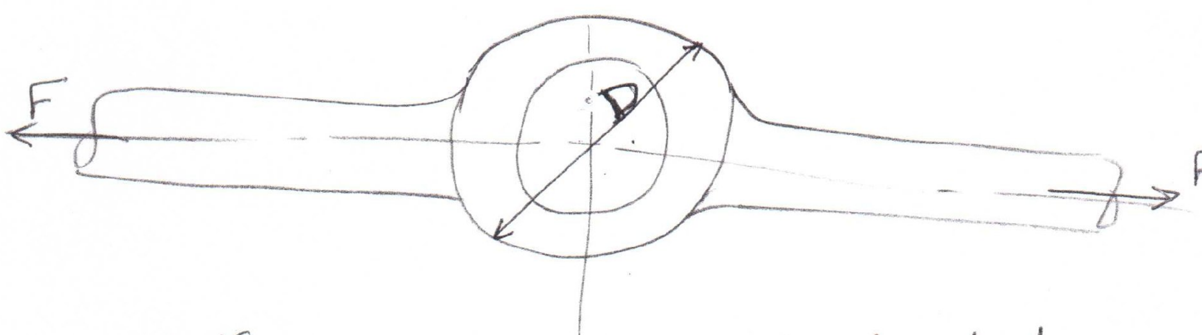
1. mechanical properties aren't Known exactly.
2. Effect of size, heat treatment and type of loading
3. Effect of wear, time and environment on m/c life
4. assumptions may not be exact.
5. overall Concern for human safety.
6. shutdown and maintenance may make loss of Cost

---

* Const. load - ductile Material f.s. = 1.2 – 2 - brittle f.s = 5-6
  Repeated ~ ~ ~ f.s. = 3 – 4 - ~ f.s. = 8 – 11
  shock ~ ~ ~ f.s. = 5 – 7 - ~ f.s. = 15 – 20

Design of Knuckle Joint





Fork, eye, pin are made of steel $S_y = 420$ MPa

use factor of safety of 3

If F = 20 KN, Find suitable dimensions.

& allowable bearing stress $\sigma_{br} = 100$ MPa

d = ??

a = ??

b = ??

dp = ??

① Design of rod (tension stress)

$$\sigma = \frac{F}{A} = \frac{S_y}{f.s.}$$

$$\frac{20 * 10^3}{\frac{\pi}{4} d^2} = \frac{420}{3} \Rightarrow d = 13.5\,mm$$

يتم التقريب للاكبر

take $d = 14\,mm$

② Design of pin (double shear)

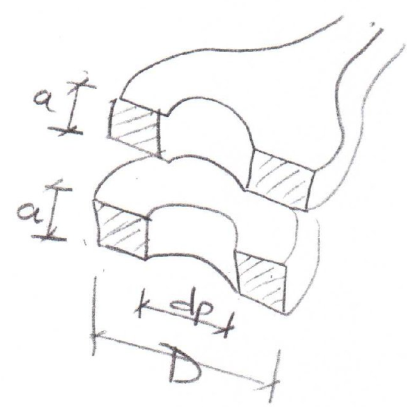
$$\tau = \frac{F}{nA} = \frac{0.5\,S_y}{f.s.}$$

$$\frac{20 * 10^3}{2 * \frac{\pi}{4} d_p^2} = \frac{0.5 * 420}{3} \Rightarrow d_p = 13.5$$

take $d_p = 14\,mm$

③ Design of Fork

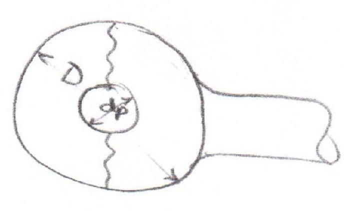
* tension stress



$$\sigma = \frac{F}{A} = \frac{S_y}{f.s.}$$

مساحة الكسر

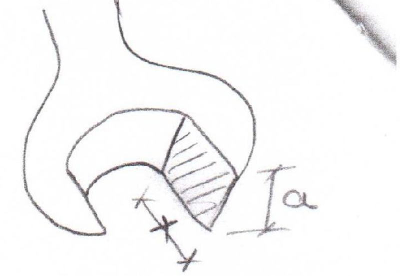
$$A = 2(D - d_p) * a$$



$$\frac{20 * 10^3}{2a(D - d_p)} = \frac{420}{3}$$

$$a = \frac{20 * 10^3 * 3}{2(D - 14) * 420} \longrightarrow ①$$

* Double shear



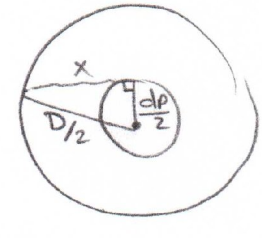
$$\tau = \frac{F}{A} = \frac{0.5\,S_y}{f.s.} \longrightarrow ②$$

$$A = 4 \times a$$

$$= 4a\sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{d_p}{2}\right)^2}$$

from ① & ②

$$\frac{\cancel{20 * 10^3}}{4 * \frac{\cancel{20*10^3}*\cancel{3}}{2(D-14)*\cancel{420}} * \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{14}{2}\right)^2}} = \frac{0.5 * \cancel{420}}{\cancel{3}}$$



بالتربيع

$$D - 14 = \sqrt{\left(\frac{D}{2}\right)^2 - 7^2}$$

$$D^2 - 28D + (14)^2 = \left(\frac{D}{2}\right)^2 - 7^2$$

$$\frac{3}{4}D^2 - 28D + 245 = 0$$

$a = 3/4$

$b = -28$

$c = 245$

$$D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{+28 \pm \sqrt{(-28)^2 - 4 * \frac{3}{4} * (245)}}{2 * \frac{3}{4}}$$

$$D = \frac{28 \pm 7}{1.5} = 23.3 \text{ mm} \quad \underline{\text{or}} \quad 14 \text{ mm}$$

take D = 24 mm — take the higher valu

sub. in ①

$$a = \frac{20 * 10^3 * 3}{2(24 - 14) * 420} = 7.14 \text{ mm}$$

take a = 8 mm

$$X = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{d_p}{2}\right)^2}$$

$$= \sqrt{\left(\frac{24}{2}\right)^2 - \left(\frac{14}{2}\right)^2} = 9.75 \text{ mm}$$

④ Design of eye

*** tension stress**

$$\sigma = \frac{F}{A} = \frac{S_y}{f.s.}$$

$$\frac{20 * 10^3}{b(D - d_p)} = \frac{420}{3} \Longrightarrow b = 14.3\ mm$$

take $b = 15\ mm$

*** shear stress**

$$\tau = \frac{F}{A} = \frac{0.5\ S_y}{f.s.}$$

$$\frac{20 * 10^3}{2\,b\,X} = \frac{0.5 * 420}{3}$$

$\therefore X = 9.75$ mm

$\therefore b = 14.7$ mm

take $b = 15\ mm$ as before $\therefore$ O.K.

*** Bearing stress bet^n fork & pin**

$$\sigma_{br} = \frac{F}{2a\,d_p} = 100 \Longrightarrow a = 8\ mm$$

as before

$\therefore$ O.K.

*** Bearing stress bet^n eye & pin**

$$\sigma_{br} = \frac{F}{b\,d_p} \Longrightarrow b = 15\ mm$$

as before

$\therefore$ O.K.