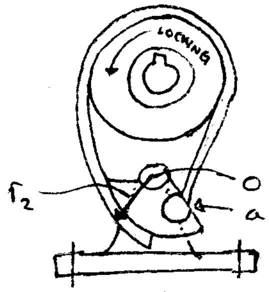
MARCH 13 /18
MACHINE DESIGN

The backstop shown schematically in Fig P17-21 is used to prevent backword rotation of the shaft. A sector is pivoted at O, and one end of the band is attached to it and operates at a radius $r_2 = 2\frac{1}{4}$ in. The other end of the band is attached at point a so that $Oa = r_1 = 1$ in. The diameter of the wheel is $8\frac{1}{4}$ in., the angle of wrap is 270°, and the width of the band is $2\frac{1}{8}$ in. The torque on the wheel is 300 lb-ft. Assuming a coefficient of friction between the band and the wheel equal to 0.2, determine the following: (a) the maximum band tension (b.) the maximum pressure between the band and the wheel (c) whether the backstop is self-locking



Solution:

a) $$(F_1 - F_2)\frac{D}{2} = T$$

but $$F_1 - F_2 = \frac{2T}{D}$$

and $$F_2 = F_1 / e^{f\theta}$$

$$\therefore F_1 - F_1/e^{f\theta} = 2T/D$$

$$F_1 = 2T/D(1 - 1/e^{f\theta})$$

$$F_1 = 2 \times 300 \times 12 / [8.25(1 - \frac{1}{e^{.2 \times 270 \times \pi/180}})]$$

$$F_1 = 1430 \text{ lb}$$

b) $$P_{max} = \frac{F_1}{br} = \frac{1430 \times 2}{(2\frac{1}{8} \times 8\frac{1}{4})} = 163 \text{ psi}$$

c) The brake is self-locking if $r_2 / e^{f\theta} < r_1$

$$r_2 / e^{f\theta} = 2\tfrac{1}{4} / e^{.2 \times 270 \times \pi/180} = 0.877$$

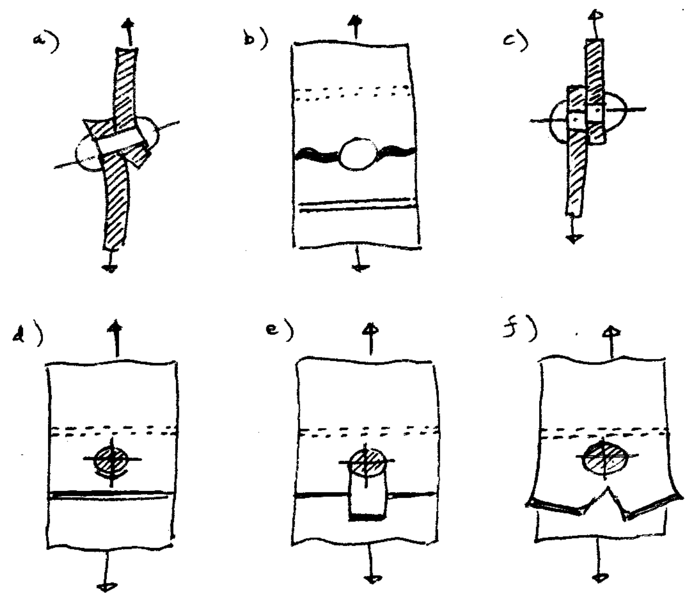
$$\therefore r_2 / e^{f\theta} = 0.877 < r_1$$

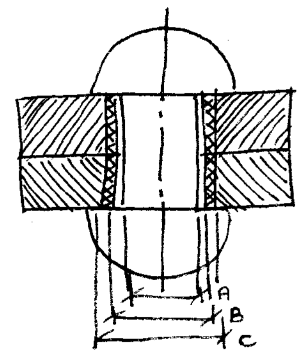
and the brake is self-locking

Welded and Riveted Connections

1 - Riveting

- the Function of a rivet in a joint is to make a connection that has strength and tightness
- It's general use should be limited to shearing loads, in the case of a tensile load, a bolt should be used.





A = nominal diameter

B = Diameter of punched hole $\varphi = d + 1/16$ in

C = Diameter to be used in calculating the strength of plate $\varphi = d + 1/8$ in

Mode of Failure of riveted joint:

a) bending of plate

b) rupturing of plate (by tension)

c) shearing of rivets

d) crushing of rivets or plates

e) sheering of margin

f) tearing of plate

- stress concentration in the riveted parts and the rivet is:
  + serious for brittle material
  + Not too serious for ductile material

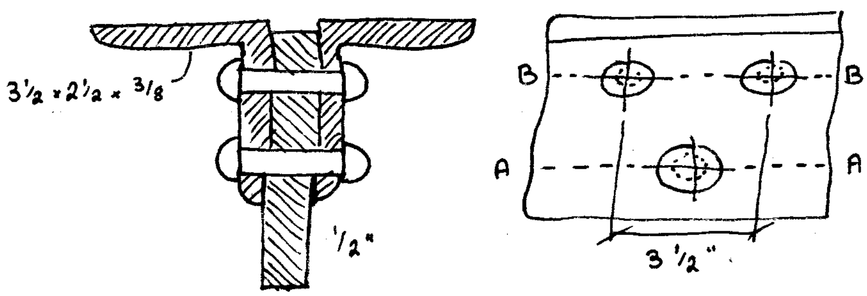
1.1 - Structural and machine member riveting

- when punched holes are used without being reamed as in structural work, the Following are observed;
  1 - rivet hole is considered to have a diameter 1/8" greater than the nominal diameter of the rivet
  2 - the nominal diameter of the rivet must be used in calculating the strength of the rivet

- For structural steel, the following may be used as allowable stress in the absense of more accurate data.

1 - For plate in tension — 20 000 psi
2 - For rivets in shear — 15 000 psi
3 - For bearing of rivets and plates
   a - single shear — 32 000 psi
   b - double shear — 40 000 psi

Example 1. - Determine the safe load that may be carried by the joint illustrated in the sketch. Rivets Ø = 3/4"



Solution :

1 - The strength of the plate along A - A

$$S = P/A$$

$$20000 = \frac{P}{[3.5 - (3/4 + 1/8)] \times 1/2} \Rightarrow P = 26,250 \text{ lb}$$

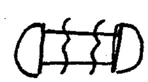
2 - The strength of all the rivets in shear is ;

$$S = P/A$$

$$15000 = P/6 \times \pi/4\, (3/4)^2$$

$$P = 39,700 \text{ lb}$$

3 rivets



double shear

∴ Twice the area

$6 \times \frac{\pi}{4} d^2$

3 - The strength of all the rivets in bearing is ;

$S = P/3td$

$40000 = P/3 \times 1/2 \times 3/4$

$P = 45,000$ lb

4 - The strength in failure of the plate in tension along section BB combined with failure of the lower rivet ;

a - in shear

$S = P/A$; $P = AS$

$P = [3.5 - 2(3/4 + 1/8)] \times 1/2 \times 20000 + 2 \times \pi/4 (3/4)^2 \times 15000$

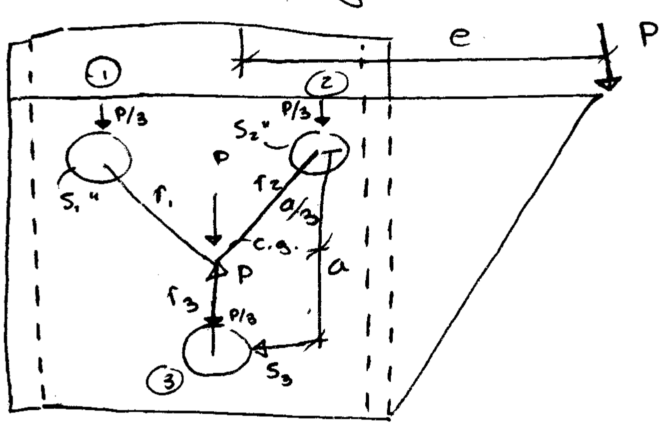
$P = 30750$ lb

b - in bearing

$P = [3.5 - 2(3/4 + 1/8)] \times 1/2 \times 20000 + 3/4 \times 1/2 \times 40000$

$P = 32500$ lb

1.2 - Eccentrically loaded connection



1 - Find or locate c.g. of rivets group.

2 - Introduce P' and P"

3 - P' induces direct shearing load = P/3 on each rivet called primary shear

4 - P" and P produces a moment Pe inducing a secondary shear S" such that

$$\frac{S_1''}{r_1} = \frac{S_2''}{r_2} = \frac{S_3''}{r_3}$$

$\Sigma M_{cg} = 0$ gives

$$Pe = S_1'' r_1 + S_2'' r_2 + S_3'' r_3$$

Solving for each secondary load we find the general solution :

$$S_n'' = \frac{P_e r_n}{r_1^2 + r_2^2 + r_3^2} = \frac{M r_n}{\sum r_i^2}$$

5 - The primary and secondary shear are then added vectorially to determine the rivet with the maximum load then the design is based on that load.

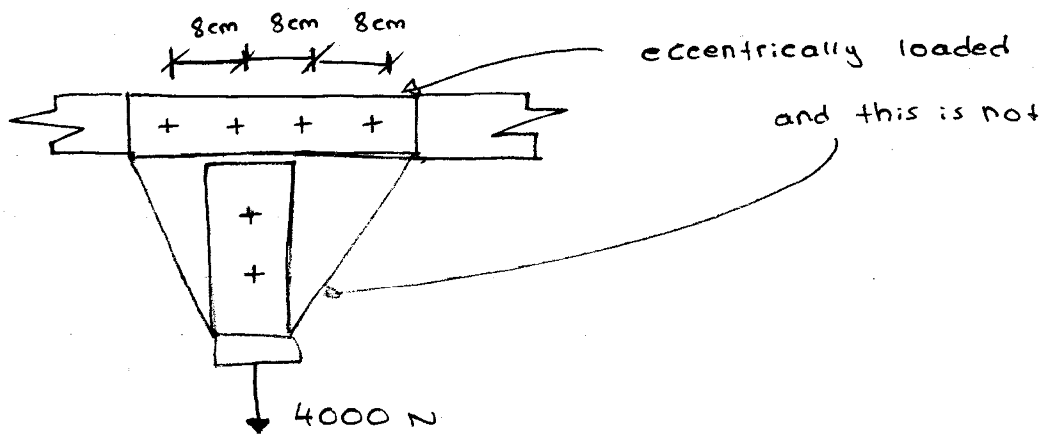
Assumptions made :

1 - Same size rivets

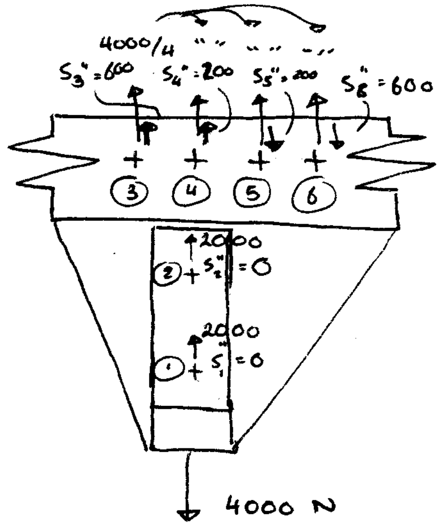
2 - Upper two rivets are equally spaced w.r.t the vertical centerline

3 - The two riveted members are rigid and the deformation takes place in the rivets first

Example 2 - Compute the shear stress in each riveted system shown, all rivets are 2cm diameter.



MARCH 15TH /18
MACHINE DESIGN



= Direct shear

The line of action of Force 4000 N passes through C.G or rivets (1) and (2). There fore, rivets (1) and (2) are subjected to direct shear only.

Shear in rivets (1) and (2) is

$= 4000/2 = 2000\ N$

shear stress in rivets (1) and (2) is

$= 2000/A = 2000/(\pi 2^2/4) = \frac{2000}{\pi}$ (N/cm²)

$= 20/\pi$ MPa $\simeq 6.37$ MPa

The direct shear in (3), (4), (5), (6) is

$= 4000/4 = 1000\ N$

The bending moment is $M = Pe$

$M = Pe = 4000 \times 4 = 16000\ N \cdot cm$

$\sum r_i^2 = 4^2 + 12^2 + 4^2 + 12^2 = 320\ cm^2$

$S_3'' = S_6'' = \frac{M r_n}{\sum r_i^2} = 16000 \times 12/320 = 600\ N$

$S_4'' = S_5'' = \frac{M r_n}{\sum r_i^2} = 16000 \times 4/320 = 200\ N$

Combined Forces in rivet (3) is :

$= 600 + 1000 = 1600\ N$

Shear stress in rivet (3) is

$= 1600/A = 1600/\pi = 509\ N/cm^2$

$= 5.09$ MPa

Combined Force in rivet (4) is

$= 1000 + 200 = 1200\ N$

Shear Stress in rivet (4) is

$= 1200/\pi = 362\ N/cm^2 = 3.62$ MPa

Combined force in rivet (5) is

$= 1000 - 200 = 800$ N

Shear stress in rivet (5) is

$= 800/\pi = 255 N/cm^2 = 2.55$ MPa

Combined force in rivet (6) is

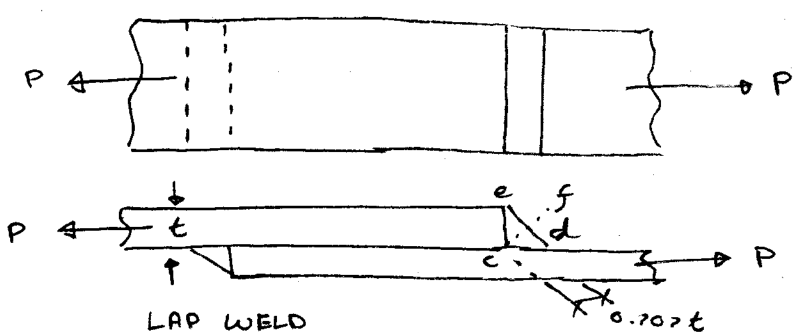
$= 1000 - 600 = 400$ N

Shear stress in rivet (6) is

$= 400/\pi = 128 N/cm^2 = 1.28$ MPa

2 - Welding

2.1 - Stresses in Welds



N.B. In determining the length of a weld required, 1/2 in should be added to allow for starting and stopping of the bead.

We have 2 welds, therefore, the load per weld is;

Load / weld $= P/2$

The normal tensile stress on ec $= P/2Lt$

The component of $P/2$ normal to cf $= P/2 \sin 45°$

$cf = t \sin 45° = 0.707\, ec$

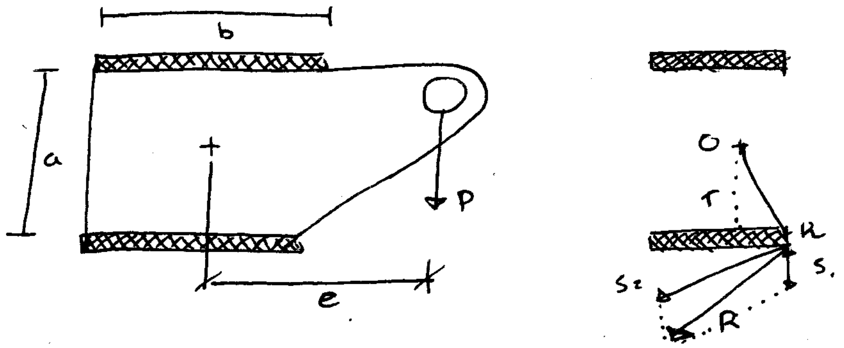
The normal stress along the throat cf $= \frac{P}{2} \times \frac{0.707}{0.707 tL} = \frac{P}{2Lt}$

2.2 - Eccentrically loaded joints

The analysis is similar to that of the eccentrically loaded riveted joints.

↳ see Table 8-7 (Handout)

"Polar moment of inertia for weld patterns"



a) welded bracket   b) weld pattern

- Bracket attached to support by fillet welds

Example 3 - Assume in the figure above $P = 1500$ lb, $e = 5$ in, $a = 3$ in, $b = 2$ in = Net length

Determine the size of the weld required for static loading.

Solution :

From table 8-7 (H.O.)

$J = bt(3a^2 + b^2)/6 = 2t(3 \times 3^2 \times 2^2)/6 = 10.3t$

$r = \frac{1}{2}\sqrt{a^2+b^2} = \frac{1}{2}\sqrt{3^2+2^2} = 1.8$ in

The primary shear stress is

$$S_1 = \frac{P}{2bt} = \frac{1500}{2 \times 2t} = \frac{375}{t}$$

The secondary shear is

$$S_2 = \frac{Tr}{J} = \frac{(1500 \times 5) \times 1.8}{10.3t} = 1,310/t$$

$$R_y = S_2 \times \left(\frac{b/2}{r}\right) + S_1$$

$$= \frac{1310}{t} \times \frac{1}{1.8} + \frac{375}{t} = 1102.78/t$$

$$R_x = S_2 \times \frac{(a/2)}{r} = \frac{1310}{t} \times 1.5/1.8 = 1091.67/t$$

$$R = \sqrt{R_x^2 + R_y^2}$$

$$R = 1/t \sqrt{(1102.78)^2 + (1091.67)^2}$$

$$R = 1552/t$$

based on the throat area t must be replaced by $0.707t$

$$R_{max} = 1552/0.707t$$

If the allowable stress is taken to be 14,000 psi

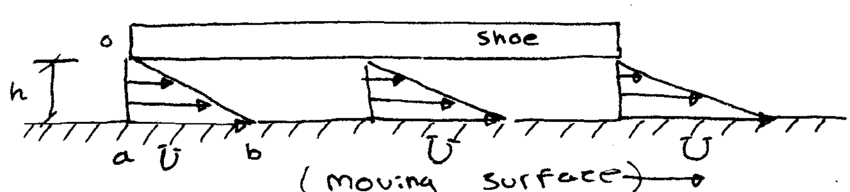
$$14,000 = 1552/0.707t$$

$$t = 1552/14000 \times 0.707 = 0.1567 \text{ in}$$

$$t \cong 3/16 \text{ in}$$

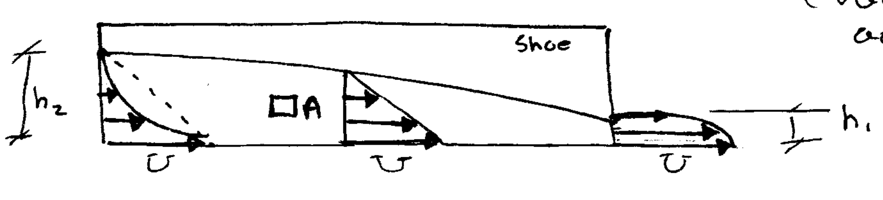
Sliding - Contact Bearings

1 - Mechanism of Fluid Lubrication



a) (uniform thickness film)

(Variation in velocity across film)



b) (converging film)