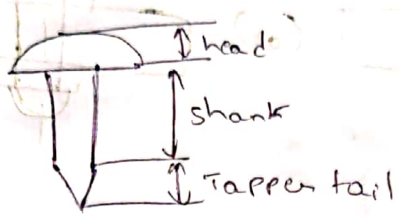
MODULE :- 05

Rivets & welded Joints

Riveted Joint :- A Rivet is a short cylinderical rod having a head & tapper tail. The main body of the rivet is called Shank

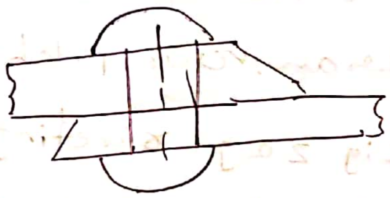


Types of Riveted Joint

1) Lap Joint :-

2) Butt Joint :-

1) Lap Joint :- the plates that are to be joined are brought face to face such that an Over lap exist as shown in figure.



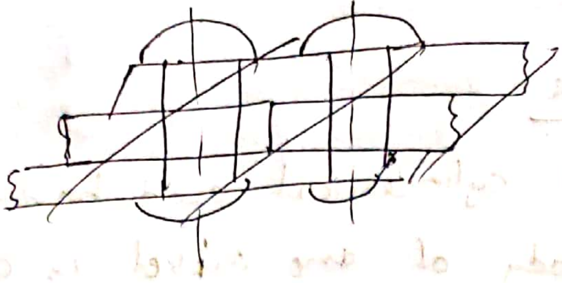
Depending upon the number of row the rivetted Joints might be classified as, single, double (or) triple rivetted lap Joint etc.

when the multiple joints are used the arrangement of rivets b/w two neighbouring row may be of two kinds.

- In chain rivetting the adjacent rows have rivets in the same transverse lines.
- In zig zag rivetting on the other end the adjacent row of rivets are staggered.

2) Butt Joint :- In this type of Joint the plates are brought to together without forming any Over lap.

Rivetted Joints are formed b/w and each of plate & one (or) two cover plate.



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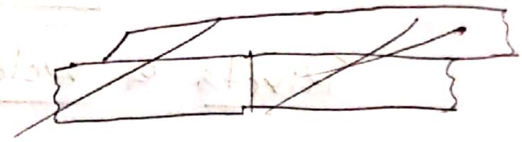

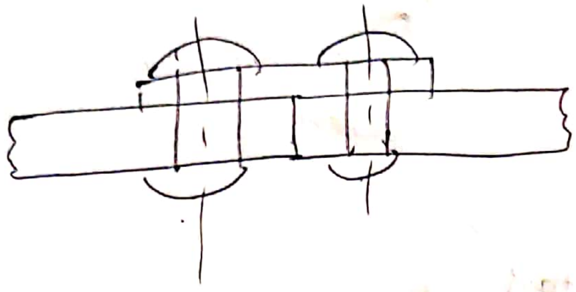

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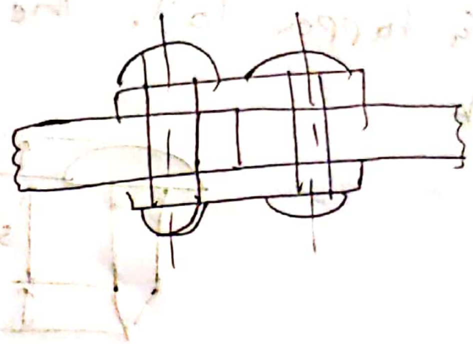


Terminology

1) Pitch (P):- It is distance b/w the centre of two successive rivets in a row.

2) margin (m):- It is distance from end of plate to the first row of rivet.

3) Transverse pitch (P_t):- The distance b/w two successive row of rivets is called Transverse pitch.

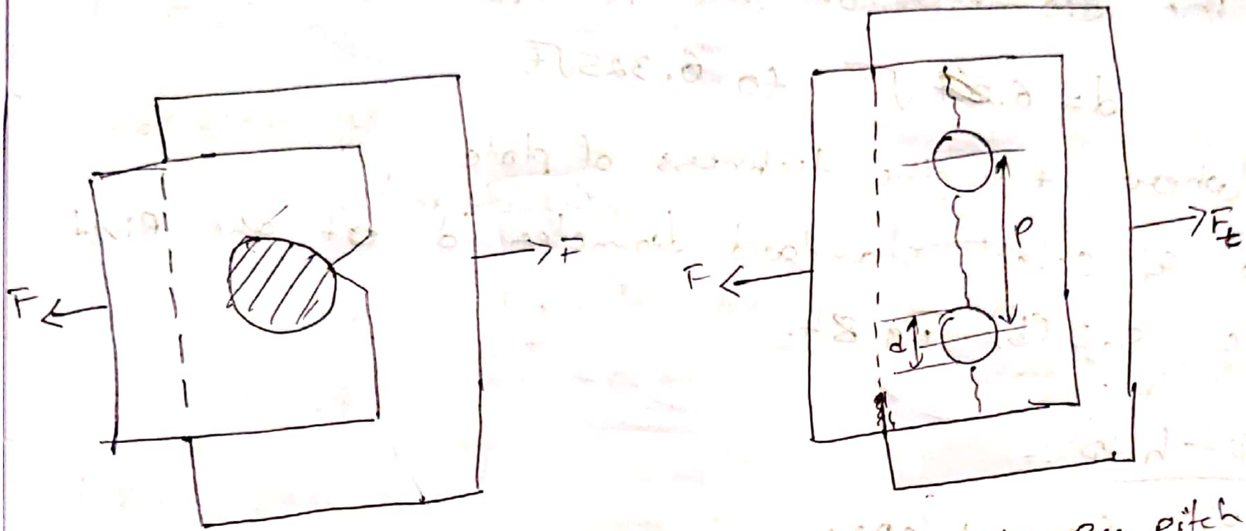
4) Diagonal pitch (P_d):- In zig zag riveting the distance b/w centre of adjacent rivets in side by side row ~~same~~ is Diagonal pitch.

Modes of failure

The Revit Joint can fail in one (or) more ways as mentioned below.

1) Tearing of plate
2) shearing of rivets
3) Crushing of rivets

1) Tearing of plate :- The Joint may fail due to tearing of plate at margin (or) Tearing of plate along the line of rivet holes.

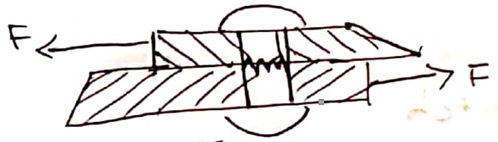


Tearing strength per pitch length

$$F_t = \sigma_t (P-d) t$$

2) Shearing of rivets

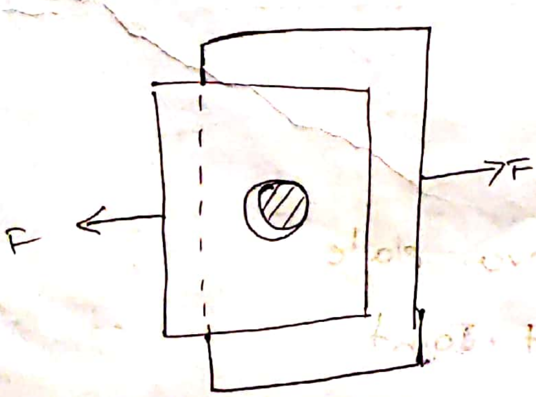
The Joint may fail due to shearing of rivets are shown in figure.



$$\tau = \frac{F}{A}$$

3) Crushing of rivets:-

when the Joint is loaded compressive stress is induced over a contact area b/w rivets & the plate



Design Procedure for Rivetted Joint to connect two plates of thickness 't'

Step 1:- The diameter of the Rivets

$$d = 6.04\sqrt{t} \text{ to } 6.325\sqrt{t}$$

where, t is the tickness of plate

Find 'd' & select standard diameter 'd' of the Rivet from table 5.3 (b) Pg 84.

Step 2:- Pitch 'p' :-

a) In General case

$$\therefore P = \frac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d \rightarrow 5.12(a) \text{ Pg } 81$$

b) As per IBR (Indian Boiler regulation), the maximum shorter pitch of the rivet is given by $\therefore P = k_1 t + 41\text{mm}$

~~P = k₁t + 41~~ where k_1 is constant from table 5.4(a) Pg 85

Take the smaller value of the pitch

Step 3 Transverse pitch 'P_t' :-

$$\boxed{P_t = 2.25d} \quad [\text{Range } 2d - 2.5d]$$

Step 4

margin (m) = 1.5 d

Step 5 Thickness of cover plate

a) For lap Joint no cover plate

b) For single cover butt Joint

$$\therefore \boxed{t_1 = 1.125t} \rightarrow 5.4(a) \text{ Pg } 79$$

c) For double cover plates with equal cover

$$\boxed{t_i = 0.625t}$$ → 5.4 (c) pg 80

d) For double cover plates with unequal cover

✓ Thickness of narrow plate

$$\boxed{t_o = 0.625t}$$ → 5.4 (e) pg 80

✓ Thickness of wider plate

$$\boxed{t_i = 0.75t}$$ → 5.4 (f) pg 80

Step 4 Efficiency of Joint

i) efficiency of plate

$$\eta_p = \frac{P-d}{P}$$ → 5.9 (E) pg 81

ii) efficiency of rivet in shear

$$\eta_s = \frac{\pi/4 \cdot d^2 (n_1 + 1.875 n_2) \tau}{P t \sigma_t}$$ → 5.9 (f) pg 81

iii) efficiency of rivet in crushing

$$\eta = \frac{(n_1 t_i/t + n_2)\sigma_c}{(n_1 t_i/t + n_2)\sigma_c + \sigma_t}$$ → 5.7 pg (80)

To find efficiency of lap joint

put $t_i/t = 1$ & $n_2 = 0$

The efficiency of Rivetted Joint is the least of above three value the Joint fails where every efficiency is minimum.

Problem

1) Design a double rivetted lap Joint to connect two plate each 20mm thick. The allowable Stress for Rivet & plate are 90MPa in tension & 60MPa in shear & 150MPa in Crushing.

soln :- Double rivetted lap Joint

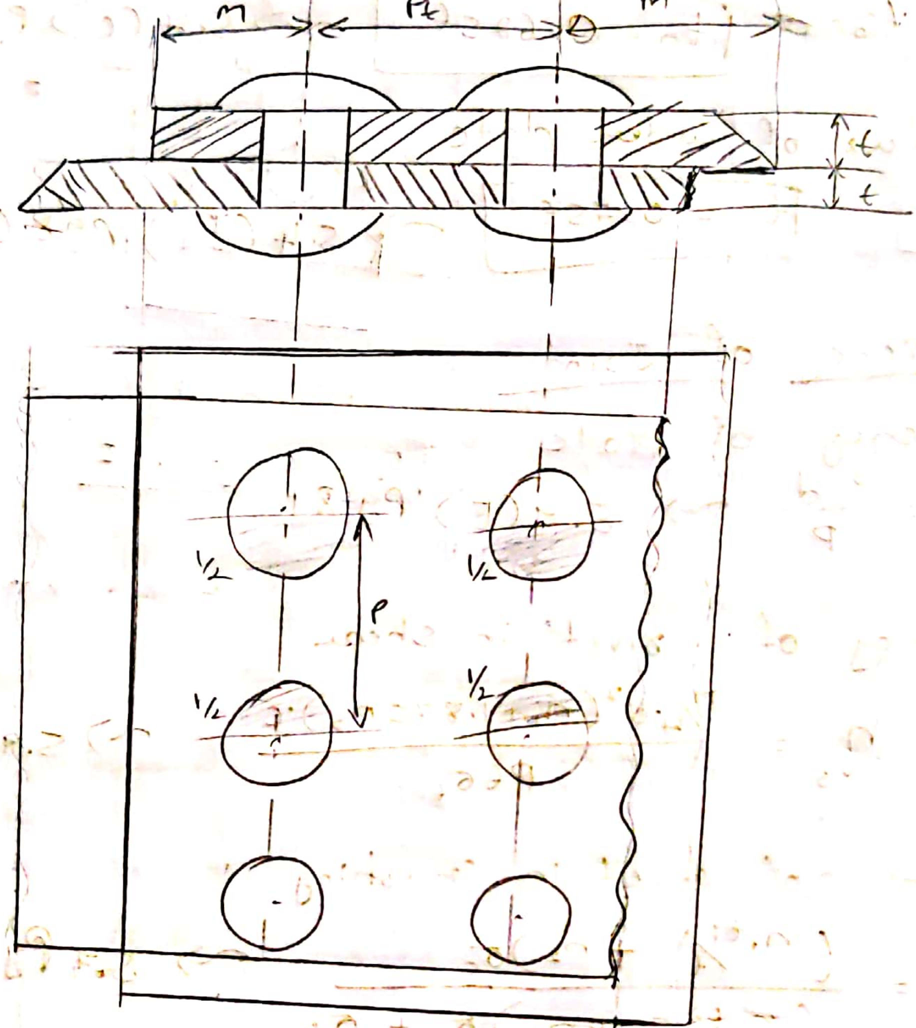


Figure shows a double lap Joint since the type of Rivetting is not mentioned. A Chain type of Rivet is assumed.

Consider one Pitch length mark as P, & theoretically no of rivets per Pitch length

✓ In line 1 $\frac{1}{2} + \frac{1}{2} = 1$ (Rivet in single shear)

✓ In line 2 $\frac{1}{2} + \frac{1}{2} = 1$ (Rivet in single shear)

Total no of Rivets per pitch length in single shear

$n_1 = 1 + 1 = 2$

Double shear $n_2 = 0$

$t = 20mm$

$\sigma_t = 90MPa$, $\tau = 60MPa$

$\sigma_c = 150MPa$

i) $d = 6.~~04~~ \sqrt{t}$ to $6.325\sqrt{t}$

$d = 6.~~04~~ \sqrt{20}$ to $6.325\sqrt{20}$

$\therefore d = 26.8328mm$ to $28.2862mm$

From Table 5.3(b) Pg 84 standard diameter of rivet

$d = 27mm$

ii) a) $P = \frac{(n_1 + 1.875n_2)\pi d^2 \tau}{4t\sigma_t} + d$

$P = \frac{(2+0)\pi (27)^2 \times 60}{4 \times 20 \times 90} + 27$

$P = 65.1703mm \approx 66mm$

b) $P = k_1 t + 41mm$

~~Ko~~ From table 5.4 (a) Pg 85

For no of rivets

$k_1 = 2.62$

$P = 2.62 \times 20 + 41mm$

$P = 93.4mm$

The smaller value of the pitch $= 66mm$ (choose shorter value)

iii) $P_t = 2.25d = 2.25 \times 27$

$P_t = 60.75mm \approx 61mm$

iv) a) efficiency of plate

$\eta_p = \frac{P-d}{P} = \frac{66-27}{66} = 59.09\%$

b) efficiency of rivet in shear

$$\eta_s = \frac{\frac{\pi d^2}{4}(n_1 + 1.875 n_2)\tau}{p t \sigma_t}$$

$$= \frac{\pi \times 27^2/4 (2+0) 60}{66 \times 20 \times 90}$$

$\eta_s = 0.5783$

$\eta_s = 57.83\%$

c) Efficiency of rivet in crushing

$$\eta = \frac{(n_1 t_i/t + n_2 \cdot 2)\sigma_c}{(n_1 t_i/t + n_2)\sigma_c + \sigma_t}$$

For lap joint $t_i/t = 1$

$$\eta = \frac{(2+0)150}{(2+0)150 + 90}$$

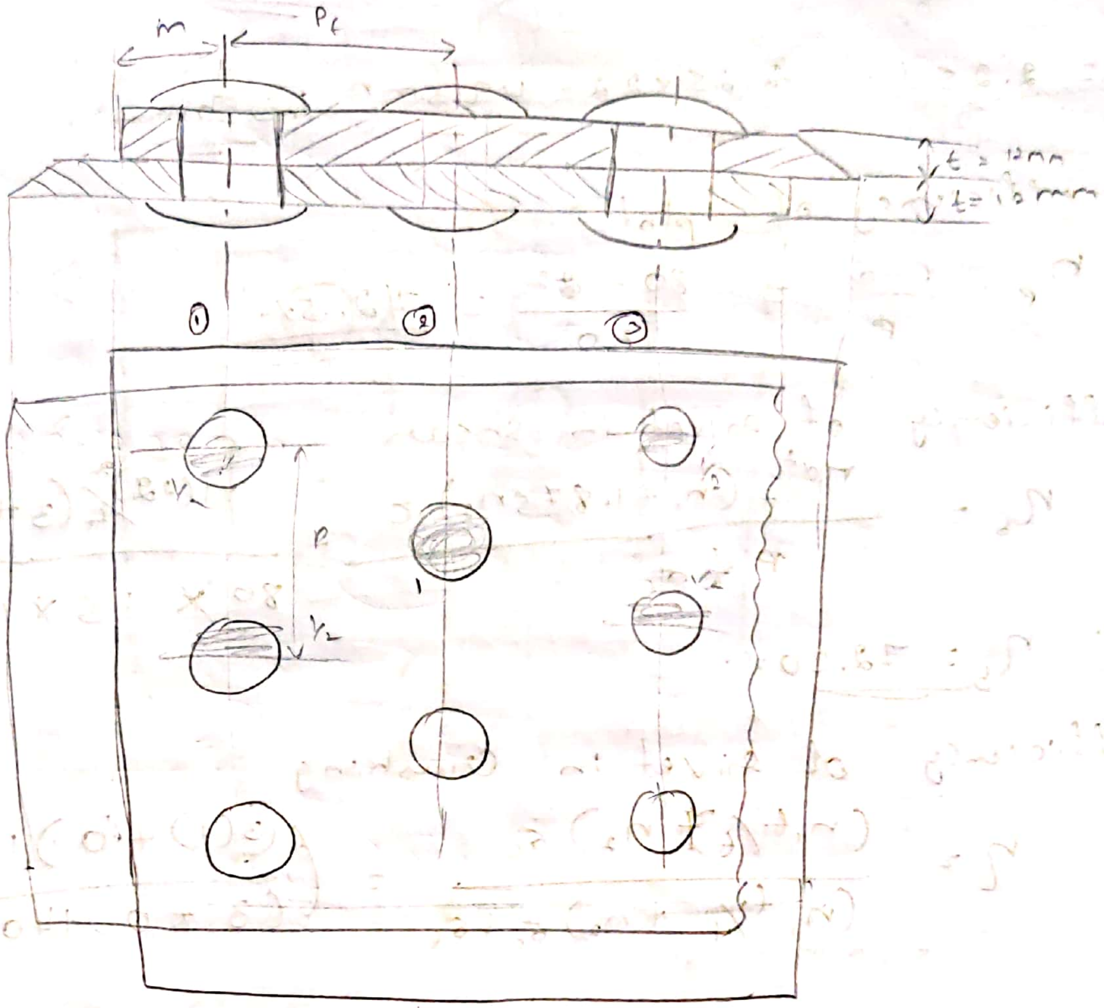
$\eta = 0.7692$

$\eta = 76.92\%$

(Suggest small efficiency value)

Efficiency of the lap joint = 57.83%

2) Design a triple rivetted zig za lap joint to connect two plates each 12mm thick. Draw a neat sketch of the joint. Take $\sigma_t = 115 MPa$, $\tau = 70 MPa$, & $\sigma_c = 140 MPa$.



Total no of Rivets per pitch length in sing shear

$n_1 = 1 + 1 + 1 = \underline{3}$

Double shear $n_2 = 0$

$t = 12mm$

$\sigma_t = 115MPa$

$\tau = 70MPa$

$\sigma_c = 140MPa$

i) $d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$= 6 \times \sqrt{12}$ to $6.325\sqrt{12}$

$d = 20.784$ mm to 21.91 mm

From Table 5.3(b) pg 84

standard diameter of rivet

$\underline{d = 22mm}$

ii) a) $p = \frac{(n_1 + 1.875n_2)\pi d^2 \tau}{4 t \sigma_t} + d$

$p = \frac{(3 + 1.875(0))\pi (22)^2 \times 70}{4 \times 12 \times 115} + 22$

$\underline{p = 79.84628mm}$

b) $p = k_t t + 41mm$

From table 5.4(a) pg 85

For no of rivets

$k_t = 3.47$

$p = 3.47 \times 12 + 41$

$\therefore \underline{p = 82.64mm}$

The smallest value of pitch $= p = 79.8462\ mm \approx 80mm$

iii) $P_t = 2.25d = 2.25 \times 22 = 49.5mm \approx 50mm$

iv) a) efficiency of plate

$$\eta_p = \frac{p-d}{p} = \frac{80-22}{80} = 72.5\%$$

b) efficiency of rivet in shear

$$\eta_s = \frac{\pi d^2/4\,(n_1 + 1.875 n_2)\,\tau}{p\, t\, \sigma_t} = \frac{\pi (22)^2/4\,(3 + 1.875(0))\,\tau}{80 \times 115 \times 12}$$

$\therefore \eta_s = 72.30\%$

c) efficiency of rivet in crushing

$$\eta = \frac{(n_1 t_1/t + n_2)\,\sigma_c}{(n_1 t_1/t + n_2)\,\sigma_c + \sigma_t} = \left(\frac{(3(1)+0)140}{(3+0)140+115}\right)$$

$\therefore \eta = 78.50\%$

(suggest the smallest efficiency value)

Efficiency of the lap Joint $= 72.3\%$

3) Design single rivetted single cover butt Joint to connect two plates 30mm thick. The yield stress for plate & rivet material is 324MPa use FOS of 2.5 for tension, 4 for shear & 2 for crushing.

Soln :- $t = 30mm$

$\sigma_y = 324MPa$

$n_t = 2.5$

$n_\tau = 4$

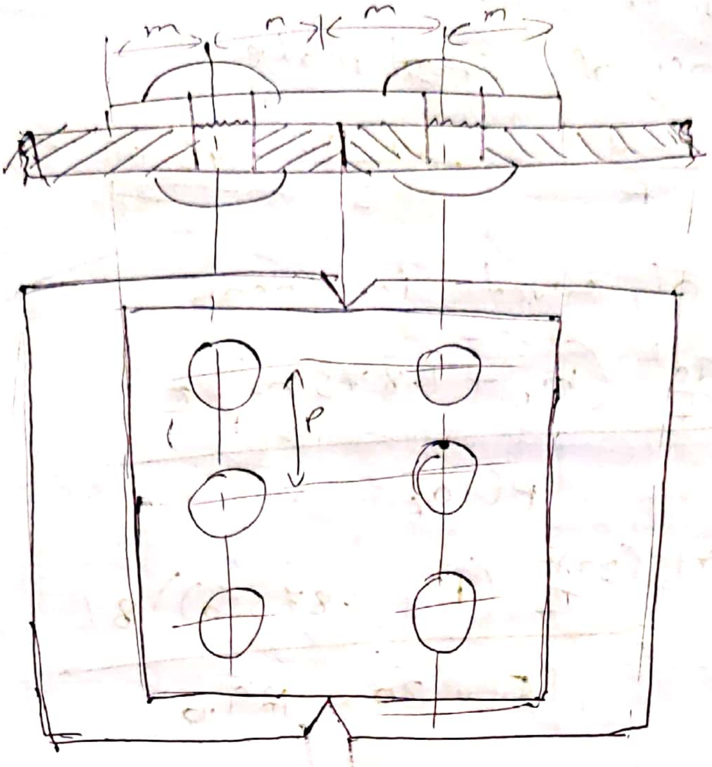
$n_c = 2$

$$\sigma_t = \frac{\sigma_y}{n_t} = \frac{324}{2.5}$$

$\sigma_t = 129.6 MPa$

$$\tau = \frac{\sigma_y}{n_\tau} = \frac{324}{4}$$

$\tau = 81 MPa$



$\sigma_c = \frac{\sigma_y}{2} = \frac{324}{2}$

$\sigma_c = 162 MPa$

$t = 30mm$

$n_1 = 1$

$n_2 = 0$

i) diameter $= 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{30}$ to $6.325\sqrt{30}$

$d = 32.8633$ to $34.643mm$

From table 5.3(b) pg 84

$\therefore d = 33mm$

ii) a) $p = \frac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_c} + d$

$= \frac{(1 + 1.875(0))\pi (33^2) 81}{4 \times 30 \times 129.6} + 33$

$\therefore p = 50.81872 mm$

b) $p = k_1 t + 44mm$ Table 5.4 pg 85 $k_1 = 1.53$

$p = 1.53 \times 30 + 44mm$

$p = 89.9 mm$

the smaller value of pitch $p = 50.8187mm \approx 51mm$

iii) margin (m) $= 1.5d = 1.5 \times 33 = 49.5mm \approx 50mm$

iv) $t_1 = 1.125t = 1.125 \times 30$

$t_1 = 33.75mm = 34mm$

efficiency of Joint

IV) ~~effici~~ a) efficiency of ~~rivet~~ plate :

$$\eta_p = \frac{p-d}{p} = \frac{51-33}{51} = 35.29\%$$

b) efficiency of rivet in shear

$$\eta_b = \frac{\frac{\pi d^2}{4}(n_1 + 1.875 n_2)\tau}{p t \sigma_t}$$

$$= \frac{\pi \frac{(33)^2}{4}(1 + 1.875(0))81}{51 \times 30 \times 129.6}$$

$$\eta_b = 0.3493 = 34.93\%$$

c) efficiency of rivet in crushing

$$\eta = \frac{(n_1(t_1/t) + n_2)\sigma_c}{(n_1 t_1/t + n_2)\sigma_c + \sigma_t}$$

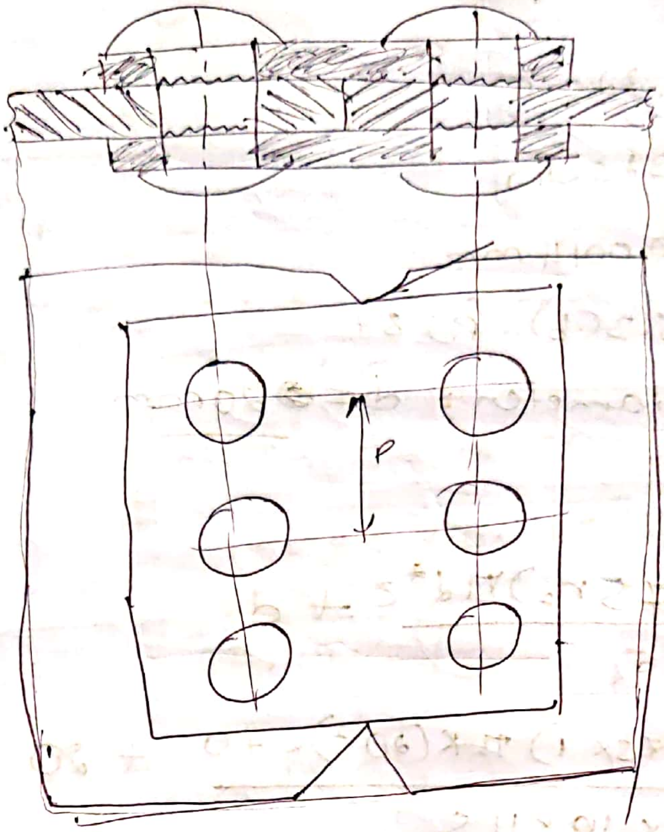
$$\eta = \frac{(1(34/30) + 0))162}{(1(34/30) + 0)162 + 129.6}$$

$$\eta = 0.586207$$

$$\boxed{\eta = 58.62\%}$$

efficiency Butt Joint $\eta = 34.93\%$

E) single riveted Butt Joint with double cover Plate.



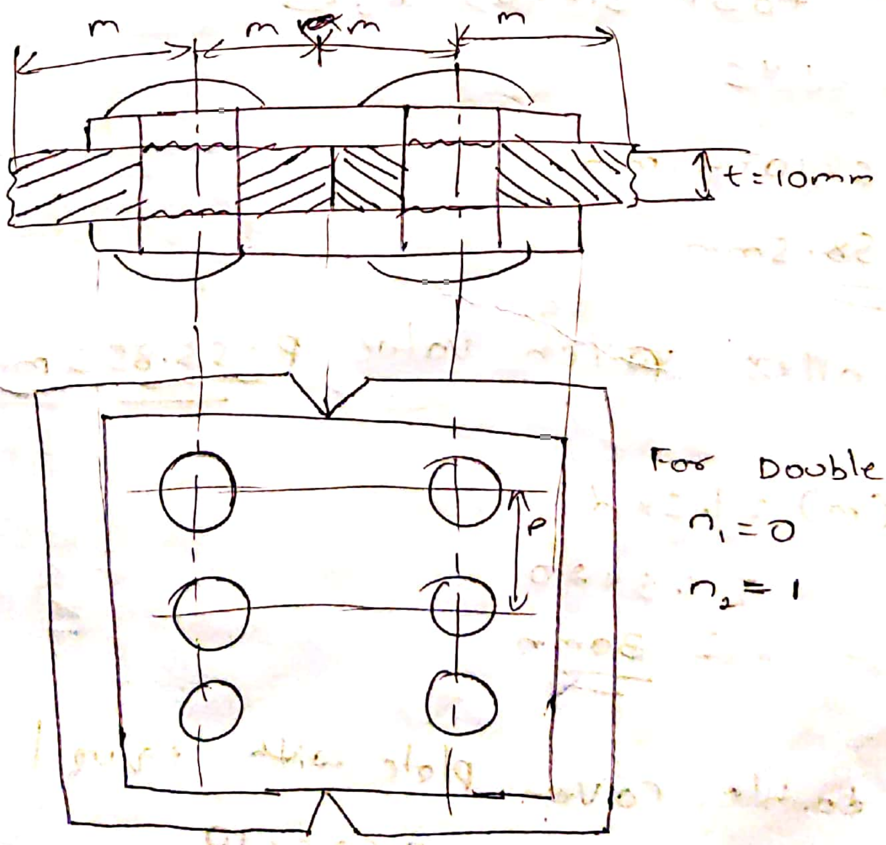
Dooble shear so

$n_1 = 0$

For Double shear

$n_2 = 1$

5) Design a single rivetted double cover butt Joint to connect two plates 10mm thick. take allowable tensile stress 115MPa & $\tau_{all} = 70MPa$ & allowable crushing stress 140MPa



For Double shear

$n_1 = 0$

$n_2 = 1$

$\sigma_{t\,all} = 115MPa$

$\tau_{all} = 70MPa$

$\sigma_c = 140MPa$

The diameter of the rivet

$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{10}$ to $6.325\sqrt{10}$

$d = 18.973$ to 20.0014 mm

From the table 5.3(b) pg 84

the standard diameter $= d = 20$ mm

Pitch

a) $p = \frac{(n_1 + 1.875 n_2) \pi d^2 \tau}{4 t \sigma_t} + d$

$p = \frac{(0 + 1.875 \times 1) \pi \times (20^2) \times 70}{4 \times 10 \times 115} + 20$

$p = 55.855$ mm

b) $p = k_1 t + 41$ mm

From table 5.4 (a) pg 85

$k_1 = 1.75$

$p = 1.75 \times 10 + 41$ mm

$p = 58.5$ mm

The smallest pitch value $p = 55.855$ mm

margin (m) $= 1.5 \times d$

$= 1.5 \times 20$

$= 30$ mm

c) For double cover plate with equal

$t_1 = 0.625 t = 0.625 \times 10$

$t_1 = 6.25$ mm

v) Efficiency of ~~riveted shear~~ Joint

i) $\eta_p = \frac{p-d}{p} = \frac{55.855-20}{55.855}$

$\boxed{\eta_p = 64.19\%}$

ii) $\eta_s = \frac{\pi/4\, d^2 (n_1 + 1.875 n_2)\tau}{p t \sigma_t}$

$= \frac{\frac{\pi}{4} \times (20)^2 (0 + 1.875 \times 1)\, 70}{55.855 \times 10 \times 115}$

$\boxed{\eta_s = 64.19\%}$

iii) $\eta = \frac{(n_1 t_1/t + n_2)\sigma_c}{(n_1 t_1/t + n_2)\sigma_c + \sigma_t}$

$\eta = \frac{(0+1)\,140}{(0+1)\,140 + 115}$

$\boxed{\eta = 54.90\%}$

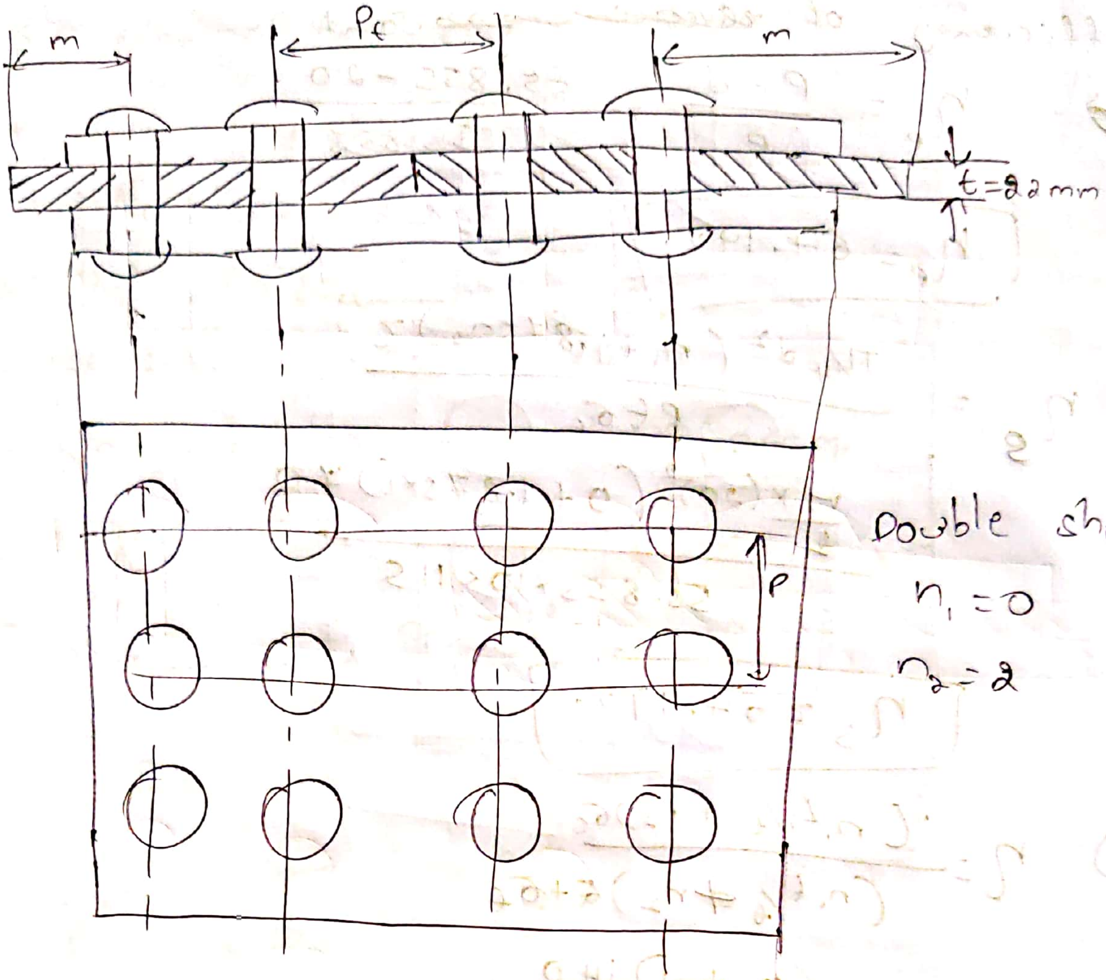
efficiency of the Butt Joint = 54.90%

6) Double riveted Butt Joint with double cover ~~plate~~ equal plate thick 22 mm,

$\sigma_t = 90\,MPa$

$\tau = 60\,MPa$

$\sigma_c = 150\,MPa$



Double shear

$n_1 = 0$

$n_2 = 2$

$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{22}$ to $6.325\sqrt{22}$

$d = 28.14$ to 29.66 mm

From table 5.3(b) Pg 84

The standard diameter $\underline{d = 30mm}$

Pitch

a) $P = \dfrac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d = \dfrac{(0 + 1.875 \times 2)\pi \times (30^2) \times 60}{4 \times 22 \times 90} + 30$

$\underline{P = 110.3248 \text{ mm}}$

b) $P = K_1 t + 44m$

From table 5.12 (b) pg 85

$K_1 = 3.5$

$P = 3.5 \times 22 + 44$

$\underline{P = 121mm}$

Scanned with CamScanner

The smallest pitch value $P = 110.3248 \approx 111\,mm$

✓ $P_t = 2.25d = 2.25 \times 30 = 67.5\,mm$

✓ margine, $m = 1.5 \times 30 = 45\,mm$

✓ ~~stere~~ For double cover plate with equal

$t_1 = 0.625t = 0.625 \times 22$

$t_1 = 13.75\,mm$

✓ i) $\eta_p = \frac{P-d}{P} = \frac{111 - 30}{111} = 72.97\%$

~~η_p~~

ii) $\eta_s = \frac{\frac{\pi}{4} d^2 (n_1 + 1.875 n_2)\tau}{P t \sigma_t} = \frac{\frac{\pi}{4} \times (30^2)(0 + 1.875 \times 2)60}{111 \times 22 \times 90}$

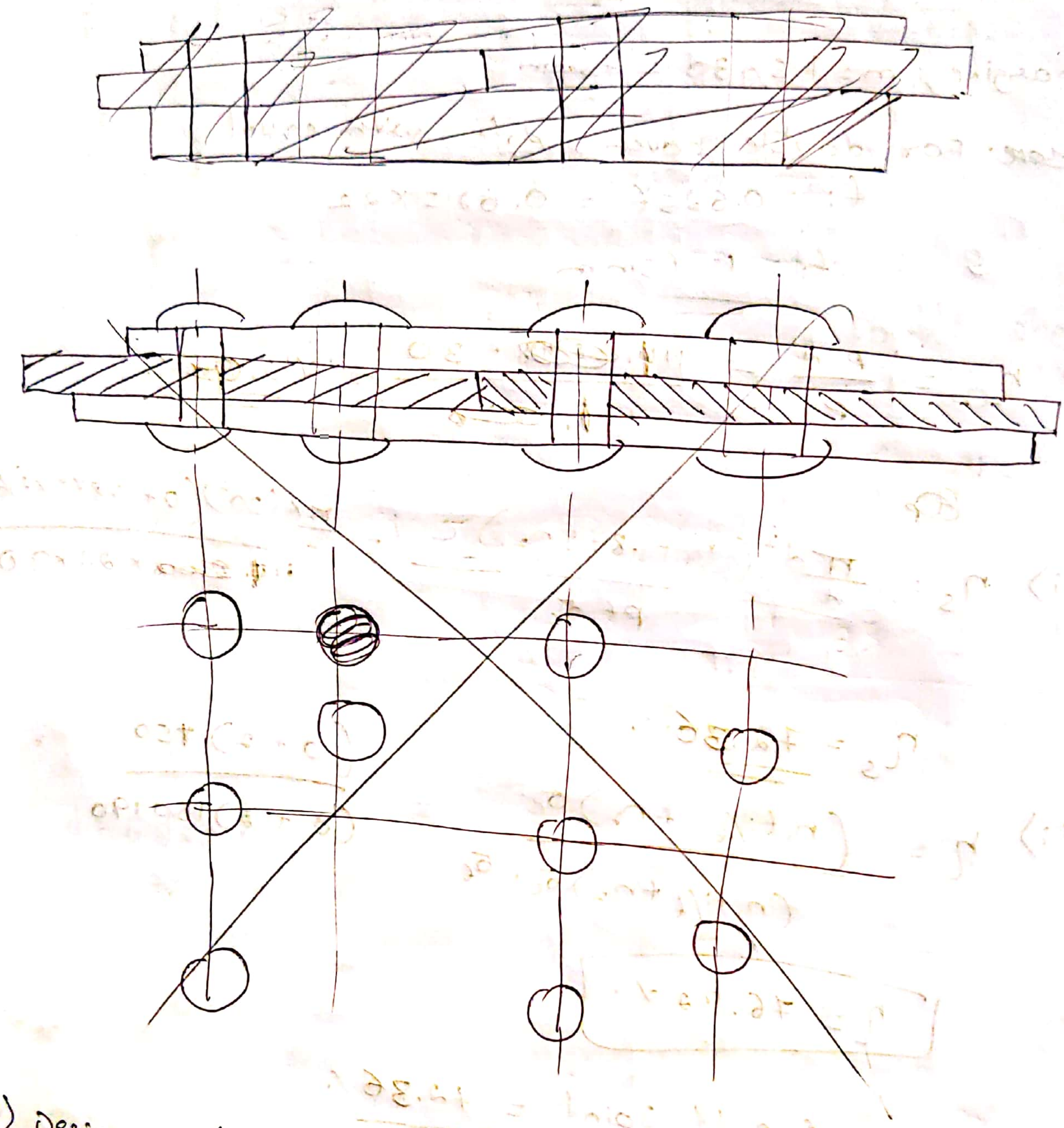
$\eta_s = 72.86\%$

iii) $\eta = \frac{(n_1 t_1/t + n_2)\sigma_c}{(n_1 t_1/t + n_2)\sigma_c + \sigma_t} = \frac{(0+2)150}{(0+2)150+90}$

$\eta = 76.92\%$

Efficiency of Butt Joint $= 72.86\%$

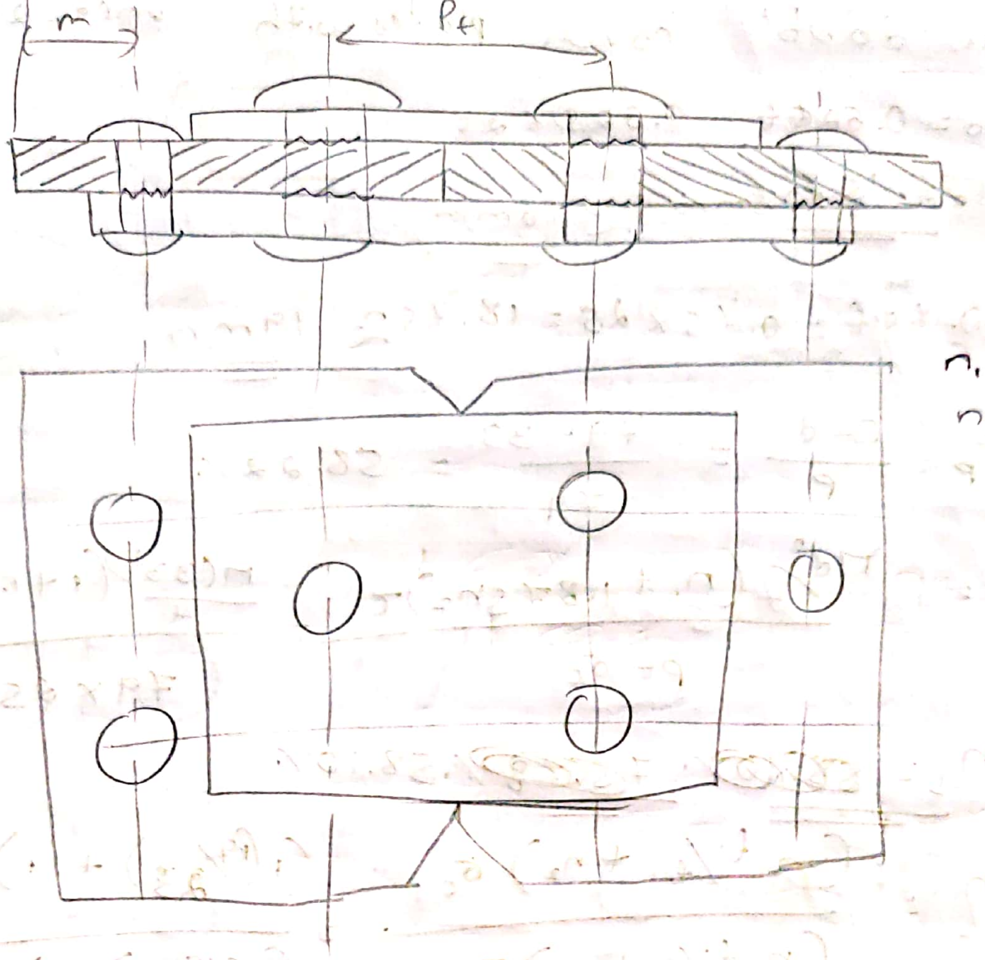
~~7) Double Rivetted Butt Joint, Double Cover Plate with unequal length, Zig Zag arrangement~~



7) Design a double rivetted double cover Butt joint with unequal covers & zig zag rivetting to connect two plates of 25mm thick assume $\sigma_t = 150MPa$

$\tau = 70MPa$

$\sigma_c = 140MPa$



$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{25}$ to $6.325\sqrt{25}$

$d = 30$ to 31.625 mm

From Table 5.3(b) pg 84

The standard diameter, $d = 33$ mm

pitch

a) $P = \dfrac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d = \dfrac{(1 + 1.875\times1)\pi(33^2)\times 70}{4\times25\times150} + 33$

$P = 78.9010$ mm

$P = K_1 t + 44$ mm =

From the table 5.4(a) pg 85

$K_1 = 3.5$

$P = 3.5\times25 + 44$ mm $= 131.5$ mm

The smallest pitch value $= 78.9010$ mm ≈ 79 mm

$P_t = 2.25\times d = 2.25\times33 = 74.25$ mm ≈ 75 mm

$m = 1.5\times d = 1.5\times33 = 49.5$ mm ≈ 50 mm

For double cover plates with unequal cover

$t_o = 0.625t = 0.625 \times 25$

$t_o = 15.625\,mm \approx 16\,mm$

$t_i = 0.75t = 0.75 \times 25 = 18.75 \approx 19\,mm$

i) $\eta_p = \frac{p-d}{p} = \frac{79-33}{79} = 58.22\%$

ii) $\eta_s = \frac{\pi d^2/4\,(n_1 + 1.875 n_2)\tau}{p t \sigma_t} = \frac{\frac{\pi (33^2)}{4}(1 + 1.875\times1)70}{79 \times 25 \times 150}$

$\eta_s = 58.10\%$

iii) $\eta = \frac{(n_1\, t_i/t + n_2)\sigma_c}{(n_1\, t_i/t + n_2)\sigma_c + \sigma_t} = \frac{(1(19/25) + 1)140}{(1(19/25)+1)140 + 150}$

$\eta = 68.179\%$

$\eta = 58.22\%$

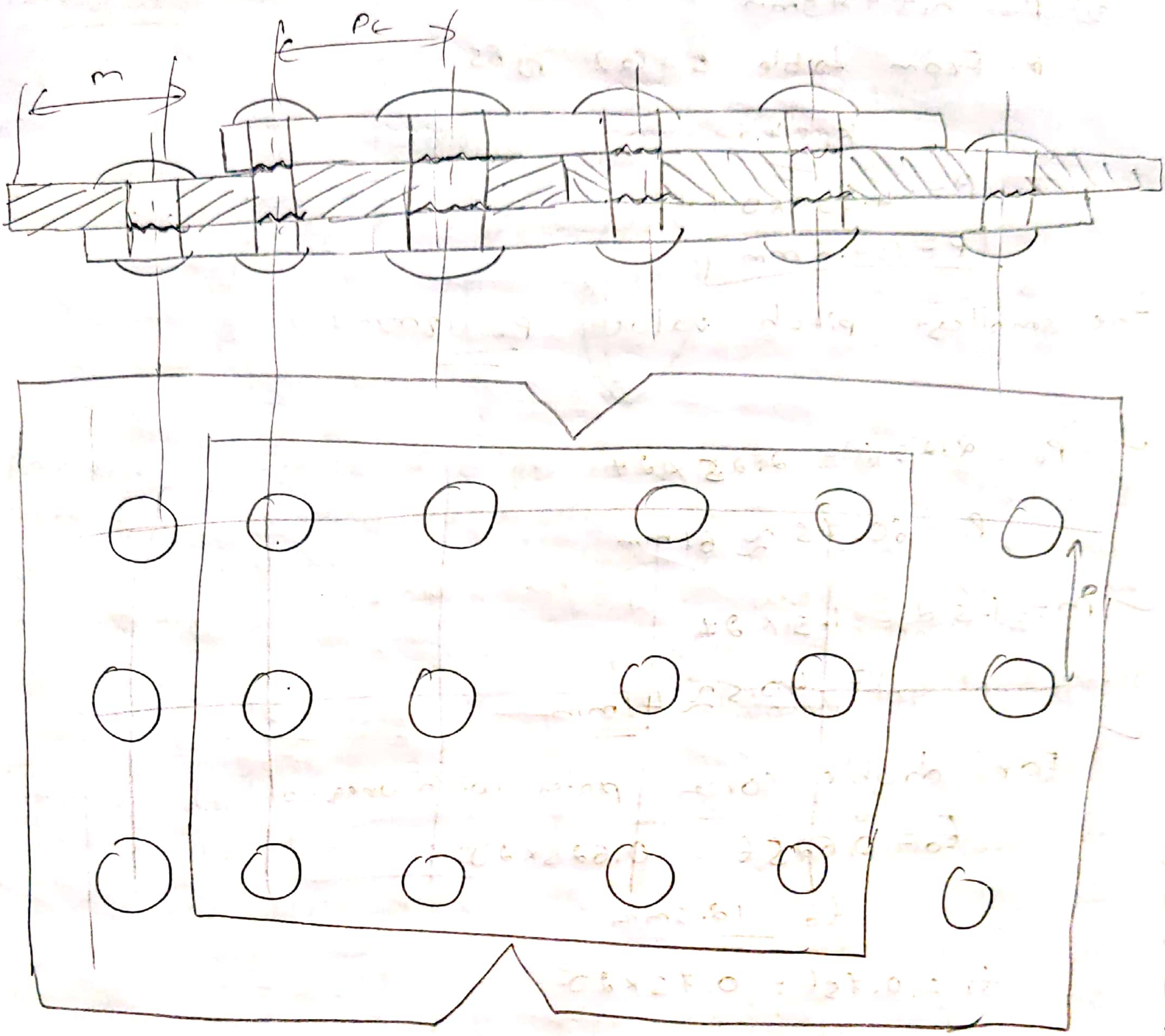
8) Design a Triple rivetted Butt Joint unequal cover plate

8) Design a Triple rivetted double cover butt joint with unequal cover plate to connect two plates of 20 mm thickness,

$\sigma_t = 90\,MPa$

$\tau = 60\,MPa$

$\sigma_c = 150\,MPa$



$n_1 = 1$, $n_2 = 2$ } $n_1 = 1$, $n_2 = 2$

$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{20}$ to $6.325\sqrt{20}$

$d = 26.83$ to 28.285 mm

From Table 5.3 (b) pg 84

the standard diameter is 27mm

pitch

a) $p = \frac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d = \frac{(1 + 1.875 \times 2)\pi \times 27^2 \times 60}{4 \times 20 \times 90} + 27$

$P = 117.65 \approx 118$ mm

b) $P = k_1 t + 45 mm$

From table 5.4 (a) pg 85

$k_1 = 4.63$

$P = 4.63 \times 20 + 45$

$P = 137.6 mm$

The smallest pitch value $P = 118 mm$.

$P_t = 2.25 d = 2.25 \times 27$

$P_t = 60.75 \approx 61 mm$

$m = 1.5 d = 1.5 \times 27$

$= 40.5 \approx 41 mm$

For double cover plates with unequal

$t_o = 0.625 t = 0.625 \times 20$

$t_o = 12.5 mm$

$t_i = 0.75 t = 0.75 \times 20$

$t_i = 15 mm$

i) $\eta_p = \frac{P - d}{P} = \frac{118 - 27}{118}$

$\eta_p = 77.11\%$

ii) $\eta_s = \frac{\pi d^2/4 (n_1 + 1.875 n_2) \tau}{P t \sigma_t}$

$\eta_s = \frac{\pi \times 27^2/4 (1 + 1.875 \times 2) 60}{118 \times 20 \times 90}$

$\eta_s = 76.82\%$

iii) $\eta = \frac{(n_1 t_i/t + n_2) \sigma_c}{(n_1 t_i/t + n_2) \sigma_c + \sigma_t}$

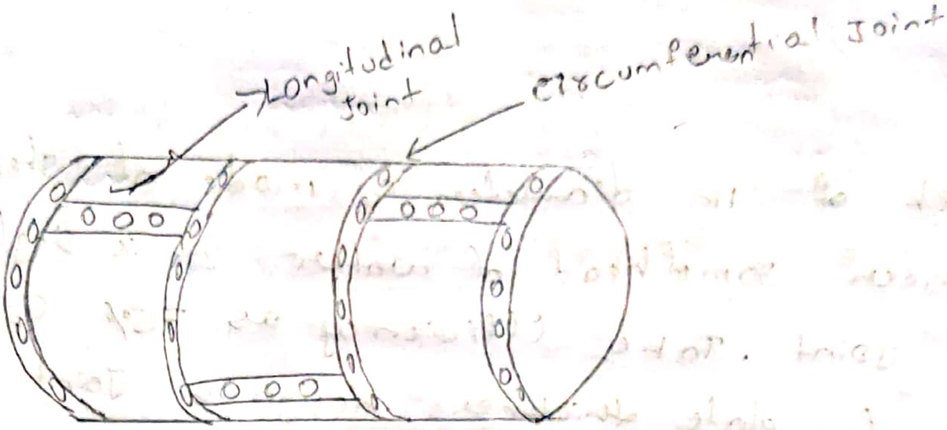
$\eta_c = \left(\frac{1 (15/20) + 2) 150}{(1 (15/20) + 2) 150 + 90} \right.$

$\eta = 82.08$

The efficiency of bolt Joint

$\eta = 76.82\%$

Pressure vessels :-



Pressure vessels are generally fabricated by Joining several plates using the rivetted Joint. the rivetted Joint which is use to form a cylinder is known as longitudinal Joint : the rivetted Joint which is used to connect two cylinder are known as circumferential Joint.

The circumferential Joint is always lap Joint (preff-erable double rivetted).

The longitudinal Joint is always butt Joint with unequal cover plate).

(Prefferable triple rivetted

Design procedure for Boiler Point :-

1) Longitudinal Joint :-

a) Thickness of plate, $t = \frac{P_i D}{2\sigma_t \eta} + C$ ⟶ [eq s.l pg 7a]

where P_i is pressure acting inside the cylinder (or) Boiler

D Internal diameter of pressure vessels.

η Efficiency of longitudinal Joint.

C corrosion allowance range 1 to 3mm

b) Diameter of the rivet

$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

select standard dimeter using table in DHB

c) pitch

same as designing in rivet.

problem

1) A penstock of 1m diameter & made of steel plates is operated under 30m of head of water. It is single Rivetted logitudinal joint. Take efficiency as 75% & 2mm corrosion allowance for plate thickness design a joint. The following allowable stress may be use. $\sigma_t = 120 MPa$.

$\tau = 96 MPa$

$\sigma_c = 162 MPa$.

*** [10m of head of water = 1bar = 0.1MPa]

Soln:-

D = 1.0m = 1000mm

head of water = 30m = 3bar = 0.3MPa

logitudinal Joint & single rivetted

$\eta = 0.75$

c = 2mm

$\sigma_t = 120 MPa$

$\tau = 96 MPa$

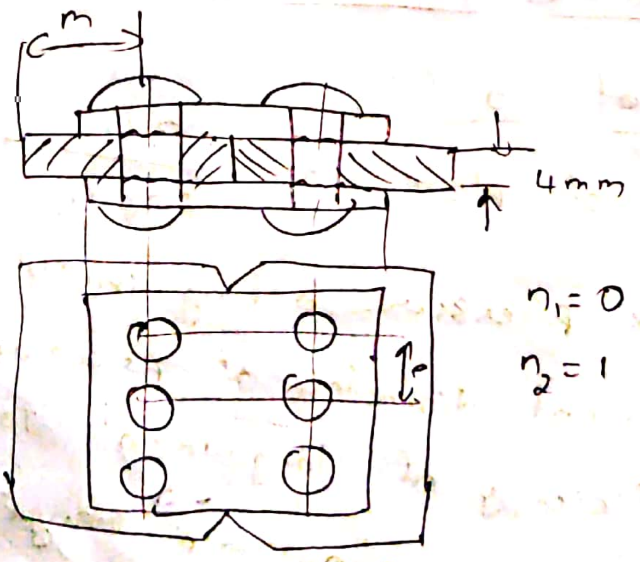
$\sigma_c = 162 MPa$

t = ?

$$t = \frac{P_i D}{2\sigma_t \eta} + c$$

$$t = \frac{0.3 \times 1000}{2 \times 120 \times 0.75} + 2$$

$\therefore t = 3.667mm \simeq 4mm$



$n_1 = 0$

$n_2 = 1$

✓ Diameter

$d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 6\sqrt{4}$ to $6.325\sqrt{4}$

d = 12 to 12.65mm

From the table 5.3(b) pg 84

The standard diameter $d = 12$ mm

pitch 'p'

a) $P = \dfrac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d$

$P = \dfrac{(0 + 1.875 \times 1)\pi \times (12)^2 \times 96}{4 \times 4 \times 120} + 12$

$P = \underline{54.4115}$ mm

b) $P = k_1 t + 41$mm

From table 5.4 (a) pg 85

$k_1 = 1.53$

$P = 1.53 \times 4 + 41$mm

$P = 47.12$mm $\simeq \underline{48}$mm

The smallest pitch value $P = \underline{48}$mm

margin $m = 1.5d = 1.5 \times 12 = 18$mm

For double cover plates with equal

$t_1 = 0.625t = 0.625 \times 4 = \underline{2.5}$mm

i) $\eta_p = \dfrac{P-d}{P} = \dfrac{48-12}{48} = 75\%$

ii) $\eta_s = \dfrac{\pi d^2/4 \,(n_1 + 1.875 n_2)\tau}{P t \sigma_t} = \dfrac{\pi \times 12^2/4 \,(0 + 1.875 \times 1) 96}{48 \times 4 \times 120}$

$\eta_s = 88.35\%$

iii) $\eta = \dfrac{(n_1 t_1/t + n_2)\sigma_c}{(n_1 t_1/t + n_2)\sigma_c + \sigma_t} = \dfrac{(0 + 1)162}{(0+1)162 + 120}$

$\eta = \underline{57.44\%}$ efficiency of the butt joint

$\therefore \eta = 57.44\%$

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2) Design a double riveted double strap butt joint for longitudinal seam of boiler of dia 1.3m, with a steam pressure of 2.9 MPa. The working stresses are to be used are 77 MPa in tension, 54 MPa in shear, 120 MPa in crushing, Assume joint efficiency as 81%.

Sol^n

$D = 1.3m = 1300mm$

$P = 2.4 MPa$

$\sigma_t = 77$

$\tau = 54$

$\sigma_c = 120$

$\eta = 0.81$

$$t = \frac{P.D}{2\sigma_t \eta} + C$$

$$= \frac{2.4 \times 1300}{2 \times 77 \times 0.81} + 2$$

$t = 27.012 mm \simeq 28mm$

ii) $d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$= 31.75$ to 33.46

$d = 36mm$

$n_1 = 0$

$n_2 = 9$

iii) a) $$P = \frac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_t} + d$$

$P = 131.6 mm$

b) $P = K_1 t + 41$

$P = 3.5(27) + 41$

$P = 135.5mm$

iv) $m = 1.5d = 54mm$

v) $$\eta = \frac{P-d}{P} = 72.72\%$$

vi) $$\eta = \frac{\pi/4 \, d^2 (n_1 + 1.875 n_2)\tau}{P t \sigma_t} = 72.42\%$$

vii) $$\eta = \frac{(n_1 t_1/t + n_2) \cdot \sigma_c}{(n_1 (t_1/t) + n_2)\sigma_c + \sigma_c} = 75.7\%$$

$t_1 = 0.625t$

$t_1 = 17.5$

$\therefore \eta = 72.42\%$

Design procedure for circumferential joints

The plates to be riveted being same in both longitudinal & circumferential Joints (t being same)

The diameter of rivets, Transverse pitch & margin are same.

Step 1:- Total steam load → F = The internal dia. Area of pressure vessel × steam press

$$\therefore F = \left(\frac{\pi}{4} D_i^2\right) \times P_f$$

Step 2:- strength of each rivet

a) In shear

$$\therefore \boxed{F_\tau = \frac{\pi}{4} d^2 \tau}$$

b) In crushing.

$$\boxed{F_c = d t \sigma_c}$$

Step:- min strength of rivet ⇒ F_1 = least of above values.

Step 3:- no of rivets required = $\frac{\text{Total steam load}}{\text{min. strength of rivet}}$

$$\therefore \boxed{i = \frac{F}{F_1}}$$

Step 4:-

$$\text{Rivets/row} = \frac{\text{Total no of rivets}}{\text{no of rows of rivets}} = \frac{i}{\text{no of rows of rivets}}$$

no of rivets :- 1) For single riveted Joint = 1
of row
2) For double riveted Joint. = 2

Step 5:- pitch of circumferential Joint

$$P_c = \frac{\text{Circumference}}{\text{Rivets/rows}} = \frac{\pi D_i}{(\text{rivets/rows})}$$

Step 6 :- efficiencies :-

1) $\eta_p = \frac{P_c - d}{P_c}$ → plate

2) $\eta_s = \frac{\pi/4 \, d^2 (n_1 + 1.875 n_2) \tau}{P_c t \sigma_t}$

3) $\eta = \frac{(n_1 \frac{t_1}{t} + n_2)\sigma_c}{(n_1 t_1/t + n_2)\sigma_c + \sigma_t}$

∴ efficiency (or) boiler Joints is least (or) above 3 values (3 from longitudinal joint & 3 for circumferential joint).

i) Design the main dimension for longitudinal & circumferential joints for boiler whose inner dia is 1.7 m & steam pressure of 2.05 MPa. The rivet in double shear will have an effective resistance not greater than 87.5% over that in single shear. Assume $\sigma_t = 90$ MPa, $\tau = 60$ MPa, $\sigma_c = 150$ MPa, η (or) Joint 75%. C = 2 mm

Sol^n $d = 1.7\text{m} = 1700\text{mm}$

$P = 2.05$ MPa

$\eta = 0.75$

$n = 1$, $n = 2$ } for longitudinal Joint

i) $t = \frac{P.D}{2\sigma_t \eta} + C$

$t = 27.8 \approx 28\text{mm}$

ii) $d = 6\sqrt{t}$ to $6.325\sqrt{t}$

$d = 31.74$ to 33.46

∴ $d = 33\text{mm}$

iii) $P = \frac{(n_1 + 1.875 n_2) \pi d^2 \tau}{\eta + \sigma_b}$

$P = 129.7 mm$

$P = k.t + c$

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2) Design the longitudinal & circumferential joint for a Boiler of 2m diameter subjected to a pressure of 1MPa. The longitudinal joint is a triple rivetted butt joint with equal covers & efficiency 85%. The circumferencial joint of double rivetted lap joint. The pitch of the outter row is twice the pitch of inner row. The yield stress for plate & rivet material is 353MPa. Take FOS = n = 3 for tension, FOS = 5 for shear & FOS = 2 for crushing.

Soln:-

$D_i = 2m = 2 \times 10^3 mm$

$P_f = 1 MPa$

$\eta = 0.85$

$\sigma_y = 353 MPa$

For tension

$\sigma_{all_t} = \frac{\sigma_y}{n}$

$\therefore \sigma_{all_t} = \frac{353}{3} = 117.667 MPa$

For Shear

$\tau_{all} = \frac{\sigma_y}{n}$

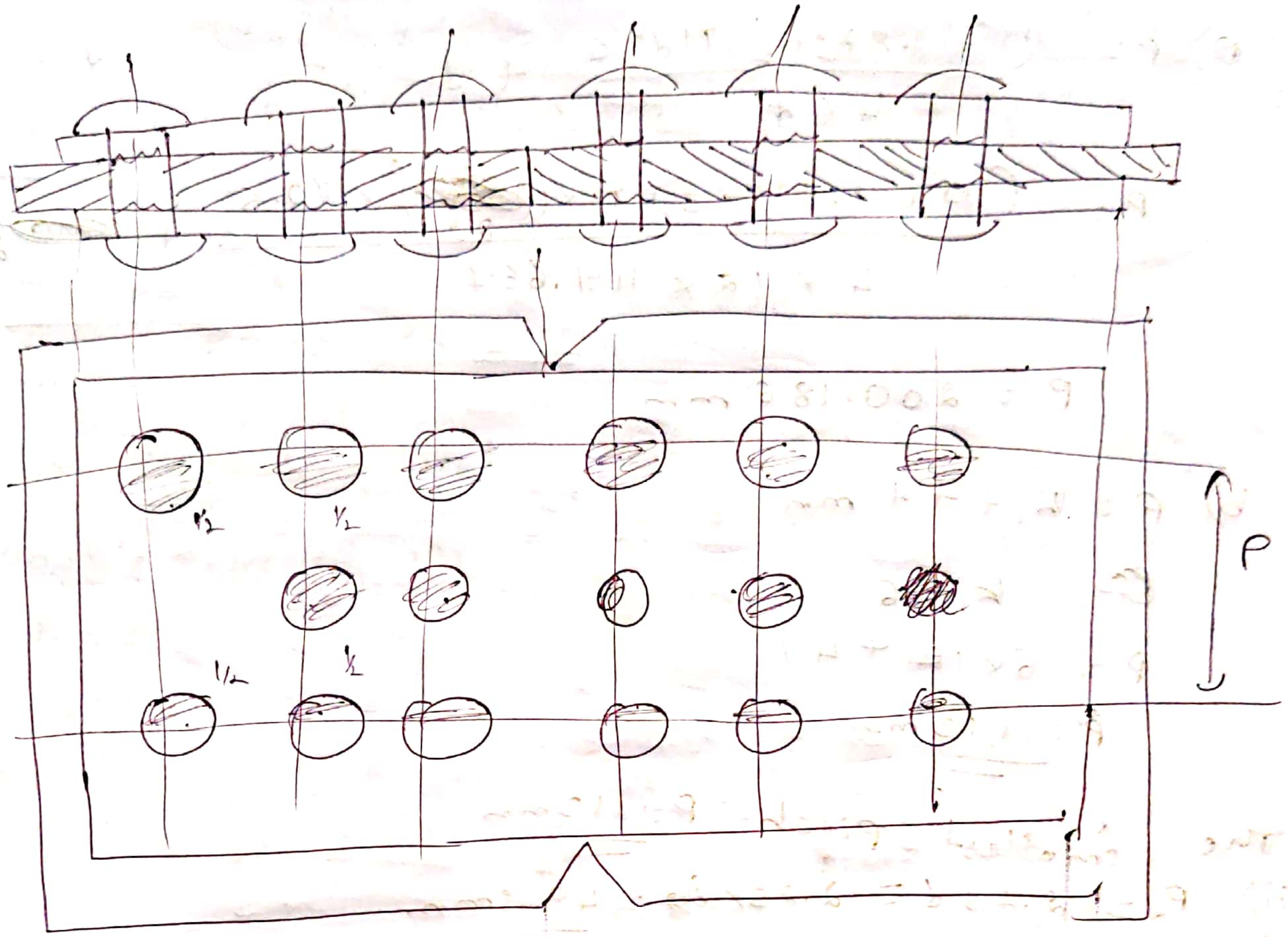
$\tau_{all} = \frac{353}{5}$

$\therefore \tau_{all} = 70.6 MPa$

For crushing

$\sigma_c = \frac{\sigma_y}{n} = \frac{\sigma_y}{2} = \frac{353}{2}$

$\therefore \sigma_c = 176.5 MPa$



$n_1 = 0$

$n_2 = 3 + 2$

$\therefore n_2 = 5$

logitudinal

i) Tickness of plate (t)

$$t = \frac{P D_i}{2 \sigma_t \eta} + C$$

$$t = \frac{1 \times 2 \times 10^3}{2 \times 117.667 \times 0.85} + 2 \qquad C = 2 \text{ assumed}$$

$$t = 11.998 \text{ mm} = \underline{12 \text{ mm}}$$

ii) $d = 6\sqrt{12}$ to $6.325\sqrt{12}$

$d = 20.78$ to 21.91 mm

Standard diameter $d = 22$ (table 5.3(b) Pg 84)

iii) a) $P = \frac{(n_1 + 1.875 n_2)\pi d^2 \tau}{4 t \sigma_c} + d$

$P_1 = \frac{(0 + (1.875 \times 5)\pi \times (22)^2 \times 70.6}{4 \times 12 \times 117.667} + 22$

$P = 200.186$ mm

b) $P = k_1 t + 41$ mm

$k_1 = 6$

$P = 6 \times 12 + 41$

$P = 113$ mm

The smallest pitch $P = 113$ mm

iii) $P_c = 2.25 d = 2.25 \times 22 = 49.5$ mm

iv) $m = 1.5 d = 1.5 \times 22 = 33$ mm

v) $t_i = 0.625 t = 0.625 \times 12$

$t_i = 7.5$ mm $\simeq 8$ mm

vi) $\eta_p = \frac{P - d}{P} = \frac{113 - 22}{113}$

$\eta_p = 80.53\%$

$\eta_s = \frac{\pi d^2/4 (n_1 + 1.875 n_2)\tau}{P t \sigma_c}$

$= \frac{\pi (22^2)/4 (0 + 1.875 \times 5) \times 70.6}{113 \times 12 \times 117.667}$

$\eta_s = 1.5768 = 157.68\%$

$$\eta = \frac{(n_1(t_i/t) + n_2)\sigma_c}{(n_1(t_i/t) + n_2)\sigma_c + \sigma_t} = \frac{(0+5)\,176.5}{(0+5)\,176.5 + 117.667}$$

$\eta = 88.23\%$

$\eta = 80.53$

For Circumferential Joint

Double rivetted lap joint

$n_1 = 2$

$n_2 = 0$

$d = 22\,mm$

i) Total steam $F = \pi/4 \times D_i^2 \times P_t$

$F = \pi/4 \times (2 \times 10^3)^2 \times 1$

$F = 3.14 15 \times 10^6\,N$

ii) shear strength of rivet

$$F_\tau = \frac{\pi}{4} d^2 \tau = \frac{\pi}{4} (22)^2 \times 70.6$$

$\therefore F_\tau = 26.8373 \times 10^3\,N$

Crushing strength of rivet

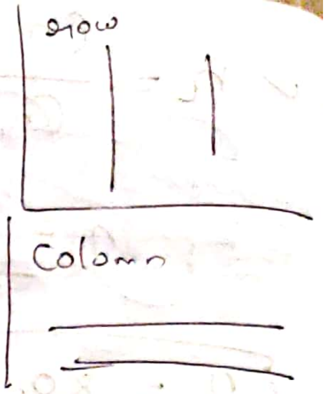
$F_c = d\,t\,\sigma_c = 22 \times 12 \times 176.5$

$\therefore F_c = 46.596 \times 10^3\,N$

min. strength of rivet $\Rightarrow F_1 = 26.8373 \times 10^3\,N$

iii) No of required

$$i = \frac{F_c}{F_1} = \frac{3.1415 \times 10^6}{26.8373 \times 10^3}$$



$$i = 117.05723 \approx \underline{118}$$

iv) Rivets required per row

$$\text{rivets/row} = \frac{i}{\text{no of rivets row}} = \frac{118}{2}$$

$$= \underline{59/\text{row}}$$

v) Circumferential pitch, $P_c = \frac{\pi \times D_i}{\text{Rivets/row}}$

$$= \frac{\pi \times 2000}{59}$$

$$= \underline{106.49 \text{mm}}$$

vi) $\eta_p = \frac{P_c - d}{P_c} = \frac{106.49 - 22}{106.49}$

$$\underline{\eta_p = 79.34\%}$$

$$\eta_s = \frac{\pi \frac{d^2}{4} (n_1 + 1.875\, n_2)\, \tau}{P_c\, t\, \sigma_t}$$

$$= \frac{\pi (22^2)/4\, (2 + 1 [illegible]) \times 70.6}{106.49 \times 12 \times 117.667}$$

$$\eta_s = \underline{35.69\%}$$

$$\eta = \frac{(n_1(t_i/t) + n_2)\sigma_c}{(n_1\, t_i/t + n_2)\sigma_c + \sigma_t}$$

$t_i/t = 1$

$$\eta = \frac{(2+0) \times 176.5}{(2+0)176.5 + 117.667}$$

~~η = [illegible] = 524.99%~~

η = 75.010%