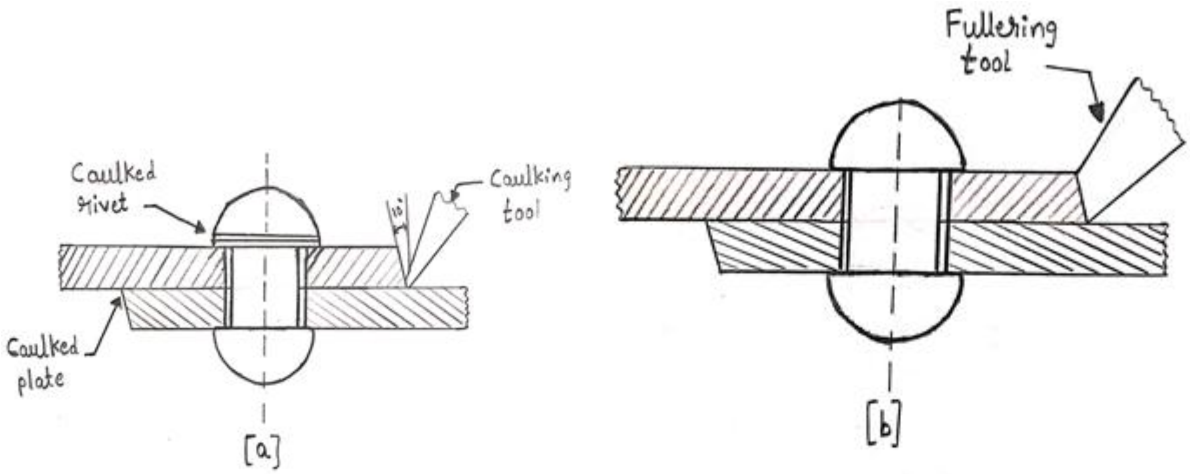
<u>Design of Machine Elements – 1</u>

<u>Module – IV,</u>

<u>Riveted Joints and Welded Joints</u>

Design Data Hand Book Referred – Dr. K. Lingaiah Volume1

Riveted Joints



Caulking and Fullering

a. Uneven plates, scale on the plates, fins performed in punching the rivets holes and other causes prevent the plate from the coming into close contact to make a leak proof joint in boiler works.
b. Riveted joints may be made tight against leakage of gases and liquids by caulking ie. By forcing the edge of the cover plate against the main plate. The caulking is done by hammering a blunt nosed tool against the edge. It is a good practice to caulk not only the plate but also around the rivet head as shown in fig.
c. A more satisfactory way of making the joints string and tight is known a fullering. It is similar to the caulking except that the thickness of fullering tool at the end is equal to that of the plate.

Failure of riveted joints :

1. By tearing of plate at the edge.
2. By tearing of plate across the row of rivets.
3. Shearing of rivets.
4. Crushing of rivets of plates.

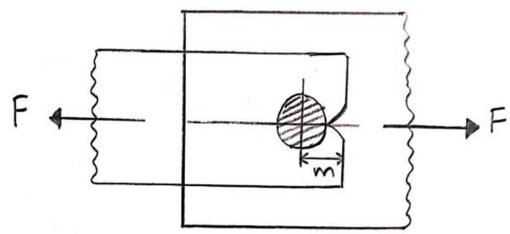


Fig-1

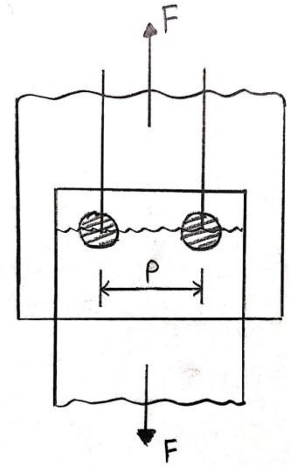
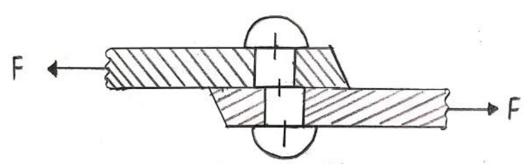
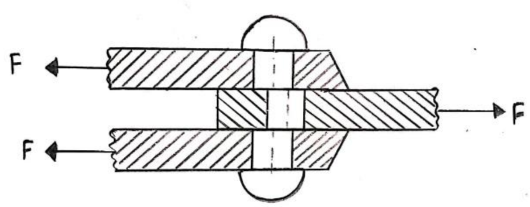


Fig-2



Single Shear

Fig-3



Double Shear

Fig-3

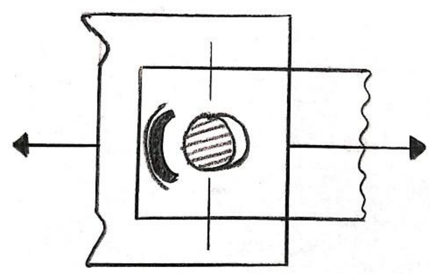


Fig-4

Assumptions made while designing a riveted joint for pressure vessels :

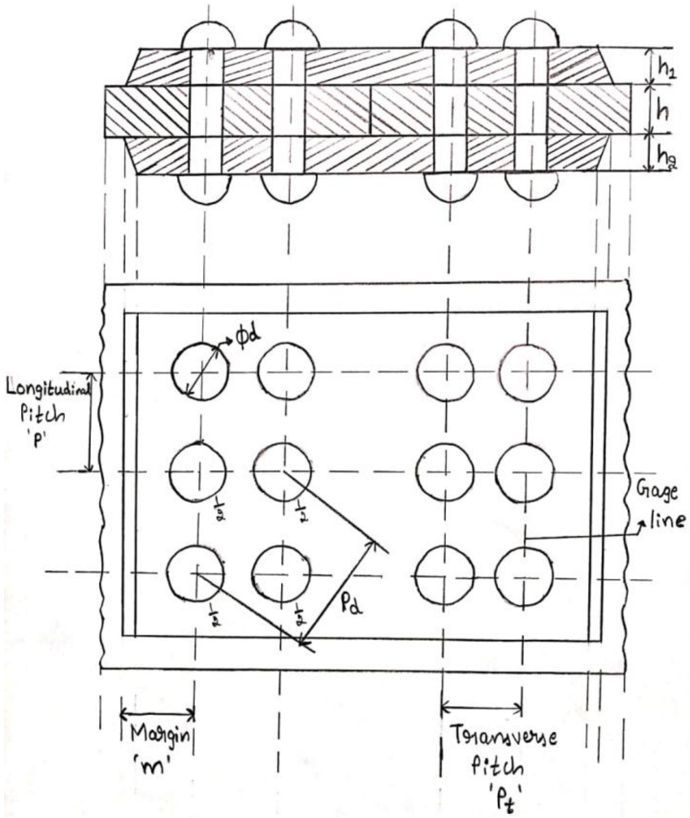
1. The load is distributed among the rivets according to the shear stress.
2. The tensile stress is equally distributed over the section of metal between the rivets.
3. The crushing stress is equally distributed over the projected area of the rivets.
4. There is no bending stress in the rivets.
5. The rivets completely fill the hole after it is driven.
6. Friction between adjacent surfaces doesn't affect the strength of the joint.

Butt joints

Design of boiler joints :

1. Longitudinal joints or butt joint
2. Circumferential joints or lap joints

Design of boiler joints :



The above fig shows double row chain riveting, double cover plate with equal width butt joint.

Where h= thickness of main plate

h_1= thickness of outer cover plate

h_2= thickness of inner cover plate

d= diameter of the rivet= $6\sqrt{h}$ $\Rightarrow$ 13.510

d_h= diameter of riveted hole $\Rightarrow$ T 13.2

P= pitch or longitudinal pitch $\Rightarrow$ 13.12(a)

P_t= transverse pitch

P_d= diagonal pitch

m= margin

η =efficiency of riveted joints.

Procedure for butt joints :

1. Calculate the main plate thickness.

$$h = \frac{P_i D_i}{2\eta\sigma_t}$$

$where\ P_i = pressure\ inside\ the\ boiler$

$D_i = dia\ of\ the\ boiler$

$\sigma_t = \sigma_\theta = tensile\ stress\ or\ hoop\ stress$

$\eta = efficiency\ (from\ T13.4/13.6)$

2. Choose the type of joint (draw suitable fig)

3. Rivet diameter

$6\sqrt{h}$ to $6.3\sqrt{h}$ $\Rightarrow$ 13.5(c) /13.1

4. To find cover plate thickness (h_1 and h_2)

$h_2 = 0.75h$ $h_1 = 0.625h$ $\Rightarrow$ 13.15/13.2

(for unequal width cover plate)

$h_1 = 0.625h$ $\Rightarrow$ 13.17(a) /13.2

$h_2 = 0.625h$ $\Rightarrow$ 13.17(b) /13.2

(for equal width cover plates)

5. To find the length of the rivet

L=13.31(a)/13.3 to 13.31(c)/13.3

6. To find pitch

$$P = \frac{(2i_2 + i_1)\pi\ d_h^2\ \tau}{4h\sigma_\theta} + d \quad \Rightarrow 13.30/13.3$$

Where i_1=number of rivets under single shear/pitch length

i_2=number of rivets under double shear/pitch length

H= thickness of main plate

$\tau =$ shear stress

σ_θ = tensile stress or hoop stress

7. Transverse pitch

$$P_t = 2.5d_h \quad \textit{for chain riveting}$$
$$P_t = 2d_h \quad \textit{for zigzag riveting} \quad \Rightarrow 13.6(a)/13.1$$

8. To find margin

   m=1.5d_h $\Rightarrow$ 13.11(a)

9.

$$\eta = \frac{\textit{least resistance to failure}}{\textit{strength of solid plate}} \qquad \Rightarrow \frac{13.21 \textit{ to } 13.26}{13.20 \textit{ to } 13.2}$$

PROBLEMS :

1. Design a longitudinal joint for a boiler of diameter 1m subjected to steam pressure of 2MPa. Select a double riveted joint with required efficiency of 75% take allowable stress 1) tensile stress=80MPa 2) allowable shear stress 60 MPa 3) allowable crushing stress 120 MPa

Sol: D_i= 1m

P= 2MPa

η = 75%= 0.75

$\sigma_t = \sigma_\theta = 80\text{MPa}$

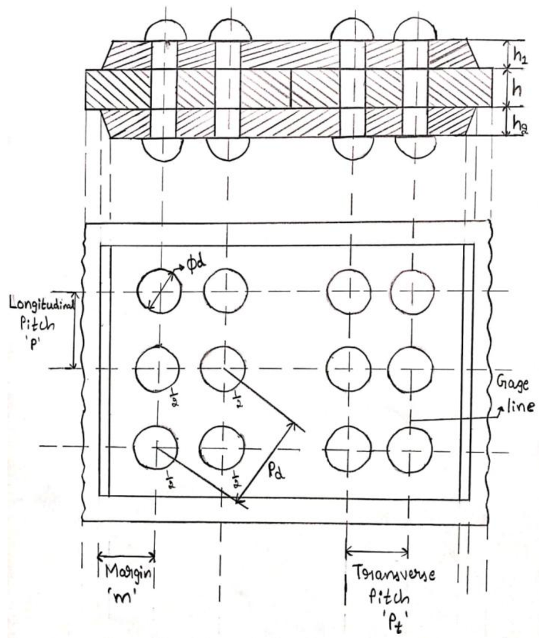
$\tau = 60\text{MPa}$

$\sigma_c = 120\text{MPa}$

1.

$$h = \frac{P_i D_i}{2\eta\sigma_t}$$
$$= \frac{2 \times 1000}{2 \times .75 \times 80}$$
$$h = 16.66mm \approx 17mm$$

2. The type of joint is boiler joint. Select chain riveting with equal width cover plate .



3. d= $6\sqrt{h}$ = $6\sqrt{17}$ = 24.73mm

   d_{std} =27mm $\Rightarrow$ from T13.2/13.5

   d_h = 28.5mm

4. h_2=h_1=0.625h = 0.625(17) =10.625mm ≈11mm
5. $L = h + h_1 + h_2 + 1.6d_h$

   = 17+11+11+(1.6×28.5) = 84.666mm

6.

$$P = \frac{(2i_2 + i_1)\pi \ d_h^2 \ \tau}{4h\sigma_\theta} + d$$

$$where \ \ i_2 = 2 \qquad i_1 = 0$$

$$P = \frac{(2\times 2 + 0)\pi \ (28.5^2)(60)}{4\times 17\times 80} + 27$$

$$P = 139.57 \approx 140mm$$

P = 3.5h+40 T13.14/Type 'g'

p = 3.5(17) +40

=99.5 ≈ 100mm

Henceforth take least pitch value, Take p=100mm

P_t = 2.5d_h

=2.5(28.5) = 71.25mm

m = 1.5d_h

= 1.5(28.5) = 42.75mm

$$\eta = \frac{F}{F_\theta}$$

$$F_\theta = (P - d_h)h.\sigma_\theta$$

= (100-28.5)× 17×80 --13.21/13.2

=97.24 × 10^3 N

$$F_\tau = (2i_2 + i_1)\,\frac{\pi\, d_h^2}{4}.\tau$$

$$= (2(2) + 0).\frac{\pi \times 28.5^2}{4}.60$$ --13.22/13.2

$$= 153.105 \times 10^3\, N$$

$$F_c = (i_2 h_1 + i_1 h_2) d_h.\sigma_c$$

$$= (2 \times 17 + 0 \times 11) \times 28.5 \times 120$$ --13.23/13.2

$$= 116.28 \times 10^3\, N$$

$$F_{\tau_i} = (P - 2dh)h \times \sigma_\theta + \frac{\pi\, d_h^2}{4}.\tau$$

$$= (100 - 2 \times 28.5) \times 17 \times 80 + \frac{\pi.28.5^2}{4}.60$$ --13.24/13.2

$$= 96.75 \times 10^3\, N$$

$$F_{c1} = (P - 2d_h)h \times \sigma_\theta + d_h.h.\sigma_c$$

$$= (100 - 2 \times 28.5) \times 17 \times 80 + (28.5 \times 17 \times 120)$$

$$= 116.62 \times 10^3\, N$$

$$F_\theta = P.h.\sigma_\theta$$

$$= 100 \times 17 \times 80$$ --13.20/13.2

$$= 136 \times 10^3\, N$$

$$\eta = \frac{F_{lowest}}{F_\theta}$$

$$= \frac{96.75 \times 10^3}{136 \times 10^3} = 71.13\%$$

Therefore, resistance due to shearing of rivets in first row needs improvement or it is not safe.

2. Design a double riveted butt joint with 2 cover plates for longitudinal seam of a boiler shell 1.5m diameter subjected to a steam pressure of 0.95 N/mm^2.Assume required efficiency of 75%, take allowable tensile stress in plate as 90 N/mm^2 allowable compressive stress is 140 N/mm^2, allowable shear stress is 56 N/mm^2

Sol:

D_i= 1.5m

P_i= 0.95N/mm^2

η = 75%= 0.75

$\sigma_t = \sigma_\theta = 90$ N/mm^2

$\tau = 56$ N/mm^2

$\sigma_c = 140$ N/mm^2

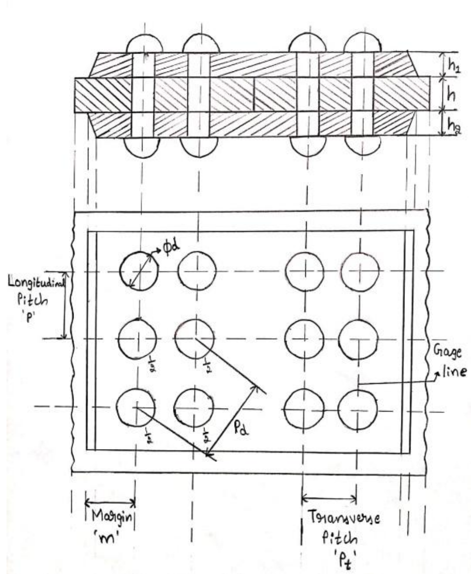
1.

$$h = \frac{P_i D_i}{2\eta\sigma_t}$$

$$= \frac{0.75 \times 1.5 \times 10^3}{2 \times .75 \times 90} \quad +\text{d}$$

$$h = 10.55mm \approx 11mm$$

2. The type of joint is boiler joint .Select double row chain riveting with equal width cover plate



3. d= $6\sqrt{h}$ = $6\sqrt{11}$ = 19.89mm

   d_{std} =20mm $\Rightarrow$ from T13.2/13.5

   d_h = 21mm

4. $h_2 = h_1 = 0.625h = 0.625(11) = 6.875mm \approx 7mm$

5. $L = h + h_1 + h_2 + 1.6d_h$

   = 11+7+7+(1.6×21) = 58.6mm

$$P = \frac{(2i_2 + i_1)\pi\ d_h^2\ \tau}{4h\sigma_\theta} + d$$

$$where\ \ i_2 = 2 \qquad i_1 = 0$$

$$P = \frac{(2 \times 2 + 0)\pi\ (21^2)(56)}{4 \times 11 \times 90} + 20$$

$$P = 98.369 \approx 99mm$$

P = 3.5h+40

= 3.5(11) +40

=78.5 ≈ 79mm

Henceforth take least pitch value

$P_t = 2.5d_h$

=2.5(21) = 52.5mm

m = $1.5d_h$

= 1.5(21) = 31.5mm

$$\eta = \frac{F}{F_\theta}$$

$$F_\theta = (P - d_h)h.\sigma_\theta$$
$$= (79 - 11)\times 21\times 90$$
$$= 57.420\times 10^3$$

$$F_\tau = (2i_2 + i_1)\frac{\pi\ d_h^2}{4}.\tau$$
$$= ((2)+0).\frac{\pi\ (21^2)}{4}.56$$
$$77.584\times 10^3 N$$

$$F_c = (i_2 h + i_1 h_2)d_h.\sigma_c$$
$$= (2\times 11 + 0\times 7)\times 21\times 140$$
$$= 64.680\times 10^3 N$$

$$F_{\tau_i} = (P - 2dh)h\times \sigma_\theta + \frac{\pi\ d_h^2}{4}.\tau$$
$$= (79 - 2(21))\times 11\times 90 + \frac{\pi\ (21^2)}{4}.56$$
$$= 56.026\times 10^3\ N$$

$$F_{c1} = (P - 2d_h)h\times \sigma_\theta + d_h.h.\sigma_c$$
$$= (79 - 2\times 21)\times 11\times 90 + (21\times 11\times 140)$$
$$= 68.970\times 10^3 N$$

$$F_\theta = P.h.\sigma_\theta$$
$$= 79\times 11\times 90$$
$$= 78.210\times 10^3 N$$

$$\eta = \frac{F_{lowest}}{F_\theta}$$
$$= \frac{56.026\times 10^3}{78.210\times 10^3} = 72.14\%$$

Tensile strength of perforated strip along the outer gauge line heeds to be improved or its not safe.

3. Design a triple riveted butt joint to join two plates of thickness 10mm, the pitch of rivets in the extreme rows which are in single shear is twice the pitch of rivets in the inner rows which are in double shear . The design stress of the material of the main plates and rivets are as follows:

a) For plate material in tension is is 120MPa
b) For rivet material in compression is 160MPa
c) For rivet material in shear is 80MPa
Draw a neat sketch of the joints in 2 views.

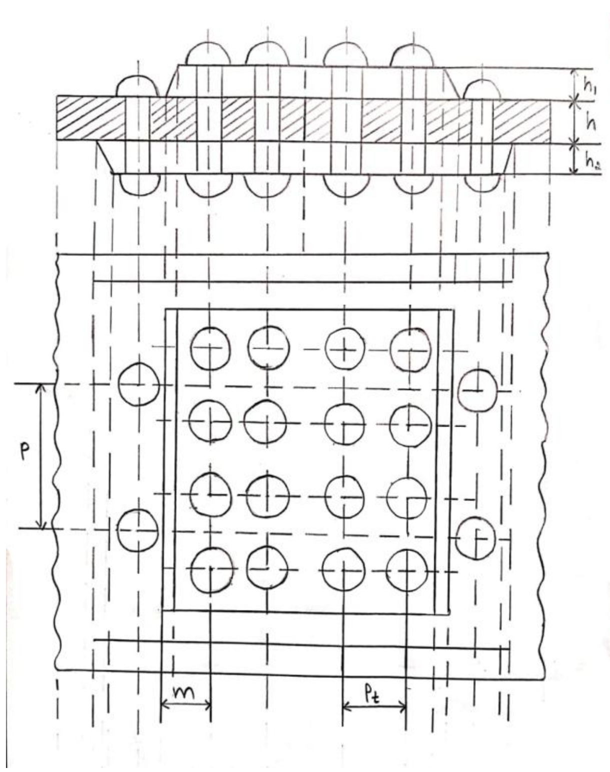
Sol:

h=10mm

$\sigma_t = 120 MPa$

$\sigma_c = 160 MPa$

$\tau = 80 MPa$



The above figure shows triple riveted unequal width double cover plate chain riveting

$d = 6\sqrt{h} = 6\sqrt{10} = 18.97mm$

$d_{std} = 20mm$ $\Longrightarrow$ from T13.2/13.5

$d_h = 21mm$

$h_1 = 0.625h = 0.625(10) = 6.25mm$

$h_2 = 0.75h = 0.75(10) = 7.5mm$

$L_1 = h + h_2 + 1.6d_h$

$= 49mm$

$$L_2 = h + h_1 + h_2 + 1.6d_h$$

$= 10+6.25+7.5+(1.6\times21) = 57.35mm$

$$P = \frac{(2i_2 + i_1)\pi\, d_h^2\, \tau}{4h\sigma_\theta} + d$$

where $i_2 = 4 \quad i_1 = 1$

$$P = \frac{(2\times4+1)\pi\,(21^2)(80)}{4\times10\times120} + 20$$

$$P = 227.81 \approx 228mm$$

$P_t = 2.5d_h$

$= 2.5(21) = 52.5mm$

$m = 1.5d_h$

$= 1.5(21) = 31.5mm$

$$\eta = \frac{F}{F_\theta}$$

$$F_\theta = (P - d_h)h.\sigma_\theta$$

$= (228-21)\times 10\times120$

$= 248.4 \times 10^3$ N

$$F_\tau = (2i_2 + i_1)\,\frac{\pi\, d_h^2}{4}.\tau$$

$$= (2(4)+1).\frac{\pi\times21^2}{4}.80$$

$$= 443.35\times10^3\, N$$

$$F_c = (i_2 h + i_1 h_2) d_h.\sigma_c$$

$$= (4\times10+1\times7.5)\times21\times160$$
$$= 159.6\times10^3 N$$

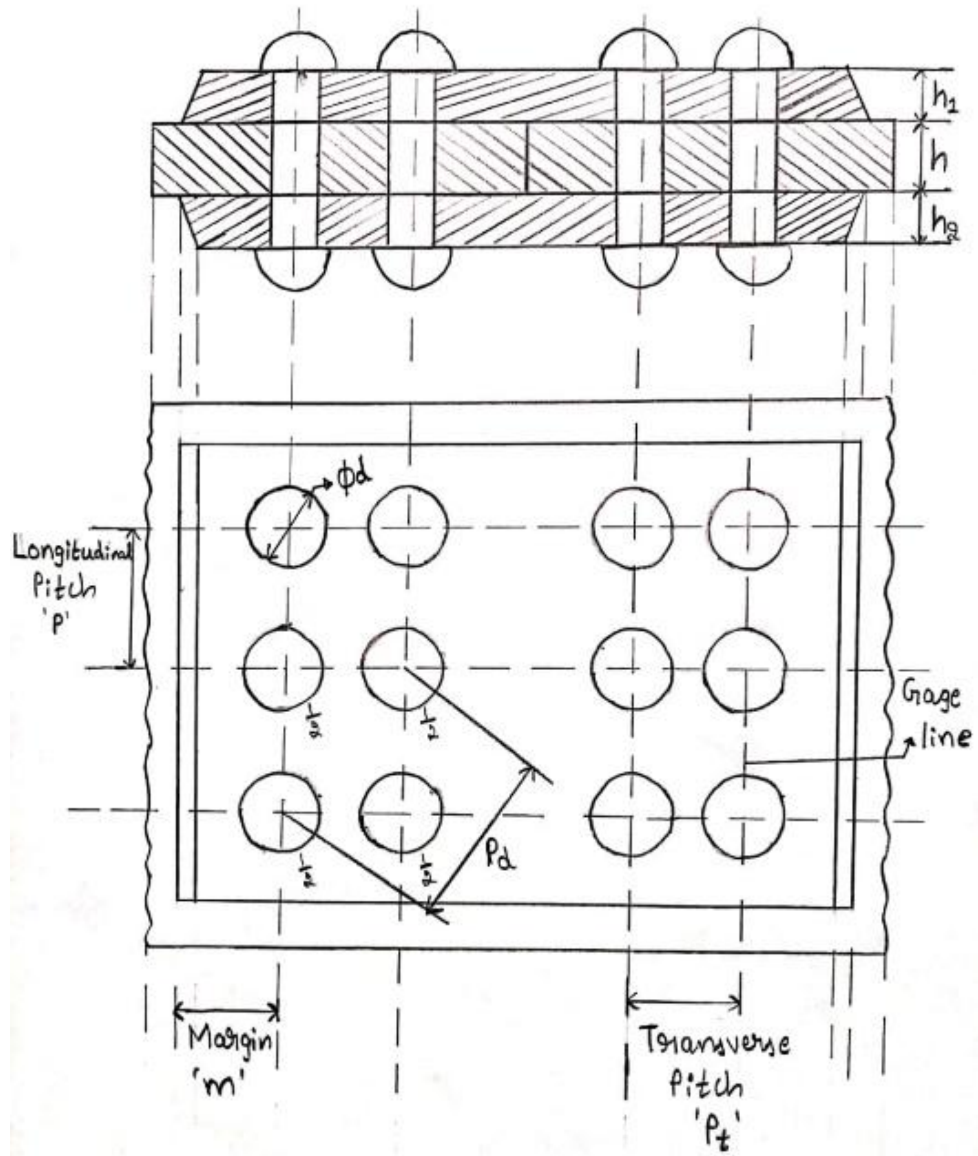
$$F_{\tau_i} = (P-2dh)h\times\sigma_\theta + \frac{\pi\, d_h^2}{4}.\tau$$
$$= (228-2\times21)\times10\times120+\frac{\pi.21^2}{4}.80$$
$$= 250.91\times10^3 N$$
$$F_{c1} = (P-2d_h)h\times\sigma_\theta + d_h.h.\sigma_c$$
$$= (228-2\times21)\times10\times120+(21\times10\times160)$$
$$= 256.8\times10^3 N$$
$$F_\theta = P.h.\sigma_\theta$$
$$= 228\times10\times228$$
$$= 273.6\times10^3 N$$
$$\eta = \frac{F_{lowest}}{F_\theta}$$
$$= \frac{159.6\times10^3}{273.6\times10^3} = 58.33\%$$

For triple riveted butt joint from T13.4/17 the efficiency range is 80-88%. Hence forth the design is not safe.

4. Design a longitudinal butt joint with equal width cover plate for a pressure vessel of dia 1200mm subjected to an internal pressure of 0.9MPa. The joint efficiency is of 75% can be assumed at this stage, for practical reasons the pitch of rivets is to be restricted to a value of not less than 3d and not more than 3.5d, where d is dia of the rivet, material selected for main plate and rivet as the following safe value, take σ_θ=120MPa, τ = 80MPa, σ_c = 160MPa. Sketch the joint and determine the efficiency. Assume that the resistance of rivets in double shear is 1.875 times that of single shear.

Sol:

$D_i = 1200mm$, $P_i = 0.9MPa$,
$\eta = 75\%$, $\sigma_\theta = 120MPa$,
$\tau = 80MPa$, $\sigma_c = 160MPa$


h1
h
h2
Φd
Longitudinal
Pitch
'P'
Gage
line
Pd
Margin
'm'
Transverse
Pitch
'Pt'

$$i_2 = 2, \qquad i_1 = 0$$

$$P = \frac{(1.875 \times 2 + 0)\pi \times 17^2 \times 80}{4 \times 6 \times 120} + 16$$

$$P = 110.57mm$$

$$P > 3d_h = 3 \times 17 = 51mm$$

$$P < 3.5d_h = 3.5 \times 17 = 59.5mm$$

$$\therefore P = 59mm$$

$$P_t = 2.5d_h = 2.5 \times 17 = 42.5mm$$

$$m = 1.5d_h = 1.5 \times 17 = 25.5mm$$

$$\eta = \frac{F}{F_\theta}$$

$$F_\theta = (P - d_h)h\sigma_\theta \qquad \Rightarrow \frac{13.21}{13.2}$$

$$= (59 - 17)6 \times 120$$

$$F_\theta = 30.24 \times 10^3 N$$

$$h = \frac{P_i D_i}{2\eta\sigma_\theta}$$

$$= \frac{0.9 \times 1200}{2 \times 0.75 \times 120} = 6mm$$

$$d = 6\sqrt{h}$$

$$= 6\sqrt{6} = 14.69mm$$

$$d_{std} = 16mm$$

$$d_h = 17mm$$

$$h_1 = h_2 = 0.625h = 0.625(6) = 3.75 \approx 4mm$$

$$L = h + h_1 + h_2 + (1.6d_h)$$

$$= 6 + 4 + 4 + (1.6 \times 17)$$

$$L = 41.2mm$$

$$P = \frac{(1.875 i_2 + i_1) \times \pi d_h^2 \tau}{4h\sigma_\theta} + d$$

Replace 2 with 1.875 in the above equation because it is given in data

$$F_\tau = (1.875 i_2 + i_1)\frac{\pi d_h^2}{4}\tau$$

$$= (1.875\times 2 + 0)\frac{\pi\times 17^2}{4}\times 80$$

$$= 68.09\times 10^3\, N$$

$$F_c = (i_2 h + i_1 h_2) d_h \sigma_c$$

$$= (2\times 6 + 0\times 4)\times 17\times 160$$

$$F_c = 32.64\times 10^3\, N$$

$$F_{\tau_1} = (P - 2d_h)h\sigma_\theta + \frac{\pi d_h^2}{4}\tau$$

$$= (59 - 2\times 17)\times 6\times 120 + \frac{\pi 17^2}{4}\times 80$$

$$F_{\tau_1} = 36.158\times 10^3\, N$$

$$F_{\tau_1} = (P - 2d_h)h\sigma_\theta + d_h\times h\times\sigma_c$$

$$= (59 - 2\times 17)\times 6\times 120 + 17\times 6\times 160$$

$$= 34.32\times 10^3\, N$$

$$F_\theta = Ph\sigma_\theta$$

$$= 59\times 6\times 120$$

$$= 42.48\times 10^3\, N$$

$$\eta = \frac{F_{(least\ value)}}{F_\theta} = \frac{30.24\times 10^3}{42.48\times 10^3} = 71.18\%$$

5.A double rivetted lap joint with zig zag riveting is to be designed for plates 12mm thickness, allowable stresses are 80MPa in tension, 60MPa in shear and 120MPa in compression.

Sol:

$$h = 12mm$$

$$\sigma_\theta = 80MPa$$

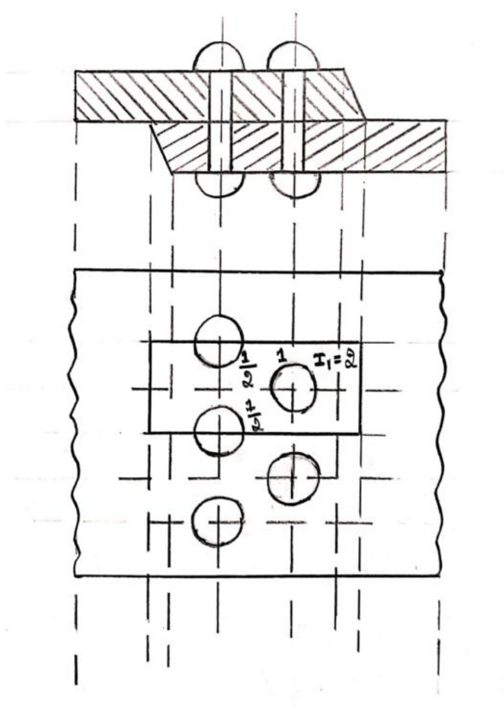
$$\sigma_c = 120MPa$$

$$\tau = 60MPa$$

$$d = 6\sqrt{h} = 6\sqrt{12} = 20.78mm$$

$$d_{std} = 22mm \qquad \Rightarrow T-13.2$$

$$d_h = 23mm \qquad \Rightarrow T-13.2$$



$$L = 2h + 1.6d_h$$
$$= 2 \times 12 + 1.6 \times 23$$
$$L = 60.8mm$$
$$P = \frac{(2i_2 + i_1)\pi d_h^2 \tau}{4h\sigma_\theta} + d$$
$$i_2 = 0, \qquad i_1 = 2$$
$$P = \frac{(2 \times 0 + 2)\pi \times 23^2 \times 60}{4 \times 12 \times 80} + 22$$
$$P = 73.93mm \approx 74mm$$

$$From \ \frac{13.14}{13.11}, \quad for\ type\ c$$
$$P = 2.62h + 40$$
$$= 2.62(12) + 40$$
$$P = 71.44mm \approx 72mm$$

$\therefore$ *By considering least value of pitch, take*

$$P = 72mm$$
$$P_t = 2d_h = 2 \times 23 = 46mm$$
$$m = 1.5d_h = 1.5 \times 23 = 34.5mm$$
$$\eta = \frac{F}{F_\theta}$$
$$F_\theta = (P - d_h)h\sigma_\theta \qquad \Rightarrow \frac{13.21}{13.2}$$
$$= (72 - 23) \times 12 \times 80$$
$$= 47.04 \times 10^3 N$$

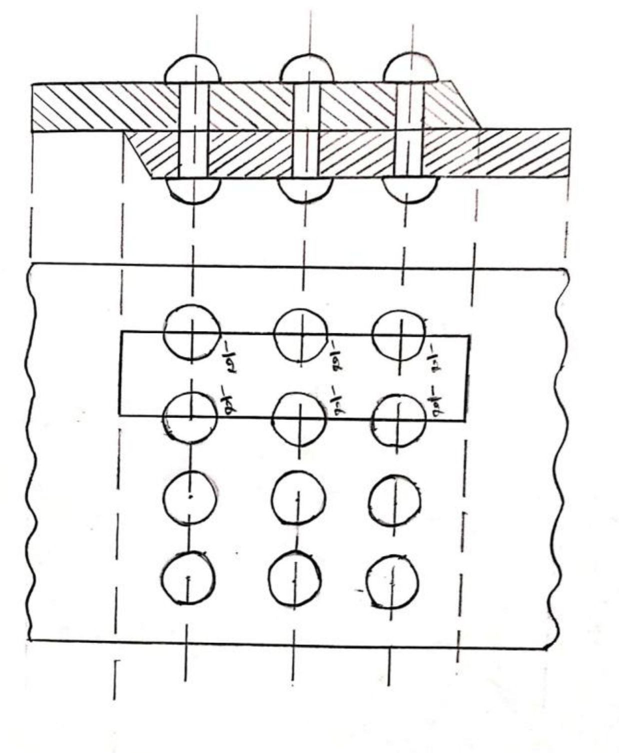
$$F_c = (i_2 h + i_1 h_2) d_h \sigma_c$$
$$= (2\times 0 + 2\times 12)\times 23\times 120$$
$$F_c = 66.24\times 10^3\,N$$
$$F_\tau = (2i_2 + i_1)\frac{\pi d_h^2}{4}\tau$$
$$= (2\times 0 + 2)\frac{\pi\times 23^2}{4}\times 60$$
$$= 49.857\times 10^3\,N$$
$$F_{\tau_1} = (P - 2d_h)h\sigma_\theta + \frac{\pi d_h^2}{4}\tau$$
$$= (72 - 2\times 23)\times 12\times 80 + \frac{\pi 23^2}{4}\times 60$$
$$F_{\tau_1} = 49.88\times 10^3\,N$$
$$F_{c_1} = (P - 2d_h)h\sigma_\theta + d_h h\sigma_c$$
$$= (72 - 2\times 23)\times 12\times 80 + 23\times 12\times 120$$
$$= 58.08\times 10^3\,N$$

$$F_\theta = Ph\sigma_\theta$$
$$= 72\times 12\times 80$$
$$= 69.12\times 10^3\,N$$
$$\eta = \frac{F_{(least\ value)}}{F_\theta} = \frac{47.04\times 10^3}{69.12\times 10^3} = 68.05\%$$

Given T-$\frac{13.4}{13.6}$ for double riveted joint η is between 60 -72, hence it is safe.

6.A boiler shell of 1m dia has a circumferential triple riveted lap joint. The maximum pressure in the boiler is 2MPa. Design the riveted joint if the allowable stresses in tensile, shear and crushing are 120, 80 and 160MPa respectively.

Sol:



$$D_i = 1m = 1000mm$$
$$P_i = 2MPa$$
$$\sigma_t = \sigma_\theta = 120MPa$$
$$\tau = 80MPa$$
$$\sigma_c = 160MPa$$

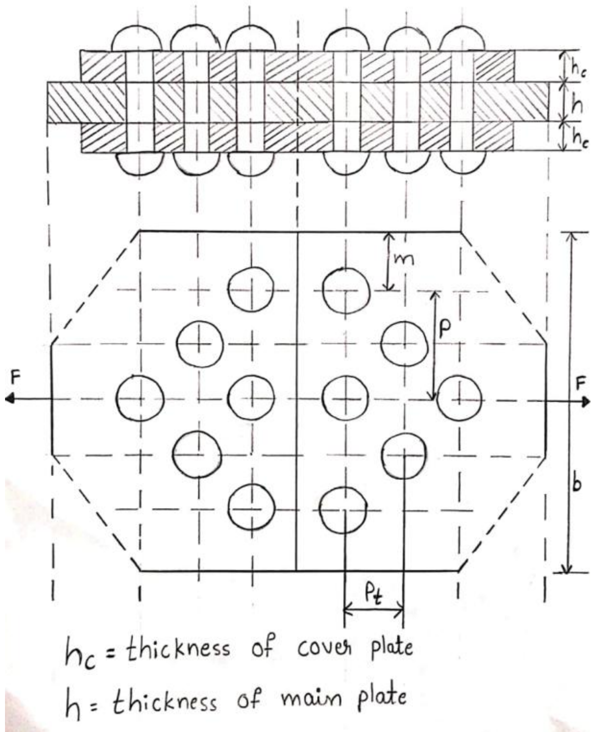
$$h = \frac{P_i D_i}{2\eta\sigma_\theta} = \frac{2\times1000}{4\times\eta\times120}$$

$$\eta - From\ Table\ T - \frac{13.4}{13.6}, \quad Take\ \ \eta = 76\%$$

$$h = \frac{2000}{2\times120\times0.76} = 10.96 \approx 11mm$$

Remaining steps Same as previous Problem

LOZENGE JOINT OR DIAMOND JOINT



Where

b is width of the plate

m is margin

F is forces applied

1. $d = 6\sqrt{h}$
2. $m = 1.75d$
3. $P_t = 2.5d$
4. $b = 2P + 2m$
5. $P = \dfrac{b - 2m}{2}$
6. $F_t = \sigma_t (b - d_h)h$
7. $F_\tau = 1.875 \dfrac{\pi d^2}{4} \tau_s$
8. $F_c = dh\sigma_c$
9. $h_c = 0.6h + 2.5 \qquad \Rightarrow 13.12(b)$

$$n = \frac{Maximum\ load\ on\ the\ jo\text{int}}{least\ \ force} = \frac{F_t}{F_c (or) F_\tau}$$

$(n = number\ of\ \ rivets\ respectively)$

$Generally\ should\ be\ \ 3, 6, 10, \ldots\ldots\ldots..$

1. A mild steel of rectangular plate for a bridge structure is 250mm width and 18mm thick. Design this joint completely taking the design stresses are 100MPa in tension, 70MPa in shear and 160MPa in crushing

Sol:

$b = 250mm$

$h = 18mm$

$\sigma_\theta = 100MPa$

$\tau = 70MPa$

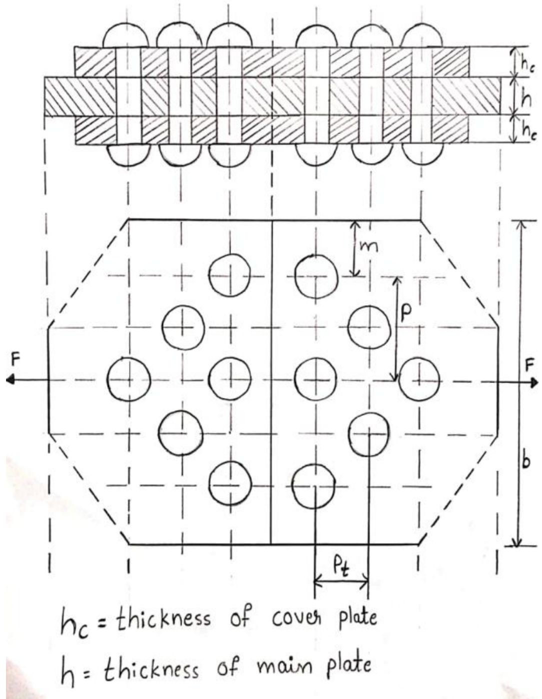
$\sigma_c = 160MPa$

$d = 6\sqrt{h} = 6\sqrt{18} = 25.45mm$

$d_{std} = 27mm, \quad d_h = 28.5mm \qquad \Rightarrow T - 13.2$

$m = 1.75d = 1.75 \times 27 = 47.25mm$

$P_t = 2.5d = 2.5 \times 27 = 67.5mm$



$$P = \frac{b - 2m}{2}$$

$$= \frac{250 - 2(47.25)}{2}$$

$$P = 77.75mm$$

$$F_t = \sigma_t h(b - d_h)$$

$$= 100 \times 18(250 - 28.5)$$

$$F_t = 398.7 \times 10^3 N$$

$$F_c = dh\sigma_c = 27 \times 18 \times 160 = 77.76 \times 10^3 N$$

$$F_\tau = 1.875 \frac{\pi d^2}{4} \tau_s$$

$$= 1.875 \frac{\pi (27)^2}{4} \times 70$$

$$F_\tau = 75.15 \times 10^3 N$$

No of rivets required,

$$n = \frac{Max\ load\ on\ the\ joint(F_t)}{Least\ \ force(F_c or F_\tau)}$$

$$n = \frac{398.7 \times 10^3}{75.15 \times 10^3}$$

$$n = 5.3 \approx 6\ rivets$$

Thickness of the cover plates, h_c

$$h_c = 0.6h + 2.5 \qquad \Rightarrow \frac{13.12(b)}{13.2}$$

$$= 0.6 \times 18 + 2.5 = 13.3mm$$

$$h_c = 14mm$$

To find efficiency, η

$$F_{t_1} = (b - d_h)h\sigma_\theta$$

$$= (250 - 28.5)18 \times 100$$

$$F_{t_1} = 398.7 \times 10^3 N$$

$$F_{t_2} = (b - 2d_h)h\sigma_\theta + F_\tau \qquad \Rightarrow (Shear\ between\ F_c\ and\ F_\tau, F_\tau < F_c$$

Hence design is due to shear)

$$= (b - 2d_h)h\sigma_\theta + 1.875\frac{\pi d^2}{4}\tau_s$$

$$= (250 - 2 \times 28.5) \times 18 \times 100 + 1.875 \times \frac{\pi(27)^2}{4} \times 70$$

$$F_{t_2} = 422.547 \times 10^3 N$$

$$F_{t_3} = (b - 3d_h)h\sigma_\theta + 3F_\tau$$

$$F_{t_3} = 521.54 \times 10^3 N$$

$\therefore$ *Shear force of all rivets*

$$F_{t_6} = 6F_\tau$$

$$= 6 \times 1.875 \times \frac{\pi d^2}{4} \times \tau$$

$$F_{t_6} = 450.88 \times 10^3 N$$

$$F_\theta = bh\sigma_\theta$$

$$= 250 \times 18 \times 100$$

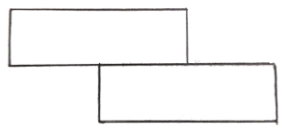
$$F_\theta = 450 \times 10^3 N$$

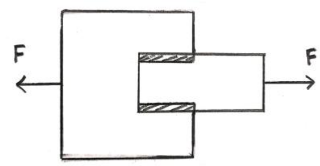
$$\eta = \frac{F_{least}}{F_\theta} = \frac{398.7 \times 10^3}{450 \times 10^3} = 88.6\%$$

WELDED JOINTS

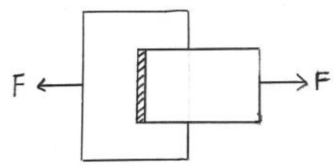
There are two types of welded joints:

1. Parallel Fillet Weld





2. Normal Welding



$$\sigma = \frac{F}{0.707h \times l} \qquad \rightarrow 12.10$$

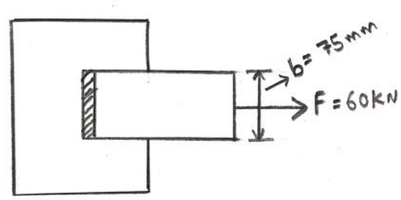
$$\tau = \frac{F}{0.707h \times l} \qquad \rightarrow 12.\ 5(a)$$

Problems:

1. A steel plate of 75mm wide and 10mm thickness is loaded in tension by a load of 60KN and is welded to a plate with normal weld as shown in figure. Determine length weld required.

sol

Given: b=75mm, F=60KN, h=10mm



WKT,

$\sigma = \dfrac{F}{0.707h \times l}$ $\rightarrow 12.10$

From table 12.8,

Under Recommended design stress for static loading.

Under Static condition the stress is tension

Static load σ=110.3Mpa

$110.3 \times 0.707 \times 10 = \dfrac{60 \times 10^3}{l}$

$l = 77mm$

Effective Length of weld on each side

$L = \dfrac{l}{2} = 38.5mm$

Total length of the welded joint = L+5i

Where i = No of free ends at that particular joint

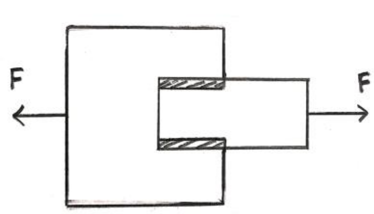
Total length = 38.5+5(2) = 48.5mm

2. A plate of 100mm wide and 12mm thick is to be welded to another plate by a double parallel weld. The plates are subjected to a static of 50KN. Find the length of the weld if the permissible shear stress in the weld is 56MPa.

Sol.

Given: b=100mm, F=50KN, h=12mm

$\tau = 56Mpa$



$\tau = \dfrac{F}{0.707h \times l}$ $\rightarrow 12.15(a)$

$$56 = \frac{50 \times 10^3}{0.707 \times 12 \times l}$$

$$l = 105.5mm$$

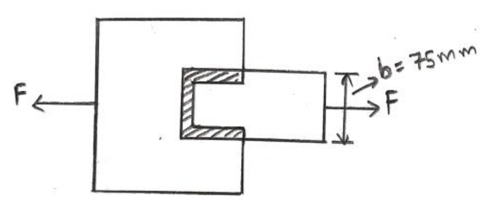
Effective Length, L= $\frac{l}{2} = 52.75mm$

Total length of the welded joint L_r = L+5i

= L+5(2)

= 62.7mm

3. A plate of 75mm wide and 10mm thick joined with another plate by a single transverse and double Parallel fillet weld as shown in figure. Max Shear and Tensile stress of weld are 60MPa and 80MPa respectively. Find the length of the parallel weld if it is subjected to both Static and Fatigue loading. Take Stress Concentration factor as 1.5 for transverse and 2.7 for parallel weld.



Given: b=75mm, h=10mm

$\tau = 60MPa$, $\sigma = 80MPa$

$$F = \text{Load} \times \text{Stress}$$

$$F = b \times h \times a$$

$$F = 75 \times 10 \times 80 = 60 \times 10^3$$

$$\text{WKT, } F_t = 0.707 \times h \times l \times \sigma$$

$$F_t = 0.707 \times 10 \times 75 \times 80$$

$$F_t = 42.4\text{KN}$$

$$\therefore F_p = F - F_t$$

$$= (60 - 42.42) \times 10^3 = 17.5\text{KN}$$

$$\therefore \text{WKT } L_p = \frac{F_p}{0.707 \times h \times \tau}$$

$$L_p = \frac{17.5 \times 10^3}{0.707 \times 10 \times 60}$$

$$L_p = 41.5mm + 10mm$$

$$L_p = 51.5mm$$

WKT For fatigue loading for parallel weld

$$\text{WKT} \quad \sigma = \frac{80}{1.5} = 53.33MPa$$

$$\tau = \frac{60}{2.7} = 22.22MPa$$

$$\text{WKT} \quad F = b \times h \times a$$

$$F = 75 \times 10 \times 53.33$$

$$F = 40 \times 10^3 N$$

$$F_l = 0.707 \times h \times l \times a$$

$$F_l = 0.707 \times 75 \times 10 \times 53.33$$

$$F_l = 28.28KN$$

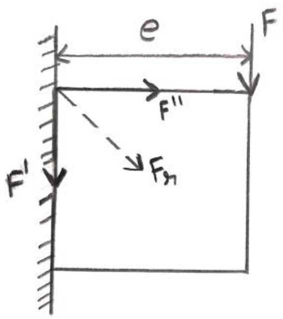
$$\therefore F_p = 40 - 28.28 = 11.72KN$$

$$L_p = \frac{F_p}{0.707 \times h \times \tau}$$

$$L_p = \frac{11.72 \times 10^3}{0.707 \times 10 \times 22.22} = 74.6mm$$

ECCENTRICALLY LOADED WELDED JOINTS

1. Bending



F' = Primary force or direct force / unit length

F'' = Secondary force

F_r = Resultant force

1. $F' = \text{direct force / unit length} = \frac{F}{l} N/mm$

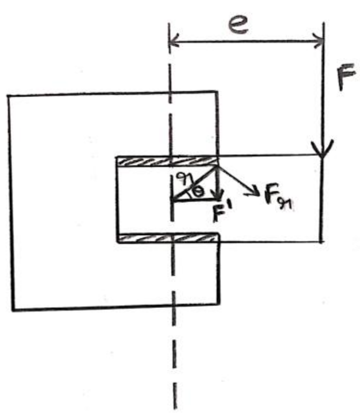
2. $F'' = \frac{Mb}{Z_w}$

From T → 12.3

3. $F_r = \sqrt{(F')^2 + (F'')^2}$

4. $\tau = \frac{F_r}{0.707h}$

2. Torsion



1. F' = direct force / unit length

2. $F'' = \dfrac{F_e r}{J_w}$

Where, r = distance from cross section of weld to point of intersection

J_w = Polar moment of inertia

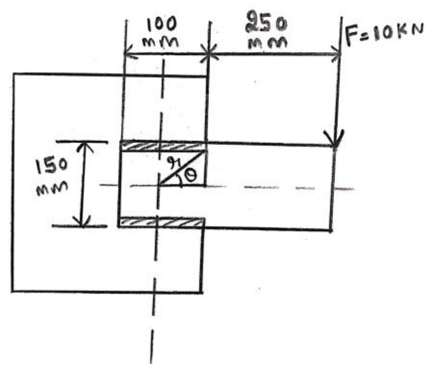
From T → 12.3

3. $F_r = \sqrt{(F')^2 + (F'')^2 + 2F'F''\cos\theta}$ → 12.21

4. $\tau = \dfrac{F_r}{0.707h}$

Problems :

1. An Eccentrically loaded welded joint is as shown in the figure. Determine size of the weld required.



1) WKT r=$\sqrt{50^2+75^2}=90.138mm$

2) F' = $\frac{F}{l}=\frac{10\times10^3}{200}=50N/mm$ $\rightarrow 12.7$

3) F'' = $\frac{F_e r}{J_w}$ $\rightarrow J_w =$ Polar moment of inertia

$$J_w=\frac{b^3+3bd^2}{6}=\frac{100^3+3\left(100\times50^3\right)}{6}=1.29\times10^6mm^3$$

$$F''=\frac{10\times10^3\times300\times90.138}{1.29\times10^6}$$

F'' = 209.62N/mm

4) Resultamt force/unit length

$$F_r=\sqrt{(F')^2+(F'')^2+2F'F''\cos\theta}$$ $\cos\theta=\frac{50}{90.138}$

$F_r=240.9N/mm$ $\cos\theta=0.53$

We have,

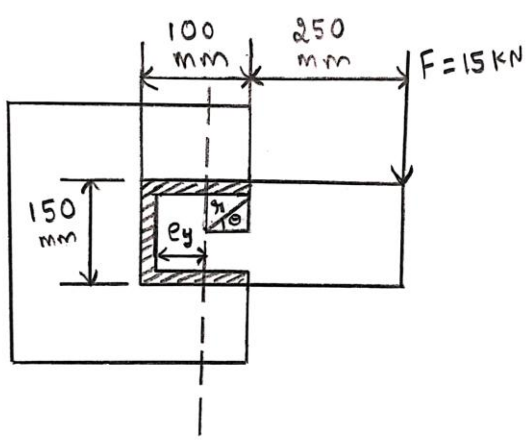
$$\tau=\frac{F_r}{0.707h}$$

$$h=\frac{F_r}{0.707\times\tau}=\frac{240.9}{0.707\times96.5}$$ From table 12.6

$h=3.53mm$ τ=96.5Mpa

$\therefore$ Size of the belt = 4×4

2. Determine size of weld for welded joint shown in figure.



From table 12.3

$$e_y = \frac{b^2}{2b+d} = \frac{100^2}{2(100)+150} = 28.57mm$$

$$r = \sqrt{71.42^2 + 75^2} = 103.56mm$$

$$F' = \frac{F}{l} = \frac{15\times13^3}{2(100)+150} = 42.85N/mm$$

$$F'' = \frac{F_e r}{J_w}$$

$$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{2b+d}$$

$$J_w = 1.78\times10^6 mm^3$$

$$F'' = \frac{15\times10^3\times(250+71.42)\times103.56}{1.78\times10^6}$$

$$F'' = 279.37N/mm$$

$$\mathrm{F}_r = \sqrt{(\mathrm{F}')^2 + (\mathrm{F}'')^2 + 2\mathrm{F}'F''\cos\theta}$$

$$\mathrm{Cos}\,\theta = 0.482$$

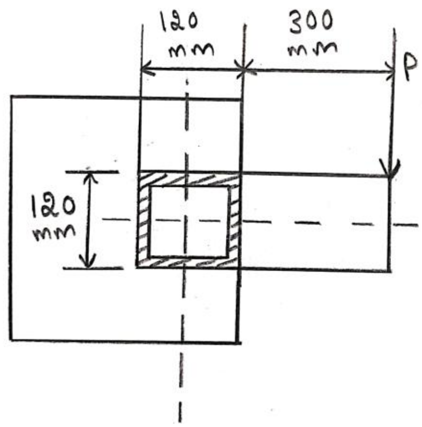
$$\mathrm{F}_r = 320.43N/mm$$

$$\tau = \frac{F_r}{0.707h}$$

$$h = \frac{320.43}{0.707\times9650}$$

$$h = 4.69\times4.69mm$$

3. A bracket supporting a load P is welded to a plate by a four-fillet weld of size 6mm. What is the maximum load 'p' that may be carried by the joint if the stress in the joint is 96MPa



$r = \sqrt{60^2 + 60^2} 84.85mm$

$F' = \frac{P}{l} = \frac{P}{120 \times 4} = 2.088 \times 10^{-3} P$ N/mm

WKT $\quad F'' = \frac{P_e r}{J_w}$ $\qquad J_w = \frac{(b+d)^3}{6} = \frac{(120+120)^3}{6}$

$J_w = 2.304 \times 10^6 mm^3$

$F'' = 0.013P$ N/mm

$F_r = \sqrt{(F')^2 + (F'')^2 + 2F'F''\cos\theta}$

$F_r = \sqrt{(2.088 \times 10^{-3} P)^2 + (0.013P)^2 + 2 \times 2.088 \times 10^{-3} \times 0.013P \times 0.707}$

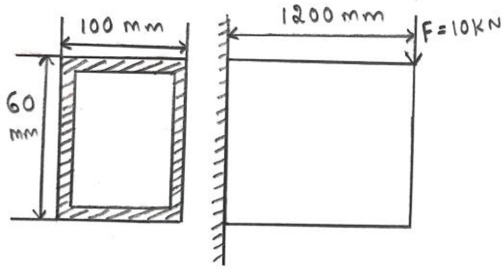
$F_r = 0.014P$ N/mm

$\tau = \frac{F_r}{0.707h}$

$96 = \frac{0.014P}{0.707 \times 6}$

$P = 27.088\ KN$

4. Determine the size of fillet weld for a welded joint loaded as shown in figure.



From table 12.3

1) $Z_w = \frac{2bd + d^2}{3} = \frac{d^2(2b+d)}{3(b+d)}$

$Z_w = \frac{(2\times100\times60)+60^2}{3} = 5200mm^2$

2) $F' = \frac{F}{l} = \frac{10\times10^3}{100+(2\times60)} = 45.45\ N/mm$

3) $F'' = \frac{M_b}{Z_w} = \frac{10\times10^3\times1200}{5200} = 2.30\times10^3$ N/mm $\qquad$ $(M_b = F\times e)$

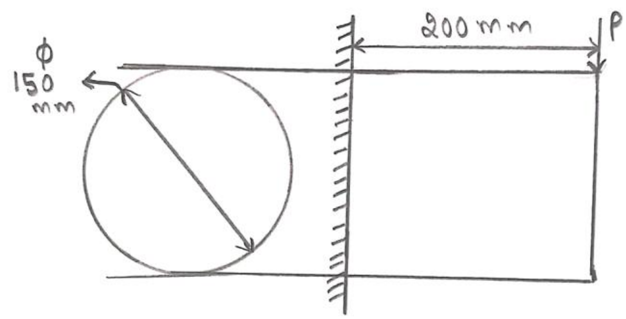
4) $F_r = \sqrt{F'^2 + F''^2} = 2.30\times10^3$ N/mm

5) $\tau = \frac{F_r}{0.707h} = 96.50 \qquad \rightarrow 12.6$

$\tau = \frac{2.30\times10^3}{0.707\times h}$

h=33.71mm $\quad$ h=34$\times$34

5. A steel pipe of outer dia 150mm is welded as shown in figure. using 4mm fillet weld. Determine the load 'P' that may be applied at the free end of the 'P'.



$$1) F' = \frac{F}{l} = \frac{P}{\pi d} = \frac{P}{\pi \times 150}$$

$$F' = 2.12 \times 10^{-3} P \text{ N/mm}$$

$$2) Z_w = \frac{\pi d^2}{4} = \frac{\pi \times 150^2}{4} = 17.67 \times 10^3 mm^2$$

$$3) F'' = \frac{M_b}{Z_w} = \frac{F \times e}{17.67 \times 10^3} = \frac{P \times 200}{17.67 \times 10^3} = 0.0113\text{P N/m}$$

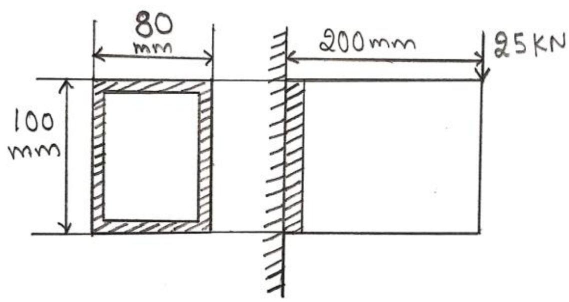
$$4) \text{F}_r = \sqrt{(\text{F}')^2 + (\text{F}'')^2} = 0.01150 P \text{ N/mm}$$

$$5) \tau = \frac{F_r}{0.707 h}$$

$$\therefore 96.50 = \frac{0.01150 P}{0.707 \times 4}$$

$$P = 23.73 \times 10^3 N$$

6. A rectangular bar is welded to a plate as shown in figure. Determine the size of the weld required.



$$1) F' = \frac{F}{l} = \frac{25\times10^3}{200+160} = 69.45 \text{ N/mm}$$

$$2) Z_w = bd + \frac{d^2}{3} = (80\times100) + \frac{100^2}{3} = 11.33\times10^3 m^2$$

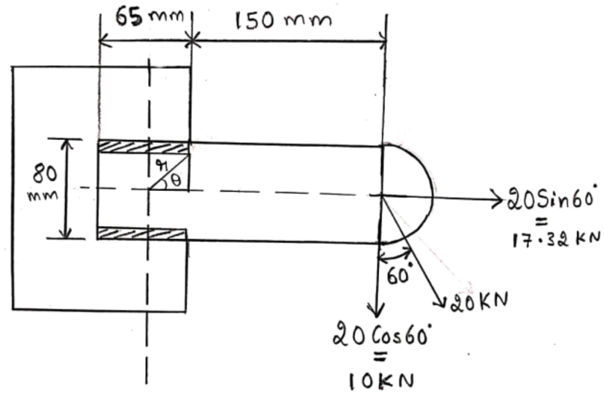
$$3) F'' = \frac{F\times e}{Z_w} = \frac{25\times10^3\times200}{11.33\times10^3} = 441.17 \text{ N/m}$$

$$4) \text{F}_r = \sqrt{(\text{F}')^2 + (\text{F}'')^2} = 0.01150P \text{ N/mm}$$

$$5) \tau = \frac{F_r}{0.707h} \qquad F_r = 446.60 \text{ N/mm}$$

$$h = 7\times7$$

7. A steel bracket is welded to a structure as shown in figure. Calculate the size of weld taking permissible stress in the weld to be 80MPa.



case 1:

$F_v = 10 \times 10^3 N$

$r = \sqrt{40^2 + 32.5^2}$

$r = 51.53mm$

1) $F' = \dfrac{F}{l} = \dfrac{10 \times 10^3}{2 \times 65} = 76.91 N/mm$

2) $F'' = \dfrac{F_e r}{J_w}$

$J_w = \dfrac{b^3 + 3bd^2}{6} = 253.77 \times 10^3$

$= \dfrac{10 \times 10^3 + 3\left(150 \times 51.53^3\right)}{253.77 \times 10^3}$

$F'' = 370.68 N/mm$

$F_r = \sqrt{(F')^2 + (F'')^2 + 2F'F''\cos\theta}$

$F_r = \sqrt{(76.9)^2 + (370.68)^2 + 2 \times 76.9 \times 370.68 \times 0.630}$

$F_r = 423.36 N/mm$

We have,

$$\tau = \frac{F_r}{0.707h}$$

$$h = \frac{F_r}{0.707 \times \tau}$$

$$h = 7 \times 7mm$$

case 2:

Considering horizontal parallel fillet weld

WKT

$$\tau = \frac{F_t}{0.707 \times h \times l}$$

$$84 = \frac{17.32 \times 10^3}{0.707 \times h \times 65 \times 2}$$

$$h = 2.24$$

$$h = 3 \times 3$$

Consider the max size

i.e h=7.5×7.5mm