Design of Riveted Joints

Instructional Objectives:

At the end of this lesson, the students should be able to understand:

- Basic failure mechanisms of riveted joints.
- Concepts of design of a riveted joint.

1.Strength of riveted joint:

Strength of a riveted joint is evaluated taking all possible failure paths in the joint into account. Since rivets are arranged in a periodic manner, the strength of joint is usually calculated considering one pitch length of the plate. There are four possible ways a single rivet joint may fail.

a) Tearing of the plate: If the force is too large, the plate may fail in tension along the row (see figure 10.2.1). The maximum force allowed in this case is

$$P_1 = s_t (p - d)t$$

where s_t = allowable tensile stress of the plate material

p = pitch

d = diameter of the rivet hole

t = thickness of the plate

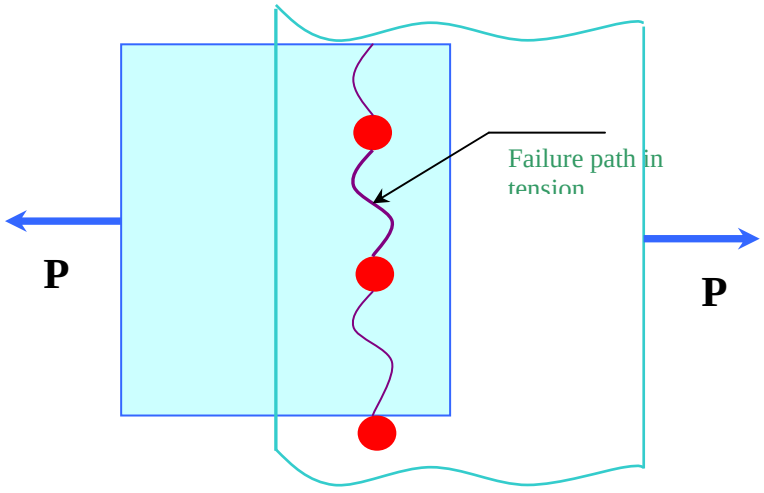

Figure 10.2.1: Failure of plate in tension (tearing)

b) *Shearing of the rivet:* The rivet may shear as shown in figure 10.2.2. The maximum force withstood by the joint to prevent this failure is

$$P_2 = s_s(\frac{\pi}{4}d^2) \quad \text{for lap joint, single strap butt joint}$$

$$= 2s_s(\frac{\pi}{4}d^2) \quad \text{for double strap butt joint}$$

where s_s =allowable shear stress of the rivet material.

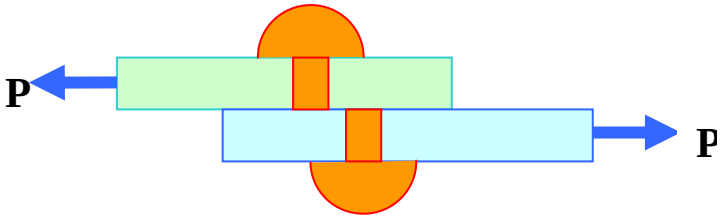

Figure 10.2.2: Failure of a rivet by shearing

c) *Crushing of rivet:* If the bearing stress on the rivet is too large the contact surface between the rivet and the plate may get damaged. (see figure 10.2.3). With a simple assumption of uniform contact stress the maximum force allowed is

$$P_3 = s_c dt$$

where s_c =allowable bearing stress between the rivet and plate material.

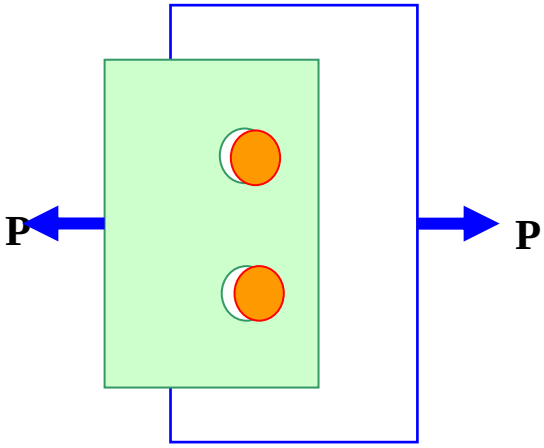

Figure 10.2.3: Failure of rivets by

d) Tearing of the plate at edge: If the margin is too small, the plate may fail as shown in figure 10.2.4. To prevent the failure a minimum margin of $m = 1.5d$ is usually provided.

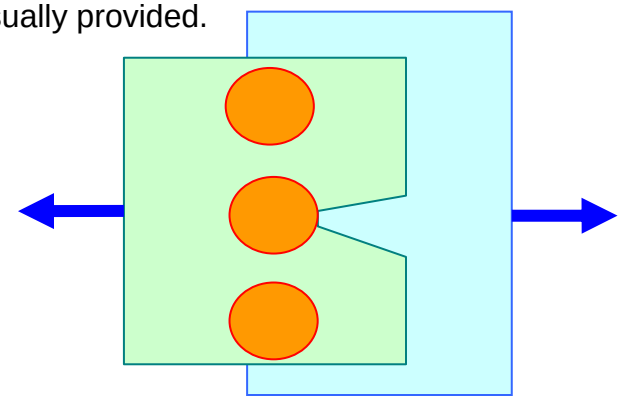

Figure 10.2.4: Tearing of the plate at the edge

2. Efficiency:

Efficiency of the single riveted joint can be obtained as ratio between the maximum of P_1, P_2 and P_3 and the load carried by a solid plate which is $s_t pt$. Thus

$$\text{efficiency } (\eta) = \frac{\min\{P_1, P_2, P_3\}}{s_t pt}$$

In a double or triple riveted joint the failure mechanisms may be more than those discussed above. The failure of plate along the outer row may occur in the same way as above. However, in addition the inner rows may fail. For example, in a double riveted joint, the plate may fail along the second row. But in order to do that the rivets in the first row must fail either by shear or by crushing. Thus the maximum allowable load such that the plate does not tear in the second row is

$$P_4 = s_t(p-d)t + \min\{P_2, P_3\}.$$

Further, the joint may fail by

(i) shearing of rivets in both rows

(ii) crushing of rivets in both rows

(iii) shearing of rivet in one row and crushing in the other row.

The efficiency should be calculated taking all possible failure mechanism into consideration.

3.Design of rivet joints:

The design parameters in a riveted joints are d, p and m

Diameter of the hole (d): When thickness of the plate (t) is more than 8 mm, Unwin's formula is used,

$$d = 6\sqrt{t} \text{ mm.}$$

Otherwise d is obtained by equating crushing strength to the shear strength of the joint. In a double riveted zigzag joint, this implies

$$s_c t = \frac{\pi}{4} d\, s_s \quad \text{(valid for } t < 8 \text{ mm)}$$

However, d should not be less than t, in any case. The standard size of d is tabulated in code IS: 1928-1961.

Pitch (p): Pitch is designed by equating the tearing strength of the plate to the shear strength of the rivets. In a double riveted lap joint, this takes the following form.

$$s_t (p-d)t = s_s \times 2(\frac{\pi}{4} d^2)$$

But $p \geq 2d$ in order to accommodate heads of the rivets.

Margin (m): $m = 1.5d$.

In order to design boiler joints, a designer must also comply with Indian Boiler Regulations (I.B.R.).

(p_b: usually $0.33p + 0.67d$ mm)

Review questions and answers:

Q. 1. Two plates of 7 mm thickness are connected by a double riveted lap joint of zigzag pattern. Calculate rivet diameter, rivet pitch and distance between rows of rivets for the joint. Assume $s_t = 90\,\text{MPa}$, $s_s = 60\,\text{MPa}$, $s_c = 120\text{MPa}$.

Ans. Since $t = 7\,\text{mm} < 8\,\text{mm}$, the diameter of the rivet hole is selected equating shear strength to the crushing strength, i.e.,

$$2\left(\frac{\pi}{4}d^2\right)s_s = 2dt\,s_c$$

yielding $d = 17.8\,\text{mm}$. According to IS code, the standard size is $d = 19\,\text{mm}$ and the corresponding rivet diameter is $18\,\text{mm}$.

Pitch is obtained from the following

$$s_t(p-d)t = 2s_s(\frac{\pi}{4}d^2)\text{, where } d = 19\,\text{mm}$$

$$p = 54 + 19 = 73\,\text{mm}$$

[Note: If the joint is to comply with I.B.R. specification, then $p_{\max} = c.t + 41.28\,\text{mm}$, where c is a constant depending upon the type of joint and is tabulated in the code.]

The distance between the two rivet rows is

$$p_d = \frac{p}{3} + \frac{2}{3}d = 37\,\text{mm}\ .$$

Q.2. A triple riveted butt joint with two unequal cover plates joins two 25 mm plates as shown in the figure below.

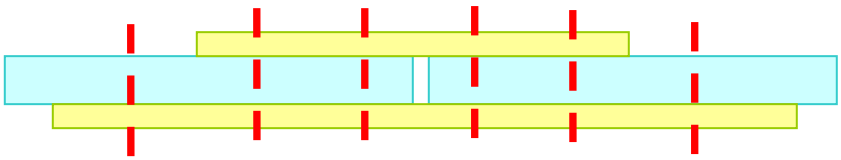

Figure: 10.2.5

The rivet arrangement is zigzag and the details are given below:

Pitch = 22 cm in outer row and 11 cm in inner rows,

Rivet diameter = 33 mm

Calculate the efficiency of the joint when the allowable stresses are 75 MPa, 60 MPa and 125 MPa in tension, shear and crushing, respectively.

Ans. From code it may be seen that the corresponding rivet hole diameter is 34.5 mm.

To find strength of the joint all possible failure mechanisms are to be considered separately.

(a) Tearing resistance of the plate in outer row:

$$P_1 = (p - d_{hole})\, t\, s_T$$ = (220-34.5) X 25 X 75 = 347.81 kN

(b) Shearing resistance of the rivet:

$$P_2 = 2 \times 4 \times \frac{\pi}{4} d^2 s_S + \frac{\pi}{4} d^2 s_S$$ = 461.86 kN

Note that within a pitch length of 22cm four rivets are in double shear while one rivet in single shear.

(c) Crushing resistance of the rivets

$$P_3 = 5 \times d\, t s_C$$ = 515.62 kN

(d) Shear failure of the outer row and tearing of the rivets in the second row

$$P_4 = (p - 2d_{hole}) t s_T + \frac{\pi}{4} d^2 s_S$$ = 334.44 kN

Note that in second row there are 2 rivets per pitch length and the rivets in outer row undergoes single shear.

There are other mechanisms of failure of the joint e.g. tearing along the innermost row and shearing or crushing of rivets in other two rows etc., but all of them will have higher resistance than those considered above. Hence the efficiency of the joint is

$$\eta = \frac{\min\{P_1, P_2, P_3, P_4\}}{pts_T}$$ = 0.8108

or when expressed in percentile 81.08 %.

Q.3. How is a rivet joint of uniform strength designed?

Ans. The procedure by which uniform strength in a riveted joint is obtained is known as *diamond riveting*, whereby the number of rivets is increased

progressively from the outermost row to the innermost row (see figure below). A common joint, where this type of riveting is done, is Lozenge joint used for roof, bridge work etc.

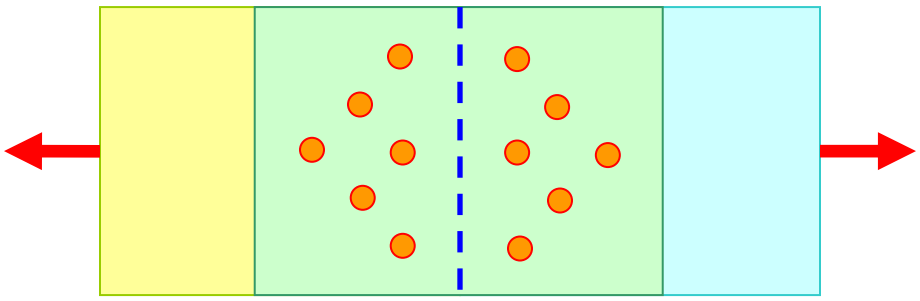

Figure 10.2.6: Diamond riveting in structural joint

Q. 4. Two mild steel tie rods having width 200 mm and thickness 12.5 mm are to be connected by means of a butt joint with double cover plates. Find the number of rivets needed if the permissible stresses are 80 MPa in tension, 65 MPa in shear and 160 MPa in crushing.

Ans. As discussed earlier for a structural member Lozenge joint is used which has one rivet in the outer row.

The number of rivets can be obtained equating the tearing strength to the shear or crushing strength of the joint, i.e., from the equation

$$(b-d)ts_T = 2n_1(\frac{\pi}{4}d^2)s_s \quad \text{[Double shear]}$$

or $(b-d)ts_T = n_2(dt)s_c$

where *b* and *t* are the width and thickness of the plates to be joined . In the problem $b = 200\,\text{mm}$, $t = 12.5\,\text{mm}$, $s_T = 80\,\text{MPa}$, $s_c = 160\,\text{MPa}$, $s_s = 65\,\text{MPa}$ and d is obtained from Unwin's formula $d = 6\sqrt{t}\ \text{mm} = 21.2\,\text{mm}$. According to IS code, the standard rivet hole diameter is 21.5 mm and corresponding rivet diameter is 20 mm. The number of rivets required is the minimum of the numbers calculated from the above two expressions. It may be checked that n_1 is found out to be 3.89 while n_2 is 4.216. Therefore, at least 5 rivets are needed.

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