

Example 11.15. Determine the size of the bolts and the thickness of the arm for the bracket as shown in Fig. 11.36, if it carries a load of 40 kN at an angle of 60° to the vertical.

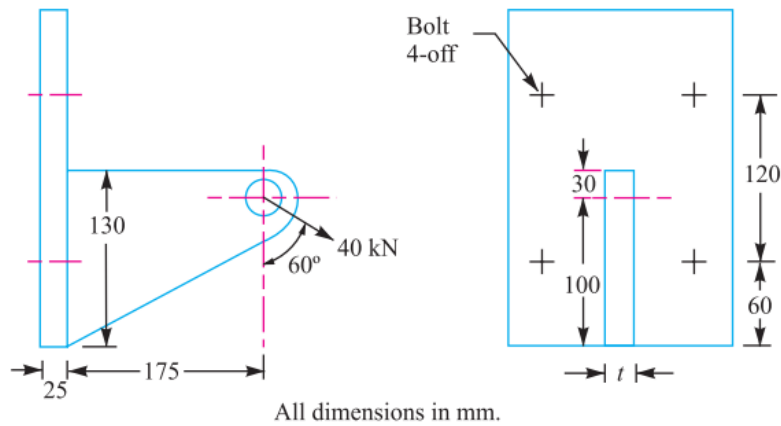


Fig 11.36

Example 11.16. An offset bracket, having arm of I-cross-section is fixed to a vertical steel column by means of four standard bolts as shown in Fig. 11.38. An inclined pull of 10 kN is acting on the bracket at an angle of 60° to the vertical.

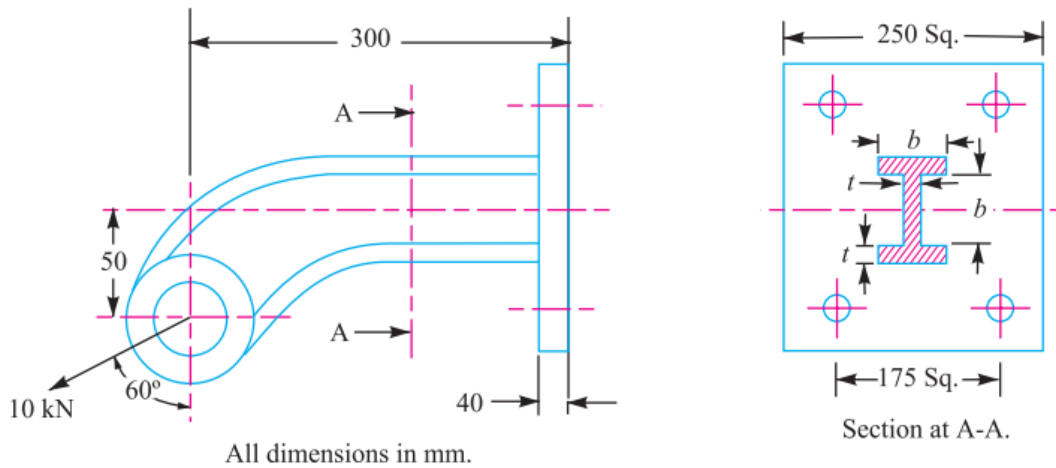


Fig. 11.38

A mounting plate for a drive unit is fixed to the support by means of four M 12 bolts as shown in Fig. 11.48. The core diameter of the bolts can be considered as 9.858 mm. Determine the maximum value of 'W' if the allowable tensile stress in bolt material is 60 MPa. **[Ans. 12.212 kN]**

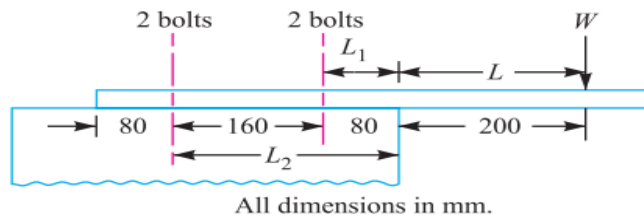
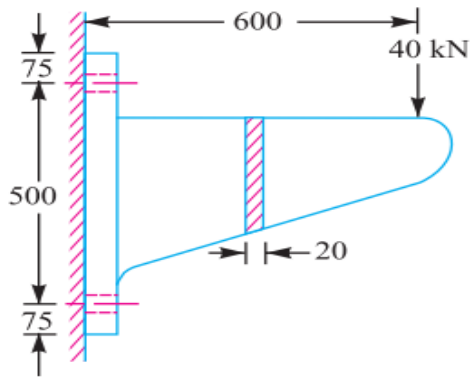


Fig. 11.48

A wall bracket, as shown in Fig. 11.50, is fixed to a wall by means of four bolts. Find the size of the bolts and the width of bracket. The safe stress in tension for the bolt and bracket may be assumed as 70 MPa. [Ans. M 30 ; 320 mm]

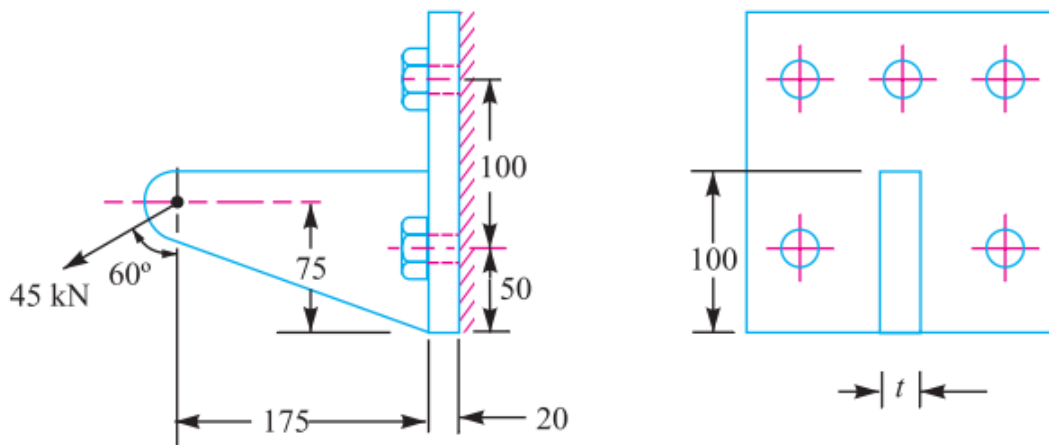


All dimensions in mm.

Fig. 11.50

A bracket, as shown in Fig. 11.53, is fixed to a vertical steel column by means of five standard bolts. Determine : (a) The diameter of the fixing bolts, and (b) The thickness of the arm of the bracket. Assume safe working stresses of 70 MPa in tension and 50 MPa in shear.

[Ans. M 18; 50 mm]



All dimensions in mm.

Fig. 11.53

Riveted Joints

9.1 Introduction

A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called *shank* or *body* and lower portion of shank is known as *tail*, as shown in Fig. 9.1. The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals.

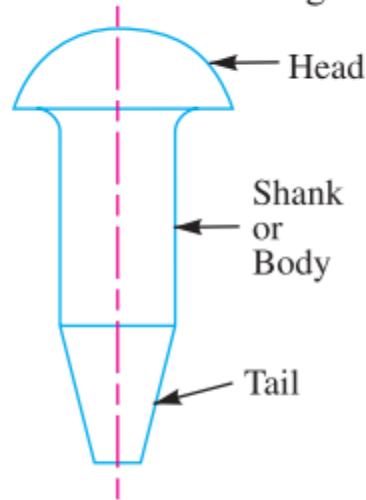


Fig. 9.1. Rivet parts.

The fastenings (*i.e.* joints) may be classified into the following two groups :

1. Permanent fastenings, and
2. Temporary or detachable fastenings.

The *permanent fastenings* are those fastenings which can not be disassembled without destroying the connecting components. The examples of permanent fastenings in order of strength are soldered, brazed, welded and riveted joints.

The *temporary or detachable fastenings* are those fastenings which can be disassembled without destroying the connecting components. The examples of temporary fastenings are screwed, keys, cotters, pins and splined joints.

9.3 Material of Rivets

The material of the rivets must be tough and ductile. They are usually made of steel (low carbon steel or nickel steel), brass, aluminium or copper, but when strength and a fluid tight joint is the main consideration, then the steel rivets are used.

The rivets for general purposes shall be manufactured from steel conforming to the following Indian Standards :

- (a) IS : 1148–1982 (Reaffirmed 1992) – Specification for hot rolled rivet bars (up to 40 mm diameter) for structural purposes; or
- (b) IS : 1149–1982 (Reaffirmed 1992) – Specification for high tensile steel rivet bars for structural purposes.

The rivets for boiler work shall be manufactured from material conforming to IS : 1990 – 1973 (Reaffirmed 1992) – Specification for steel rivets and stay bars for boilers.

Note : The steel for boiler construction should conform to IS : 2100 – 1970 (Reaffirmed 1992) – Specification for steel billets, bars and sections for boilers.

9.4 Essential Qualities of a Rivet

According to Indian standard, IS : 2998 – 1982 (Reaffirmed 1992), the material of a rivet must have a tensile strength not less than 40 N/mm^2 and elongation not less than 26 percent. The material must be of such quality that when in cold condition, the shank shall be bent on itself through 180° without cracking and after being heated to 650°C and quenched, it must pass the same test. The rivet when hot must flatten without cracking to a diameter 2.5 times the diameter of shank.

9.5 Manufacture of Rivets

According to Indian standard specifications, the rivets may be made either by cold heading or by hot forging. If rivets are made by the cold heading process, they shall subsequently be adequately heat treated so that the stresses set up in the cold heading process are eliminated. If they are made by hot forging process, care shall be taken to see that the finished rivets cool gradually.

9.6 Types of Rivet Heads

According to Indian standard specifications, the rivet heads are classified into the following three types :

1. Rivet heads for general purposes (below 12 mm diameter) as shown in Fig. 9.3, according to IS : 2155 – 1982 (Reaffirmed 1996).

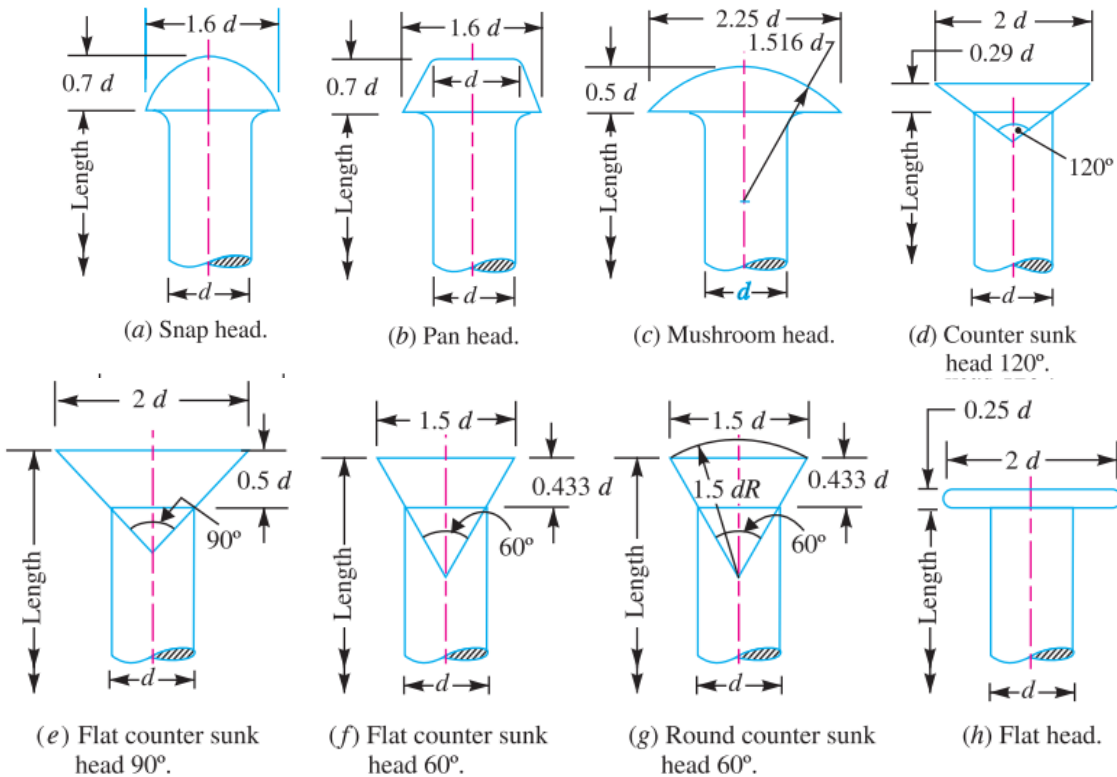


Fig. 9.3. Rivet heads for general purposes (below 12 mm diameter).

2. Rivet heads for general purposes (From 12 mm to 48 mm diameter) as shown in Fig. 9.4, according to IS : 1929 – 1982 (Reaffirmed 1996).

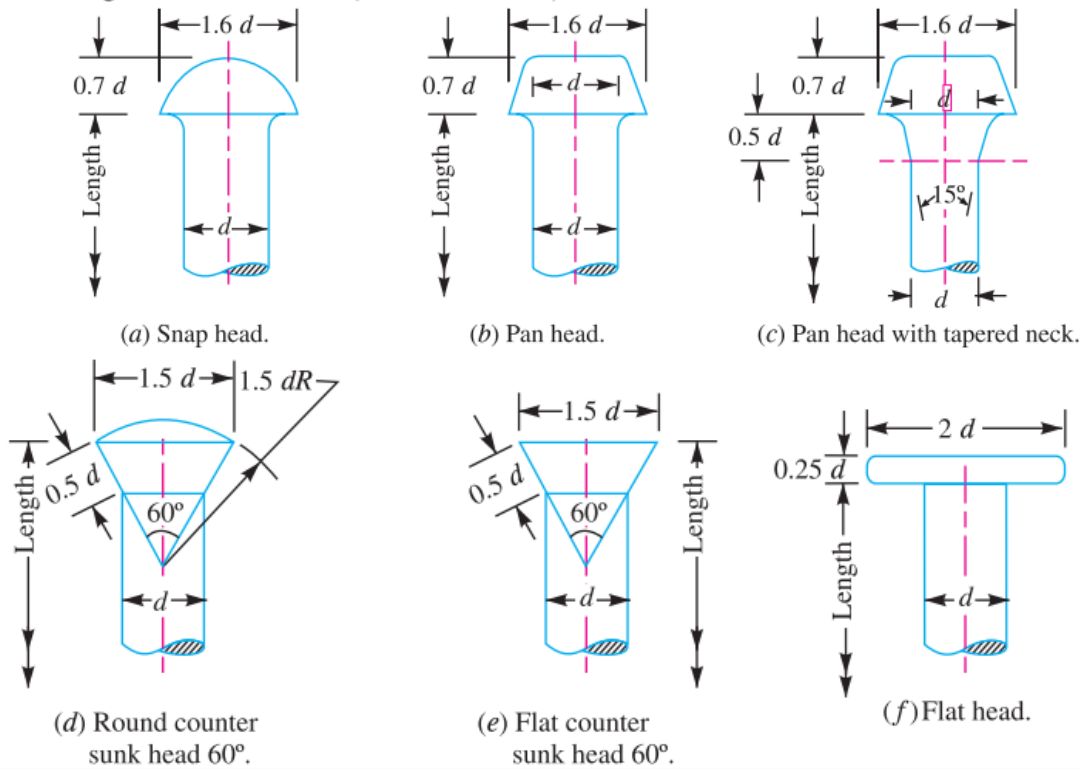
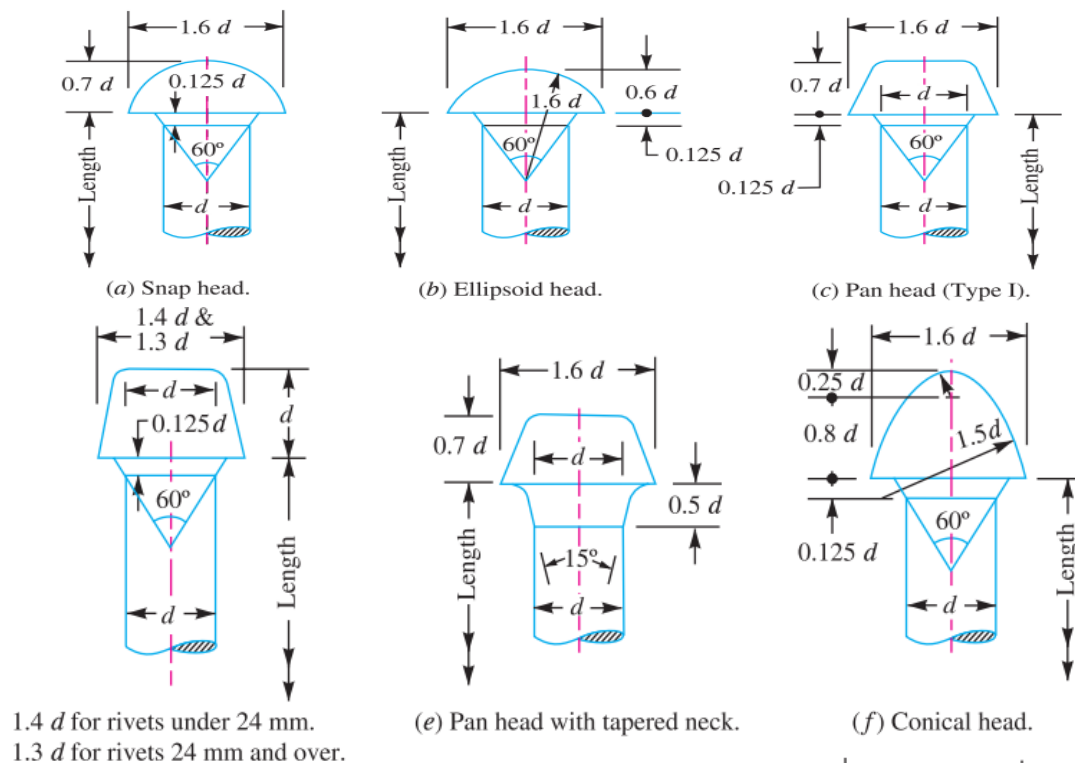


Fig. 9.4. Rivet heads for general purposes (from 12 mm to 48 mm diameter)

3. Rivet heads for boiler work (from 12 mm to 48 mm diameter, as shown in Fig. 9.5, according to IS : 1928 – 1961 (Reaffirmed 1996).



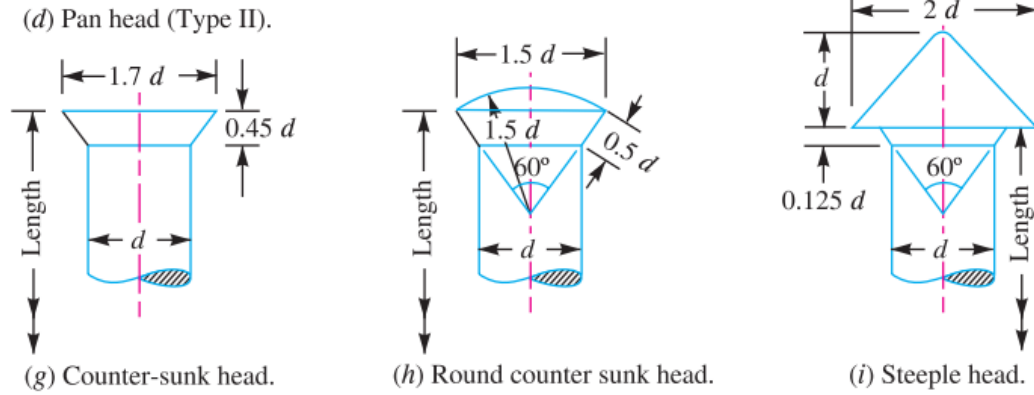


Fig. 9.5. Rivet heads for boiler work.

The **snap heads** are usually employed for structural work and machine riveting. The **counter sunk heads** are mainly used for ship building where flush surfaces are necessary. The **conical heads** (also known as **conoidal heads**) are mainly used in case of hand hammering. The **pan heads** have maximum strength, but these are difficult to shape.

9.7 Types of Riveted Joints

Following are the two types of riveted joints, depending upon the way in which the plates are connected.

1. Lap joint, and
2. Butt joint.

9.8 Lap Joint

A lap joint is that in which one plate overlaps the other and the two plates are then riveted together.

9.9 Butt Joint

A butt joint is that in which the main plates are kept in alignment butting (*i.e.* touching) each other and a cover plate (*i.e.* strap) is placed either on one side or on both sides of the main plates. The cover plate is then riveted together with the main plates. Butt joints are of the following two types :

1. Single strap butt joint, and
2. Double strap butt joint.

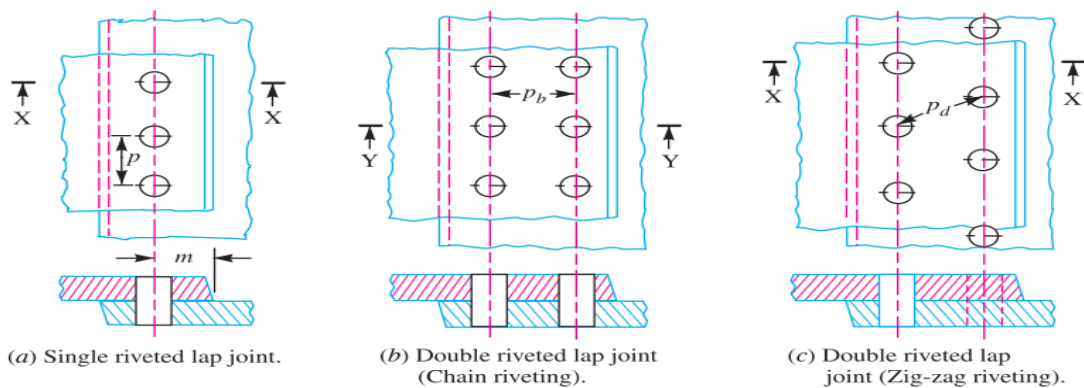


Fig. 9.6. Single and double riveted lap joints.

Similarly the joints may be *triple riveted* or *quadruple riveted*.

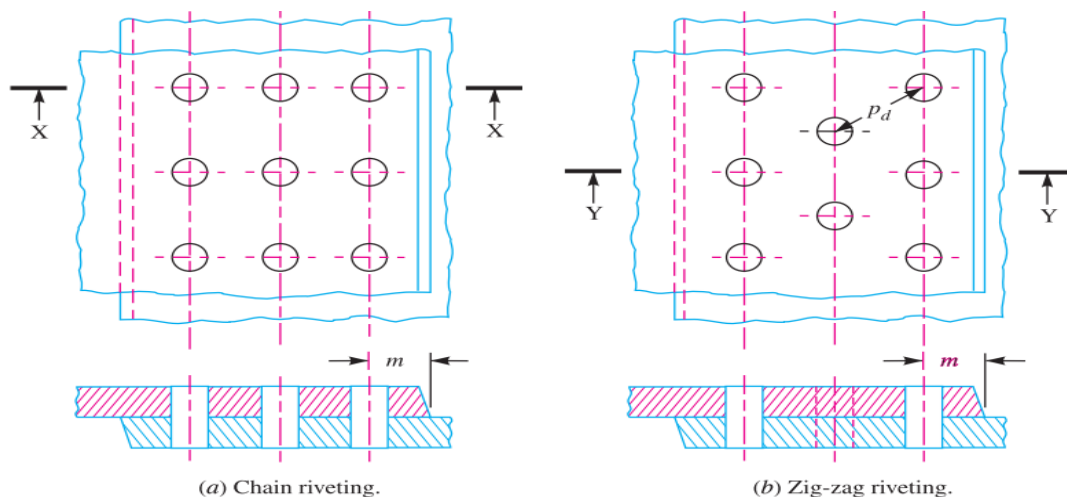


Fig. 9.7. Triple riveted lap joint.

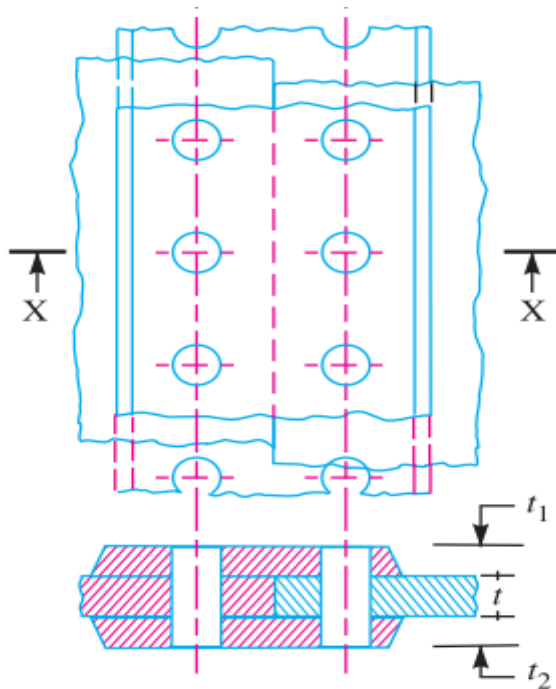


Fig. 9.8. Single riveted double strap butt joint.

9.10 Important Terms Used in Riveted Joints

The following terms in connection with the riveted joints are important from the subject point of view :

1. **Pitch.** It is the distance from the centre of one rivet to the centre of the next rivet measured parallel to the seam as shown in Fig. 9.6. It is usually denoted by p .
2. **Back pitch.** It is the perpendicular distance between the centre lines of the successive rows as shown in Fig. 9.6. It is usually denoted by p_b .
3. **Diagonal pitch.** It is the distance between the centres of the rivets in adjacent rows of zig-zag riveted joint as shown in Fig. 9.6. It is usually denoted by p_d .
4. **Margin or marginal pitch.** It is the distance between the centre of rivet hole to the nearest edge of the plate as shown in Fig. 9.6. It is usually denoted by m .

9.12 Failures of a Riveted Joint

A riveted joint may fail in the following ways :

1. Tearing of the plate at an edge. A joint may fail due to tearing of the plate at an edge as shown in Fig. 9.13. This can be avoided by keeping the margin, $m = 1.5d$, where d is the diameter of the rivet hole.

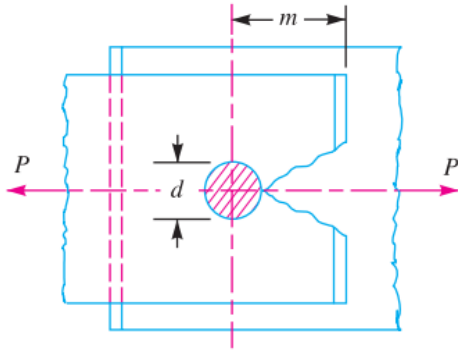


Fig. 9.13. Tearing of the plate at an edge.

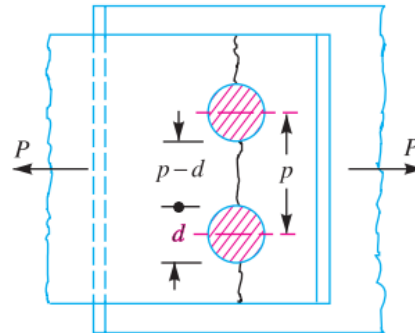


Fig. 9.14. Tearing of the plate across the rows of rivets.

2. Tearing of the plate across a row of rivets. Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets as shown in Fig. 9.14. In such cases, we consider only one pitch length of the plate, since every rivet is responsible for that much length of the plate only.

The resistance offered by the plate against tearing is known as **tearing resistance** or **tearing strength** or **tearing value** of the plate.

Let

- p = Pitch of the rivets,
- d = Diameter of the rivet hole,
- t = Thickness of the plate, and
- σ_t = Permissible tensile stress for the plate material.

We know that tearing area per pitch length,

$$A_t = (p - d)t$$

\therefore Tearing resistance or pull required to tear off the plate per pitch length,

$$P_t = A_t \cdot \sigma_t = (p - d)t \cdot \sigma_t$$

When the tearing resistance (P_t) is greater than the applied load (P) per pitch length, then this type of failure will not occur.

3. Shearing of the rivets. The plates which are connected by the rivets exert tensile stress on the rivets, and if the rivets are unable to resist the stress, they are sheared off as shown in Fig. 9.15.

It may be noted that the rivets are in *single shear in a lap joint and in a single cover butt joint, as shown in Fig. 9.15. But the rivets are in double shear in a double cover butt joint as shown in Fig. 9.16. The resistance offered by a rivet to be sheared off is known as *shearing resistance* or *shearing strength* or *shearing value* of the rivet.

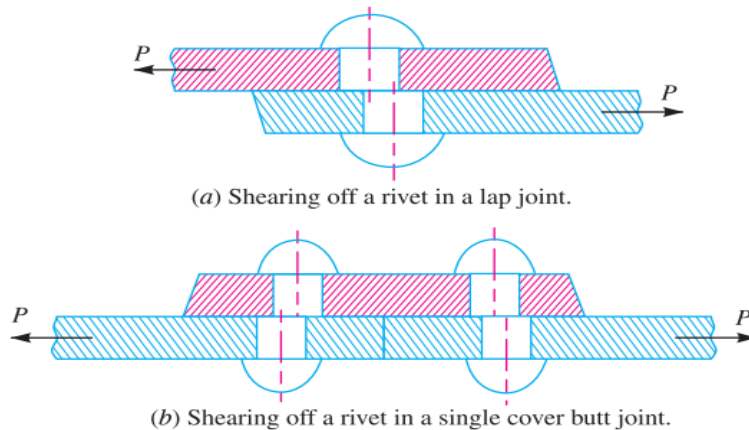


Fig. 9.15. Shearing of rivets.

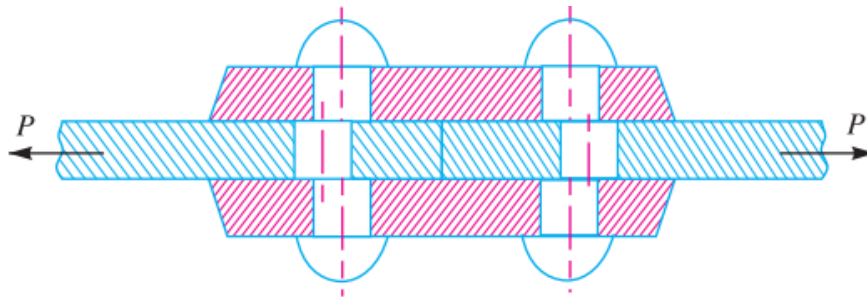


Fig. 9.16. Shearing off a rivet in double cover butt joint.

Let

d = Diameter of the rivet hole,

τ = Safe permissible shear stress for the rivet material, and

n = Number of rivets per pitch length.

We know that shearing area,

$$A_s = \frac{\pi}{4} \times d^2 \quad \dots(\text{In single shear})$$

$$= 2 \times \frac{\pi}{4} \times d^2 \quad \dots(\text{Theoretically, in double shear})$$

$$= 1.875 \times \frac{\pi}{4} \times d^2 \quad \dots(\text{In double shear, according to Indian Boiler Regulations})$$

\therefore Shearing resistance or pull required to shear off the rivet per pitch length,

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau \quad \dots(\text{In single shear})$$

$$= n \times 2 \times \frac{\pi}{4} \times d^2 \times \tau \quad \dots(\text{Theoretically, in double shear})$$

$$= n \times 1.875 \times \frac{\pi}{4} \times d^2 \times \tau \dots (\text{In double shear, according to Indian Boiler Regulations})$$

When the shearing resistance (P_s) is greater than the applied load (P) per pitch length, then this type of failure will occur.

4. Crushing of the plate or rivets. Sometimes, the rivets do not actually shear off under the tensile stress, but are crushed as shown in Fig. 9.17. Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The failure of rivets in such a manner is also known as **bearing failure**. The area which resists this action is the projected area of the hole or rivet on diametral plane.

The resistance offered by a rivet to be crushed is known as **crushing resistance** or **crushing strength** or **bearing value** of the rivet.

- Let
- d = Diameter of the rivet hole,
 - t = Thickness of the plate,
 - σ_c = Safe permissible crushing stress for the rivet or plate material, and
 - n = Number of rivets per pitch length under crushing.

We know that crushing area per rivet (*i.e.* projected area per rivet),

$$A_c = d.t$$

$$\therefore \text{Total crushing area} = n.d.t$$

and crushing resistance or pull required to crush the rivet per pitch length,

$$P_c = n.d.t.\sigma_c$$

When the crushing resistance (P_c) is greater than the applied load (P) per pitch length, then this type of failure will occur.

Note : The number of rivets under shear shall be equal to the number of rivets under crushing.

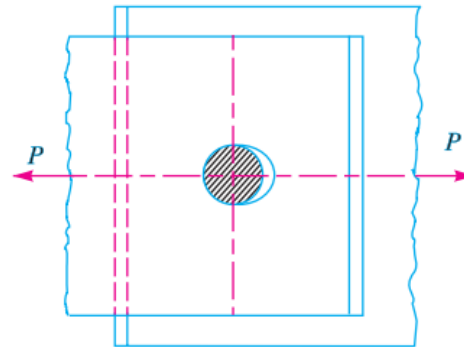


Fig. 9.17. Crushing of a rivet.

9.13 Strength of a Riveted Joint

The strength of a joint may be defined as the maximum force, which it can transmit, without causing it to fail. We have seen in Art. 9.12 that P_t , P_s and P_c are the pulls required to tear off the plate, shearing off the rivet and crushing off the rivet. A little consideration will show that if we go on increasing the pull on a riveted joint, it will fail when the least of these three pulls is reached, because a higher value of the other pulls will never reach since the joint has failed, either by tearing off the plate, shearing off the rivet or crushing off the rivet.

If the joint is **continuous** as in case of boilers, the strength is calculated **per pitch length**. But if the joint is **small**, the strength is calculated for the **whole length** of the plate.

9.14 Efficiency of a Riveted Joint

The efficiency of a riveted joint is defined as the ratio of the strength of riveted joint to the strength of the un-riveted or solid plate.

We have already discussed that strength of the riveted joint

$$= \text{Least of } P_t, P_s \text{ and } P_c$$

Strength of the un-riveted or solid plate per pitch length,

$$P = p \times t \times \sigma_t$$

\therefore Efficiency of the riveted joint,

$$\eta = \frac{\text{Least of } P_t, P_s \text{ and } P_c}{p \times t \times \sigma_t}$$

where

p = Pitch of the rivets,

t = Thickness of the plate, and

σ_t = Permissible tensile stress of the plate material.

Example 9.1. A double riveted lap joint is made between 15 mm thick plates. The rivet diameter and pitch are 25 mm and 75 mm respectively. If the ultimate stresses are 400 MPa in tension, 320 MPa in shear and 640 MPa in crushing, find the minimum force per pitch which will rupture the joint.

If the above joint is subjected to a load such that the factor of safety is 4, find out the actual stresses developed in the plates and the rivets.

Solution. Given : $t = 15$ mm ; $d = 25$ mm ; $p = 75$ mm ; $\sigma_{tu} = 400$ MPa = 400 N/mm² ; $\tau_u = 320$ MPa = 320 N/mm² ; $\sigma_{cu} = 640$ MPa = 640 N/mm²

Minimum force per pitch which will rupture the joint

Since the ultimate stresses are given, therefore we shall find the ultimate values of the resistances of the joint. We know that ultimate tearing resistance of the plate per pitch,

$$P_{tu} = (p - d)t \times \sigma_{tu} = (75 - 25)15 \times 400 = 300\,000 \text{ N}$$

Ultimate shearing resistance of the rivets per pitch,

$$P_{su} = n \times \frac{\pi}{4} \times d^2 \times \tau_u = 2 \times \frac{\pi}{4} (25)^2 320 = 314\,200 \text{ N} \quad \dots (\because n = 2)$$

and ultimate crushing resistance of the rivets per pitch,

$$P_{cu} = n \times d \times t \times \sigma_{cu} = 2 \times 25 \times 15 \times 640 = 480\,000 \text{ N}$$

From above we see that the minimum force per pitch which will rupture the joint is 300 000 N or 300 kN. **Ans.**

Actual stresses produced in the plates and rivets

Since the factor of safety is 4, therefore safe load per pitch length of the joint

$$= 300\,000 / 4 = 75\,000 \text{ N}$$

Let σ_{ta} , τ_a and σ_{ca} be the actual tearing, shearing and crushing stresses produced with a safe load of 75 000 N in tearing, shearing and crushing.

We know that actual tearing resistance of the plates (P_{ta}),

$$75\,000 = (p - d)t \times \sigma_{ta} = (75 - 25)15 \times \sigma_{ta} = 750 \sigma_{ta}$$

$$\therefore \sigma_{ta} = 75\,000 / 750 = 100 \text{ N/mm}^2 = 100 \text{ MPa} \quad \text{Ans.}$$

Actual shearing resistance of the rivets (P_{sa}),

$$75\,000 = n \times \frac{\pi}{4} \times d^2 \times \tau_a = 2 \times \frac{\pi}{4} (25)^2 \tau_a = 982 \tau_a$$

$$\therefore \tau_a = 75000 / 982 = 76.4 \text{ N/mm}^2 = 76.4 \text{ MPa} \quad \text{Ans.}$$

and actual crushing resistance of the rivets (P_{ca}),

$$75\,000 = n \times d \times t \times \sigma_{ca} = 2 \times 25 \times 15 \times \sigma_{ca} = 750 \sigma_{ca}$$

$$\therefore \sigma_{ca} = 75000 / 750 = 100 \text{ N/mm}^2 = 100 \text{ MPa} \quad \text{Ans.}$$
