UNIT 4 WELDED JOINTS

Structure

4.1 Introduction

Objectives

4.2 Welded Connections

4.3 Types of Welding Joints, Strength

4.4 T-Joint

4.5 Unsymmetrical Section Loaded Axially

4.6 Eccentrically Loaded Welded Joint

4.7 Summary

4.8 Key Words

4.9 Answers to SAQs

4.1 INTRODUCTION

The problem of connecting plates was first solved through riveted connections but the development that occurred during World War-II saw the welded joints replace riveted joints in most applications. The ship building industry was perhaps in the fore front and large ships in excess of 10,000 in number were build with welded structures welding technology, indeed provided several advantages. The ease of processing and weight reduction were the identifiable advantages in the beginning. The automation and variety of welding processes have now become the most obvious advantages the technological developments have included several steels and even non-ferrous metals in the lists of weldable materials.

Objectives

After studying this unit, you should be able to

- describe types of welded joints,
- understand strength of weldments,
- describe modes of failure of welded joint, and
- design welded joints under different load conditions including eccentric loading.

4.2 WELDED CONNECTIONS

Welding is a process of joining two or more pieces of metals. The process is of course adopted to obtain specific shapes and sizes to perform specific function. In the process of welding the temperature of metal to be jointed is raised to a level so that the metal becomes plastic or fluid. When metal is just plastic then pieces to be welded are pressed together to make the joint. When metal is melted to fluid state another metal is filled in the region of the joint and allowed to cool to solidify.

Connections between metal plates, angles, pipes, and other structural elements are frequently made by welding. Fusion welds are made by melting portions of the materials to be joined with an electric arc, a gas flame, or with thermit. In fusion welds, additional welding material is usually added to the melted metal to fill the space between the two parts to be jointed or to form a fillet. A gas shields is provided when welding certain metals to prevent rapid oxidation of the molten metal. A good welded joint will usually develop the full strength of the material being joined unless the high temperature necessary for the process changes the properties of the materials.

Metals may also be joined by resistance welding in which a small area or spot is heated under high localized pressure. The material is not melted with this type of welding. Other joining methods for metals include brazing and soldering, in which the joining metal is melted but the parts to be connected are not melted. Such connections are usually much weaker than the materials being connected. Fusion welding is the most effective method when high strength is an important factor, and it will be discussed more in detail.

At present time welding has become a powerful technology and almost all joining of steels is done by welding. Welding has replaced riveting, particularly in the manufacturing of boilers and ships, and in many cases is being preferred in construction of structure. Some of the advantages of welding over riveting are as follows :

(a) The plates and sections to be joined are not weakend as happens in case of riveting. For riveting drilling or punching removes the metal from working sections thus making them weaker. The net weight of metal making the joint is less in case of welded joints. The weight added due to filling of metal is much less than the weight added by way of riveting. The butt welded joints do not require any cover keeping the weight low.

(b) The riveted joints require a great deal of labour in marking and making holes. There is no possibility of making the riveting process automated whereas welding has become fully automatic particularly when long seams, such as in boiler are to be produced.

(c) Tight and leak proof joints are ensured by welding.

(d) Welding is a noiseless operation whereas riveting can never be noiseless

(e) Curved parts are easily joined by welding

However, following difficulties in producing good welded joints must be kept in mind. Some of these may become disadvantage of welding unless special care is taken.

(a) The parts to be joined have to be prepared carefully along the seam and arranged to have sufficient clearance so that filler metal can easily be filled.

(b) Since metal is heated to a very high temperature (to melting point in most cases) there exists a strong possibility of metallurgical changes taking place in parent metals, particularly in the close vicinity of the joint. These changes may deteriorate the mechanical properties. The loss of ductility is a major problem.

(c) Since the metal to be joined is held by clamping, residual stresses develop in the region of weld. These residual stresses are often tensile in nature and greatly affect the behaviour of metal under fatigue loading.

(d) The quality of weld is highly dependedent upon the welder if automated process is not used.

(e) The residual stresses may be removed and metallurgical changes reversed by heat treatment (annealing and normalising). But very large structures are difficult to heat.

(f) Stress concentration is produced where filler metal joins with the parent metal. Care must be taken in post welding clearing and grinding of joint to eliminate such stress concentration.

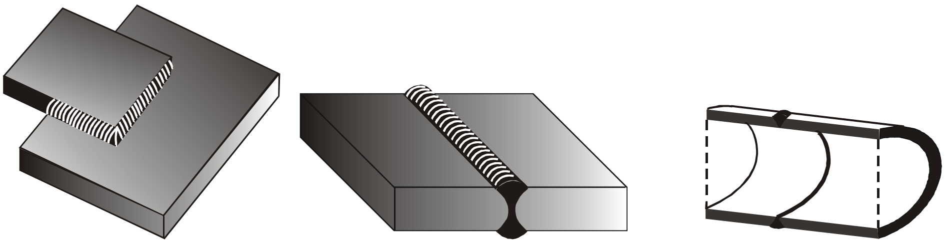
(g) The welded joints are particularly found to lose their ductility at low temperature. Combination of possible existence of defects, stress concentration and loss of ductility has been the reason of various structural failure in ships, reservoirs, pressure vessels and bridge structure.

The designer has to keep above points in mind while designing welded joins. Recommendation about treatment, grinding welds and inspection for defects must be thoroughly incorporated in design. Further, in non-automated processes the welder should be made to undergo rigorous skill tests before he is put on a job.

4.3 TYPES OF WELDED JOINTS, STRENGTH

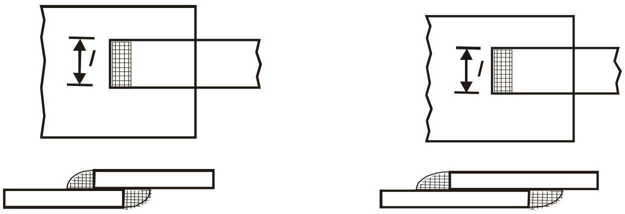
Two types of welding joints are clearly recognized viz. joints between two plates that overlap and joints between two plates that butt with each other. Figure 4.1(a) shows a fillet joint and Figures 4.1(b) and (c) show example of butt joints. Four types of fillet joints commonly used are illustrated in Figure 4.2.

It may be of interest to note that if a weld is analyzed elastically the shearing stress distribution in the weld turns out to be as shown in Figure 4.3(a). The stress is much higher at ends but quickly reduces to constant minimum. But in actual practice the ends of the weld deform plastically making distribution almost uniform. This is true if weld is ductile which is normally true. Thus, in the design of a welded joint it is reasonable to assume uniform distribution of shearing stress. However, the fillet welds are designed on the assumption that failure will occur by shearing the minimum section of the weld. This minimum section is called the throat of the weld and is shown as section *AB* in Figure 4.3(b). This is true in case of both parallel and transverse welds as shown in Figure 4.2 and is supported by experiments.

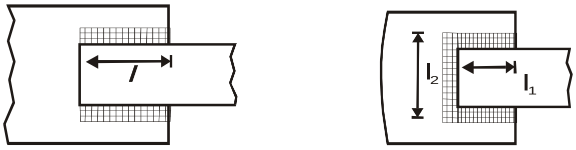


(a) Fillet Weld **(b) Butt Joint Double Vee Groove Weld** **(c) Butt Joint in Pipe Single Vee Groove Weld**

Figure 4.1 : Welded Joints



(a) Single Fillet Joint (Transverse) **(b) Double Fillet Joint (Transverse)**



(c) Parallel Fillet Joint **(d) Compound Fillet Joint**

Figure 4.2 : Types of Fillet Welded Joints

Although it is desirable to make fillet weld slightly concave, yet a reinforced weld obtained from welding is ground to obtain a triangular section with two sides equal to the thickness of plates jointed. Therefore, the width of the section *AB* in Figure 4.3(b) will be 0.707 *t* and area over which shearing will occur, for a length *l*, will be 0.707 *t l* and force of resistance will be 0.707 *t l* τ as shown in Figure 4.3(c). Here τ_s is the permissible shearing stress. The permissible shearing stress is chosen as 50% of permissible tensile stress of parents metal for manual welding. In case of automated process the permissible shearing stress in the weld is assumed as 70% of permissible tensile stress of parent metal. If the load on the joints varies between P_{min} and P_{max}, the permissible stress is multiplied by a factor γ, where

$$\gamma = \frac{1}{\frac{4}{3} - \frac{1}{3}\frac{P_{min}}{P_{max}}} \qquad \ldots (4.1)$$

Thus for a load P acting on a fillet welded joint of length l, is

$$P = 0.707\, t\, l\, \tau_s \qquad \ldots (4.2)$$

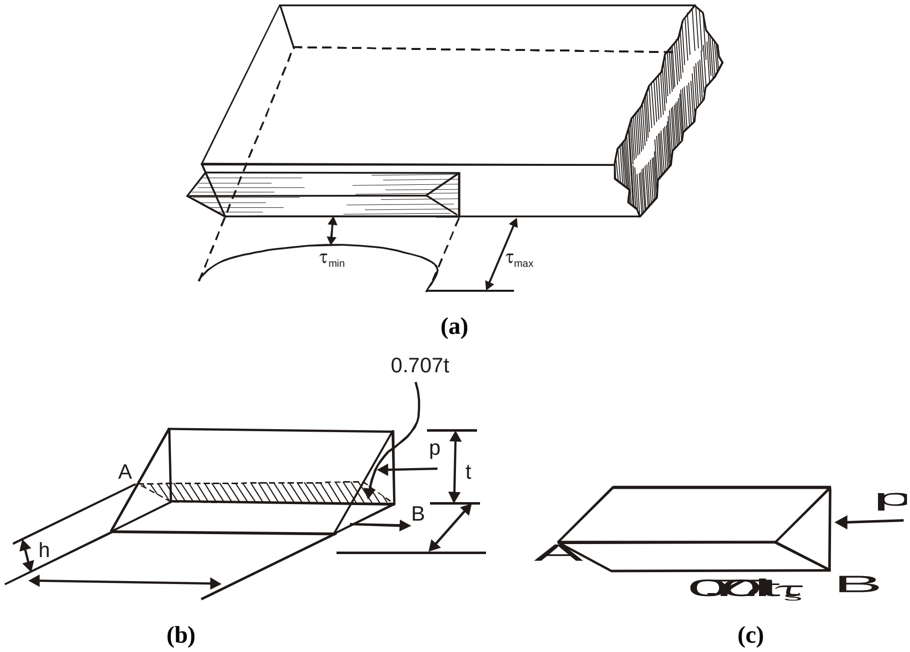


Figure 4.3

This equation will be used to calculate the design dimension l

$$l = \frac{P}{0.707}\, t\, \tau_s \qquad \ldots (4.3)$$

This length is increased by 12.5 mm to take care of starting of weld in each segment.

4.4 T-JOINT

It is a case of fillet weld but a plate is welded at right angle to another. The joint may be subject a tension, P or bending due to P acting parallel to weld, as can be seen in Figure 4.4. Two loads are shown in this figure for convenience but they will be analysed separately.

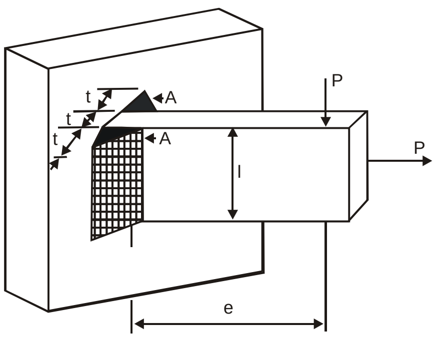


Figure 4.4 : A T-Joint under Axial and Eccentric Load

Axial Tension

It is a case of fillet weld. The leg of the weld is equal to thickness of the plate, t and the cross-section of fillet is an isosceles triangle. Thus the depth of the throat of the weld is 0.7 t as in last section. The length of the weld is l and hence the areas to resist shearing failure

$$A = 0.7\, t\, l \times 2$$

$$\therefore \qquad P = 1.4\, t\, l\, \tau_s \qquad \ldots (4.4)$$

where τ_s is the permissible shearing stress in the weld.

Eccentric Load

Figure 4.4 shows an eccentric load *P* with an eccentricity of *e* which is measured as distance between line of action *P* and the line joining the centers of gravity of triangular sections of fillet welds on two sides. The load *P* will have two actions on the fillet, viz. :

(a) induce shearing along the throat plane, and

(b) causes bending of throat plane of the weld.

The shearing stress due to *P* acting as a shearing force will be induced on the area

$$A = 0.7\, t\, l \times 2$$

$$P = 1.4\, t\, l\, \tau \qquad \text{. . . (4.5)}$$

Fore calculating bending stress, one has to consider modulus of the section of the throat plane. This section has a width of 0.7 *t* and depth equal to *l*. There are two such sections. Though both these sections are not perpendicular to the axis of the joint this fact is disregarded and modulus of section is calculated as if these sections were perpendicular to the axis.

Calling modulus of section, *Z*

$$Z = 2 \times \frac{1}{6}\, 0.7\, t\, l^2$$

Bending moment $M = P\,.\,e$

Bending stress $\sigma = \frac{M}{Z} = \frac{6Pe}{1.4 t l^2}$ . . . (4.6)

The value of bending stress σ occurs at top of the fillet at point *A* in Figure 4.4. At these points the shearing stress is given by Eq. (4.5). The maximum shearing stress can be found by using the formula,

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Here $\sigma_x = \sigma$, $\tau_{xy} = \tau$ and $\sigma_y = 0$ (Eqs. (4.5) and (4.6))

$$\therefore \qquad \tau_{max} = \sqrt{\left(\frac{3P\,.\,e}{1.41 t l^2}\right)^2 + \left(\frac{P}{1.4 t l}\right)^2}$$

or

$$\tau_{max} = \frac{P}{1.4 t l}\sqrt{\left(\frac{3e}{l}\right)^2 + 1} \qquad \text{. . . (4.7)}$$

τ_{max} should be equal to permissible shearing stress τ_s for design purposes which will be taken as 50% of permissible tensile stress in parent material for manual welding and 70% of permissible tensile stress in parent material for automatic welding.

4.5 UNSYMMETRICAL SECTION LOADED AXIALLY

Figure 4.5 presents an angle section welded to a plate. If a tensile force *P* is applied so as to pass through the centre of gravity of the section then the length of the fillet nearer to CG (l_b) will take greater proportion of the force *P* than the length of fillet weld which is away from CG. The lengths l_a and l_b are to be so proportioned that the forces carried by two fillet welds exert no moment about centre of gravity axis. The two fillets are at

distances of a and b respectively from CG (see Figure 4.5) and if S is the force per unit length carried in the welds, then

$$S\,l_a\;a - S\,l_b\;b = 0$$

or
$$\frac{l_a}{l_b} = \frac{b}{a}$$

or
$$\frac{l_a + l_b}{l_b} = \frac{l}{l_b} = \frac{a+b}{a}$$

$$l_b = \frac{a\,l}{a+b} \text{ and } l_a = \frac{b\,l}{a+b} \qquad \ldots (4.8)$$

where $l = l_a + l_b$.

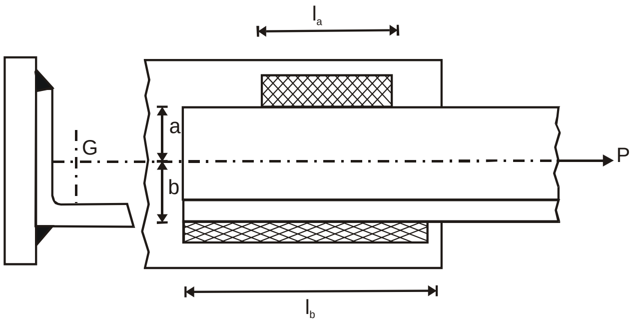


Figure 4.5 : An Unsymmetrical Section Welded to Plate and Welded along Line of CG

4.6 ECCENTRICALLY LOADED WELDED JOINT

We have earlier talked of a *T*-joint under axial load. Another example of eccentric loading is shown in Figure 4.6. In this case the force applied at a distance from the CG of the weld group is in the plane of the fillet weld. This will cause the torsional effect in the same way as was considered for riveted joint in Figure 3.16. Two equal and apposite forces are assumed at CG, each being equal to *P* will result in a couple and a single force downward at *G*. This force *P* at *G* will cause what we term as primary shearing stress denoted by τ_1

$$\tau_1 = \frac{P}{0.707\,t\,(2a+b)} \qquad \ldots (4.9)$$

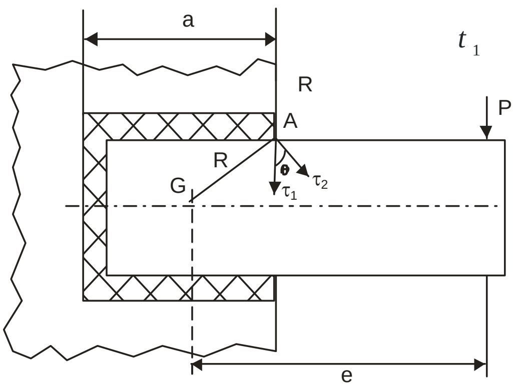


Figure 4.6 : Welded Joint Loaded Eccentrically

Here t is the thickness of the plate. The torque $P \,.\, e$ will cause secondary shearing stress τ_2 at the weld end, *A*, which will be greater than shearing stress at any other point in the weld, *A* is at a distance of *R* from CG. It can be shown that

$$\tau_2 = \frac{P \,.\, e \,.\, R}{J_G} \qquad \ldots (4.10)$$

Here, J_G is the polar moment of inertia of fillet weld about G. AS shown in Figure 4.6, τ_1 and τ_2 at A act at an angle Q. Since nature of both these stresses is same, they can be added vectorially. The resultant stress τ_A is

$$\tau_A = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1 \tau_2 \cos\theta} \qquad \ldots (4.11)$$

To solve a problem of eccentric loading such as one depicted in Figure 4.6 one would require computing the value of J_G. It is generally required to find the size of the weld, t, whereas the width involved in calculation of J_G is that of throat of the weld, say h. It is also known that $h = 0.707\ t$ so that the section of weld is an isosceles triangle. In a given problem the length a is given which is the distance from point A to the inner side of the vertical fillet while distance b will be equal to the width of the plate or distance between inner edges of horizontal fillets. To compute J_G following procedure is adopted.

(a) Determine the position of CG of weld group with reference to inside edges of vertical and horizontal fillets.

(b) Determine second moment of inertia I_{xx1} and I_{yy1}, respectively first with respect to horizontal and vertical axes passing through their CG and then transferring them to horizontal and vertical axes passing through CG of weld group.

(c) Similarly for vertical fillet determine and transfer I_{xx2} and I_{YY2} to the horizontal and vertical axes passing through CG of weld group.

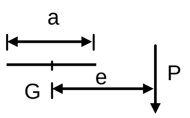
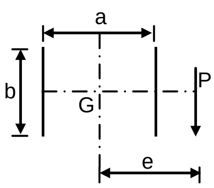
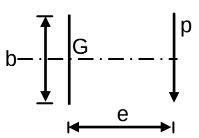
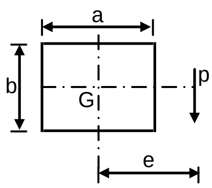
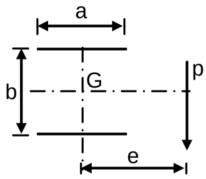
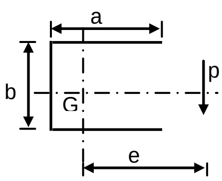
(d) By adding the four moments of inertia obtain J_G, i.e.

$$J_G = I'_{xx1} + I'_{yy1} + I'_{xx2} + I'_{yy2}$$

where quantities on right hand side refer to horizontal and vertical axes through CG of weld group.

One important point if considered during calculation will greatly help achieve solution. The expressions for I'_{xx1}, I'_{yy1}, etc. will contain terms like ah^3 and ha^3, etc. Since h is much smaller than a or b, its cube can be neglected. This will greatly reduce the efforts on computations. Finally h may be replaced by 0.707 t. The procedure will be illustrated in one of the following solved problems. Table 4.1 gives formulae for J_G in different weld groups.

Table 4.1 : Polar Moment of Inertia of Weld Groups about Axis Passing through Centre of Gravity

Weld Group	J_G	Weld Group	J_G
	$\frac{ha^3}{12}$		$\frac{hb\,(3a^2 + b^2)}{6}$
	$\frac{hb^3}{12}$		$\frac{h\,(a + b)^3}{6}$
	$\frac{ha\,(3b^2 + a^2)}{6}$		$h\,\frac{8a^3 + 6ab^2 + b^3}{12} - \frac{ha^4}{2a + b}$

Example 4.1

A steel plate strip of 150 mm width and 10 mm thickness is welded by a compound fillet weld to another plate. The strip is required to carry an axial load P such that P is equal to tensile load capacity of the strip with a factor of safety of 2.5 on ultimate tensile strength of strip. Calculate the length of the fillet weld and show on diagram. Ultimate tensile strength of strip material is 380 MPa. Find fillet length if $P_{min} = \frac{P}{2}$ and $P_{max} = P$.

Solution

This is the type of the joint shown in Figure 4.2(d). The permissible tensile stress in strip material is $\frac{380}{2.5} = 152$ MPa . Hence permissible shearing stress in the weld, with the assumption of manual welding,

$$\tau_s = \frac{1}{2} \times 152 = 76 \text{ MPa}$$

The axial load on the joint as shown in Figure 4.7

$$P = (150 \times 10)\ \sigma_t = 1500 \times 152 = 228000 \text{ N}$$

Also $\quad P = 228000 = 0.707 \times 10\ (2l_1 + l_2) \times 76$

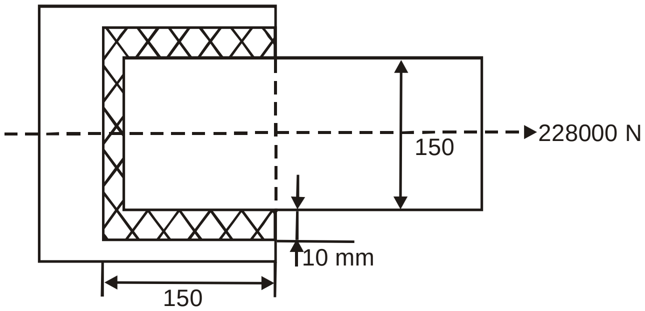


Figure 4.7

Apparently the vertical weld length, l_2 = 150 mm

$$\therefore \quad l_1 = \frac{228000}{2 \times 0.07 \times 76} - \frac{150}{2} = 137.16 \text{ mm}$$

Correct l_1 by adding 12.5 mm, l_1 = 137.16 + 12.5 = 149.66 say 150 mm.

When P varies between $P_{min} = \frac{P}{2}$ and $P_{max} = P$, the factor

$$\gamma = \frac{1}{\frac{4}{3} - \frac{1}{3}\frac{P_{min}}{P_{max}}} = \frac{1}{\frac{4}{3} - \frac{1}{3} \cdot \frac{1}{2}} = \frac{1}{\frac{8-1}{6}} = \frac{6}{7}$$

$$\therefore \quad \tau_s = \frac{6}{7} \times 76 = 65.143 \text{ N/mm}^2$$

$$\therefore \quad l_1 = \frac{228000}{2 \times 0.07 \times 65.143} - 75 + 12.5 = 185 \text{ mm}$$

Example 4.2

A bracket is welded to its support as shown in Figure 4.8. All welds are fillet welds of equal thickness. Determine the fillet size if the permissible stress in the weld is 80 N/mm^2.

Solution

The welded joint of Figure 4.8 is eccentrically loaded. The weld will be subjected to two types of shearing stress. The direct primary shearing stress τ_1 due to shearing force acting through CG. The shearing force is 25 kN, through CG of weld group. The secondary shearing stress τ_2 due to torque *P*.*e* acting about CG.

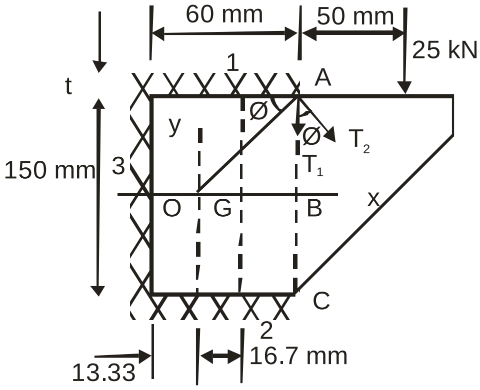


Figure 4.8

The primary shearing stress,

$$\tau_1 = \frac{P}{0.707 t\, (2a + b)}$$

Use a = 60 mm and b = 150 mm, t = ?, P = 25000 N

$$\tau_1 = \frac{25000}{0.707\,(120 + 150)\, t} = \frac{131}{t} \text{ MPa} \qquad \text{. . . (i)}$$

Position of CG

The weld group is made up of three fillet weld, 1, 2, and 3 which are regarded as rectangles of width h and lengths respectively 60 mm, 60 mm and 150 mm. With o (middle of vertical fillet of height 150 mm) ox and oy are drawn horizontal and vertical axes. Areas of fillets 1, 2 and 3 are denoted by A_1, A_2 and A_3 so that

$$A_1 = 60\, t,\ A_2 = 60\, t,\ A_3 = 150\, t \text{ mm}^2$$

Since the weld group is symmetrical about horizontal axis, CG will be on ox axis. Its distance from oy is $\bar{x}$. Then

$$\bar{x} = \frac{A_1\,(30) + A_2\,(30) + A_3\,(0)}{A_1 + A_2 + A_3}$$

i.e. $$\bar{x} = \frac{60h \times 30 + 60h \times 30}{60h + 60h + 150h} = \frac{2 \times 60 \times 30}{270}$$

$$= 13.33 \text{ mm}$$

Remember $h = 0.707\, t$.

Polar Moment of Inertia of Weld Group about CG

I_{xx} and I_{yy} denote second moments of inertia of plane rectangles about horizontal and vertical axes passing through CG of respective rectangles. I'_{xx} and I'_{yy} denote moments of inertia about horizontal and vertical axes passing through CG of weld group, G. The suffixes 1, 2 and 3 will be used to distinguish between areas as 1, 2 and 3. It may also be noted that since h is much smaller than and also not known at the initial stage, it may be neglected in comparison with transfer distances 13.33 mm and 75 mm, etc.

$$I_{xx1} = \frac{60h^3}{12} = 5h^3$$

$$I_{xx2} = \frac{60\,h^3}{12} = 5h^3$$

$$I_{xx3} = \frac{h\,(150)^3}{12} = 281.25 \times 10^3\,h$$

$$I'_{xx1} = 5h^3 + 60h\,(75)^2 = 5h^3 + 337.5 \times 10^3\,h$$

$$I'_{xx2} = 5h^3 + 60h\,(75)^2 = 5h^3 + 337.5 \times 10^3\,h$$

$$I'_{xx3} = I_{xx3} = 281.25 \times 10^3\,h$$

$$I_{yy1} = \frac{h\,(60)^3}{12} = 18 \times 10^3\,h$$

$$I_{yy2} = \frac{h\,(60)^3}{12} = 18 \times 10^3\,h$$

$$I_{yy3} = \frac{150 \times (h)^3}{12} = 12.5\,h^3$$

$$I'_{yy1} = 18 \times 10^3\,h + 60h\,(16.7)^2 = 34.7 \times 10^3\,h$$

$$I'_{yy2} = 18 \times 10^3\,h + 60h\,(16.7)^2 = 34.7 \times 10^3\,h$$

$$I'_{yy3} = 12.5h^3 + 120\,h \times (13.33)^2 = 12.5h^3 + 21.32 \times 10^3\,h$$

The polar moment of inertia of the weld group about CG.

$$J_G = I'_{xx1} + I'_{xx2} + I'_{xx3} + I'_{yy1} + I'_{yy2} + I'_{yy3}$$

$$= 5h^3 + 337.5 \times 10^3\,h + 5h^3 + 337.5 \times 10^3\,h + 281.25 \times 10^3\,h$$

$$+ 34.7 \times 10^3\,h + 34.7 \times 10^3\,h + 12.5h^3 + 21.32 \times 10^3\,h$$

$$= (22.5h^3 + 1047 \times 10^3\,h)\text{ mm}^4$$

Since h is a small quantity, contribution of its cubes, h^3, may be neglected. Hence to the first approximation,

$$J_G = 1047 \times 10^3\,h\text{ mm}^4 \qquad \ldots \text{(iii)}$$

The secondary shearing stress at any point on the fillet at a distance of R from G is given as

$$\tau' = \frac{P\,.\,eR}{J_G}$$

This stress will act perpendicular to R. Obviously its value will be higher if R is higher. R at A and C is greatest. From triangle ABG.

$$R_A = \sqrt{(AB^2 + BG^2)}$$

$$= \sqrt{(75^2 + 46.7^2)} = 88.5\text{ mm}$$

$$e = 50 + BG = 50 + 46.7 = 96.7\text{ mm}$$

Using equation for τ' and calling its value at A as τ_2

$$\tau_2 = \frac{25000 \times 96.7 \times 88.35}{1047 \times 10^3\,h} = \frac{204}{h}\text{ MPa} = \frac{288.5}{t}\text{ MPa} \qquad \ldots \text{(iv)}$$

$$\cos\,\theta = \frac{BG}{R_A} = \frac{46.7}{88.35} = 0.53$$

Since τ_1 and τ_2 are of same type they can be added vectorially to obtain resultant stress.

$$\tau_A = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1 \tau_2 \cos \theta}$$

$$= \frac{1}{t} \sqrt{(131)^2 + (288.5)^2 + 2 \times 131 \times 288.5 \times 0.53}$$

$$= \frac{1}{t} \sqrt{17161 + 832.5 + 40067} = \frac{374.8}{t} \text{ MPa}$$

The stress τ_A should not exceed 80 MPa, the permissible value

$$\therefore \qquad \frac{374.8}{t} = 80$$

$$\therefore \qquad t = \frac{374.8}{80} = 4.685 \text{ say } 5.0 \text{ mm}$$

SAQ 1

(a) What is a welded joint? Compare welded joint with riveted joint.

(b) Describe types of welded joint.

(c) Give examples of eccentrically loaded welded joints. How are they analysed?

(d) Sketch a T-joint and chow how it can be loaded. What stresses will be induced in the weld?

(e) An L 200 × 150 × 20 steel angle is to be welded to a flat plate with long side of the angle against the plate (see Figure 3.24). Determine the minimum length l_a and l_b that will cause the angle to carry maximum allowable axial load. The allowable tensile stress for the material in the angle is 124 MPa and allowable shearing stress in the weld material is 94 MPa. Each leg of the weld is 15 mm.

(f) A shaft of 20 mm diameter is welded coaxially with another shaft of much larger diameter. The shaft is to transmit a torque, which is just safe. Calculate the width of the peripheral fillet weld between two shafts. The permissible shearing stress for the shaft material is 70 MPa and that for weld is 50 MPa.

4.7 SUMMARY

The joining of plates is an important requirement of manufacturing industry. Several examples of plate joining are found in structure parts, ships, airplanes, boilers and pressure vessels. Welding is the process in which parent metal is almost melted by heat from electric or gas source and filler metal is filled in the gap by melting. The joint is then allowed to cool to develop strength, which is almost equal to that of parent metals. In riveting holes are drilled or punched and a rivet with head on one side of the shank is passed through two coaxial holes in two plates. A head is created on the other side to keep plates perfectly connected.

The welding is much more developed now and can be automated to enhance production rate and maintain quality. Both welded joints and riveted joints are loaded and tensile forces as well as eccentric loads, which do not pass through CG. The eccentric loads may act in the same plane as the joint in which case they tend to rotate the joint about an axis through CG and perpendicular to the plane of the joint. This produces shearing stress in the joint. The eccentric load may also act in a plane, which is parallel to the plane of the joint in which case they tend to bend the joint about an axis passing through CG in the plane of the joint. This produces bending stress in the joint.

4.8 KEY WORDS

Pitch : Pitch is the distance between the centres of adjacent rivets measured on the gauge line.

Eccentric Loading : Whenever the line of application of the load does not pass through the CG of the weld, the loading is known as eccentric loading.

Hot-riveting : In hot-riveting, the rivet with a single head is heated to a plastic state (900-1000^{o}C) and the shank of the rivet is inserted into the hole in the members to be fastened together.

Lap Joint : In lap joint one plate overlaps the other and the rivets pass through both the plates.

Butt Joint : In butt joint, the plates are kept in alignment and a butt strap or cover plate is placed over the joint.

4.9 ANSWERS TO SAQs

SAQ 3

(d) Refer to Figure 4.5.

Call vertical side of the angle as 1 and horizontal side as 2.

$$A_1 = 200 \times 20 = 4000 \text{ mm}^2,\ A_2 = (150 - 20)\ 20 = 2600 \text{ mm}^2$$

$$b = \frac{A_1 \times 100 + A_2 \times 10}{A_1 + A_2} = \frac{4000 \times 100 + 2600 \times 10}{4000 + 2600} = 64.55 \text{ mm}$$

$a = 200 - 64.55 = 135.45$ mm , a and b define position of G.

Assume that uniform stress is induced in the weld. Then force in the top weld $= F_a = l_a\ h\ \tau$.

A force in the bottom weld $= F_b = l_b\ h\ \tau$, h = throat size of the weld.

Taking moments about an axis through G, and perpendicular to plane of paper.

$$F_a \times a = F_b \times b$$

$$l_a\ h\ \tau\ 135.45 = l_b\ h\ \tau\ 64.55$$

$$\therefore \quad \frac{l_a}{l_b} = 0.477$$

Area of cross section of angle section, $A = A_1 + A_2 = 6600$ mm^2

The permissible stress in the angle section 124 MPa.

The maximum load carried by angle section $= 6600 \times 124 = 818400$ N

This load has to be carried by welds

$\therefore \quad 818400 = (l_a + l_b)\, h\, \tau_s$

$h = 0.707 t = 0.707 \times 15 = 10.605$ mm, $\tau_s = 94$ MPa

$\therefore \quad 818400 = (l_a + l_b)\, 10.605 \times 94$

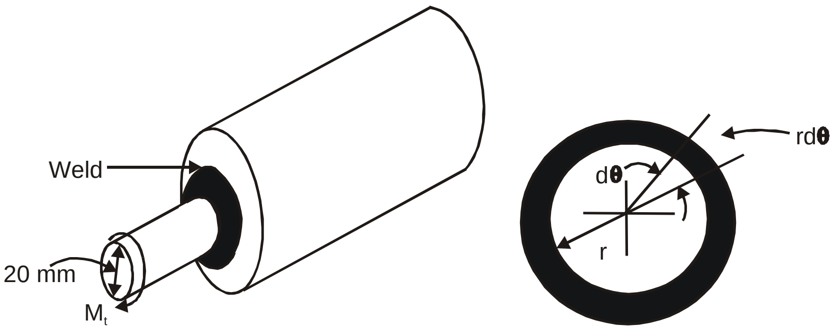
$\therefore \quad l_a + l_b = 821$

Use $\quad l_a = 0.477\, l_b$

$1.477 l_b = 821$ or $l_b = 566$ mm, $l_a = 265.14$ mm

Add $\quad$ 12.5 mm

$l_a = 277.6$ mm, $l_b = 568.5$ mm



(a) (b)

Figure 4.9

The torque that the shaft can carry safely

$$M_t = \frac{\pi}{16} d^3\, \tau_s = \frac{\pi}{16} (20)^3 \times 70 = 109956 \text{ Nmm}$$

The weld has to carry the same torque.

The weld becomes a ring whose inside diameter is diameter of shaft and width is equal to the leg of the weld. The throat is *h*, which is effective width of the ring.

If an element is considered to subtend an angle $d\,\theta$ at the centre then the length of the element is $r\, d\,\theta$, where r = rad of the ring at the periphery of the shaft.

The shearing force in the element if stress τ is induced in the ring

$$dF = \tau\, h\, r\, d\,\theta$$

The moment about central axis due to *dF*

$$dM_t = dF\, r = \tau\, h\, r^2\, d\,\theta$$

$$\therefore \quad M_t = \int_0^{2\pi} \tau\, h\, r^2\, d\,\theta$$

$$\tau = 50 \text{ N/mm}^2,\ r = \frac{20}{2} = 10 \text{ mm},\ M_t = 109956 \text{ Nmm}$$

$$109956 = h \times 50 \times 100 \times 2\pi$$

$\therefore \quad h = 3.5$ mm $= 0.707\, t$

$\therefore \quad t = 4.95$ say 5 mm, width of the fillet weld.