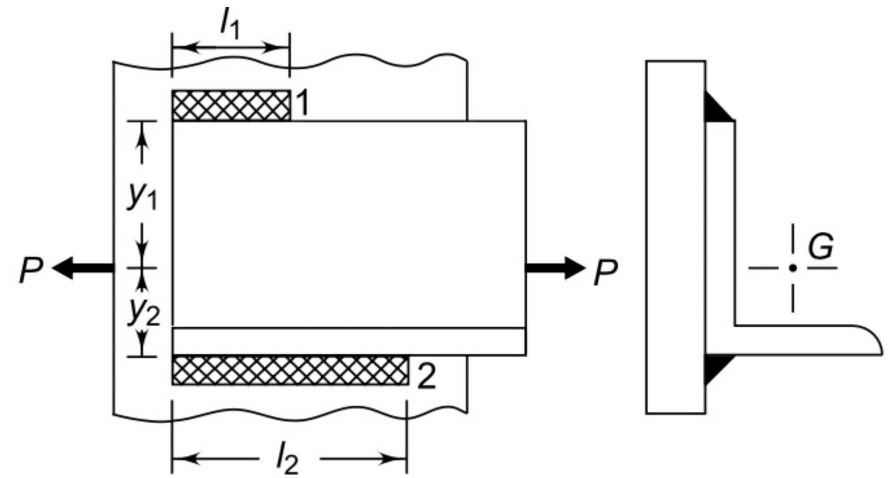
Machine Design

Course No. MEC3110

Axially loaded Unsymmetrical Welded Joints

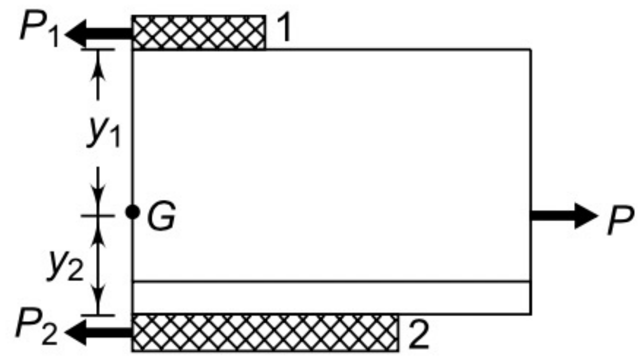
- In certain applications, unsymmetrical sections such as angle or T are welded to the steel plates or the beams.
- An angle section is welded to a vertical beam by means of two parallel fillet welds 1 and 2.
- *G* is the centre of gravity of the angle section. The external force acting on the joint passes through *G*.
- Suppose *P*1 and *P*2 are the resisting forces set up in the welds 1 and 2 respectively.



Axially loaded Unsymmetrical Welded Joints

$$P_1 = 0.707 h l_1 \tau$$

$$P_2 = 0.707 h l_2 \tau$$



The free body diagram of forces acting on the angle section with two welds.
Since the sum of horizontal forces is equal to zero,

$$P = P_1 + P_2$$

Since the moment of forces about the centre of gravity is equal to zero,

$$P_1 y_1 = P_2 y_2$$

Substituting we get

$$l_1 y_1 = l_2 y_2$$

Assuming total length of welds as l,

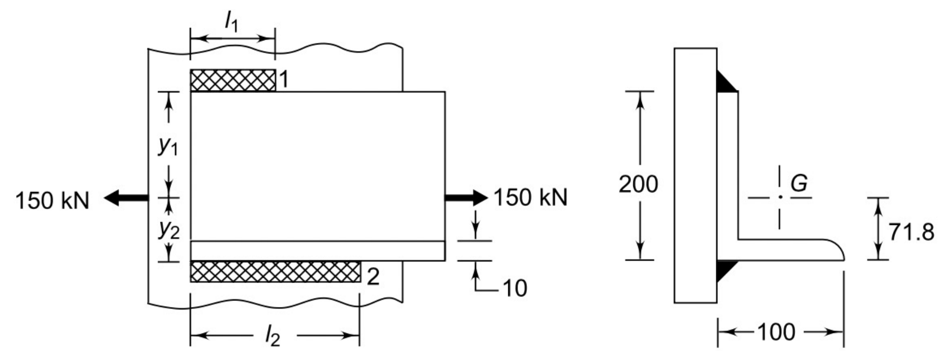
$$l_1 + l_2 = l$$

Axially loaded Unsymmetrical Welded Joints

An ISA 200 × 100 × 10 angle is welded to a steel plate by means of fillet welds. The angle is subjected to a static force of 150 kN and the permissible shear stress for the weld is 70N/mm^2. Determine the lengths of weld at the top and bottom.

Solution

P = 150 kN, t = 70 N/mm^2, h = 10 mm



Step I Total length of weld

The total length (l) of the weld required to withstand the load of 150 kN is given by.

$P = 0.707\ hl\tau$

or $150 \times 10^3 = 0.707 \times (10) \times l \times (70)$

l = 303.09 mm

Step II Weld lengths l_1 and l_2

$$l_1 y_1 = l_2 y_2$$

or $\quad l_1(200 - 71.8) = l_2(71.8)$

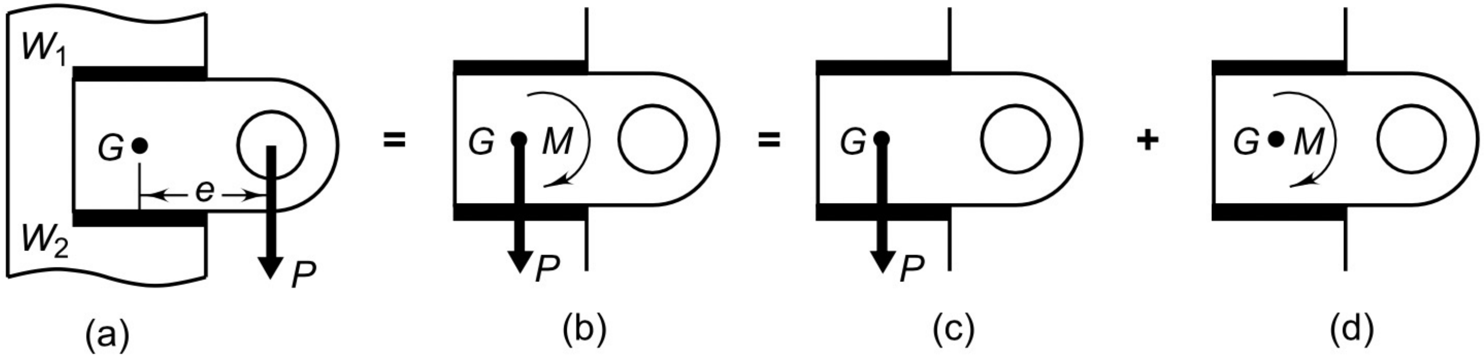
or $\quad \mathbf{128.2\ l_1 = 71.8\ l_2}$

Also,

$l_1 + l_2 = l = 303.09$ mm

l_1 = 108.81 mm and l_2 = 194.28 mm

Eccentric Load in The Plane of Welds

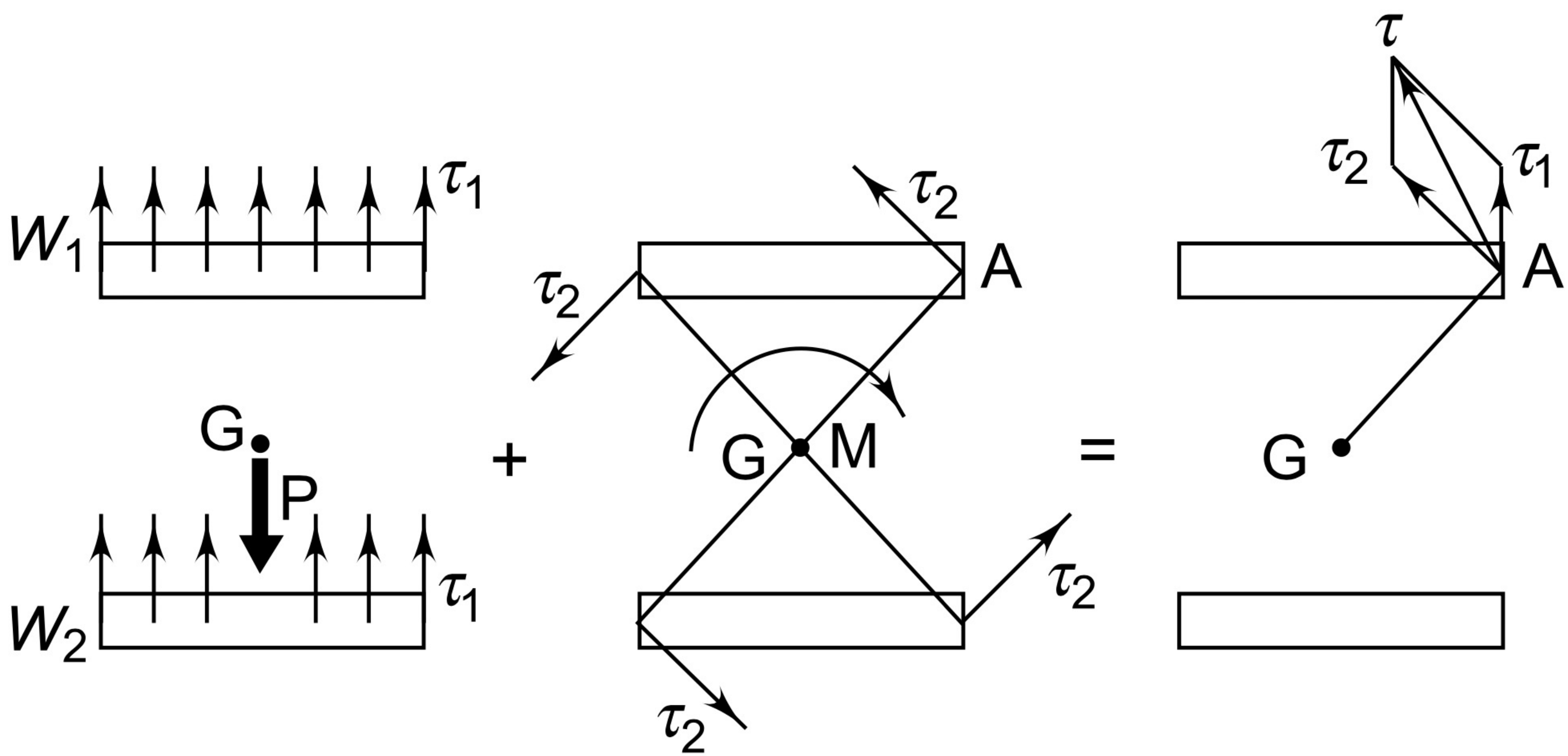


The design of welded joint subjected to an eccentric load in the plane of welds, consists of calculations of primary and secondary shear stresses.

- A bracket subjected to an eccentric force P and attached to the support by means of two fillet welds W_1 and W_2 is shown in Fig (a).
- In such problems, the first step is to determine the centre of gravity of welds, treating the weld as a line.
- Suppose G is the centre of gravity of two welds and e is the eccentricity between the centre of gravity and the line of action of force P.
- According to the principle of Applied Mechanics, the eccentric force P can be replaced by an equal and similarly directed force (P) acting through the centre of gravity G, along with a couple ($M = P \times e$) lying in the same plane Fig (b).
- The effects of the force P and the couple M are treated separately as shown in Fig (c) and (d) respectively.

Eccentric Load in The Plane of Welds

The stresses in this welded joint are as shown



(a) (b) (c)

Eccentric Load in The Plane of Welds

<u>Primary Shear Stress</u>

- Due to the load acting on the G.
- Uniformly distributed over the throat of the weld.
- The direct or primary shear stress is calculated as:

$$\tau_1 = \frac{P}{A}$$

<u>Secondary Shear Stress</u>

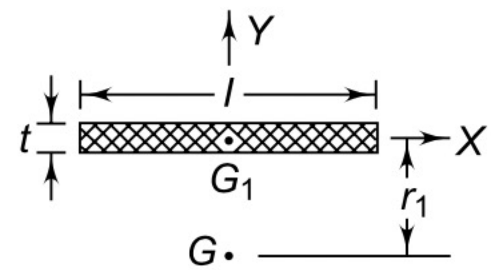
- Due to bending moment (P×e)
- Directly proportional to the distance from G.
- The secondary shear stress is calculated as:

$$\tau_2 = \frac{Mr}{J}$$

The secondary shear stress at any point in the weld is proportional to its distance from the centre of gravity. Obviously, it is maximum at the farthest point such as *A*. The resultant shear stress at any point is obtained by vector addition of primary and secondary shear stresses

Eccentric Load in The Plane of Welds

A weld of length l and throat t. G_1 is the centre of gravity of the weld, while G is the centre of gravity of a group of welds. The moment of inertia of this weld about its centre of gravity G_1 is given by,



$$J_{G1} = I_{xx} + I_{yy}$$

$$I_{xx} = \frac{lt^3}{12}$$

$$J_{G1} = I_{xx} + I_{yy} \cong I_{yy}$$

$$J_{G1} = \frac{l^3 t}{12} = \frac{Al^2}{12}$$

where A is the throat area of the weld and J_{G1} is the polar moment of inertia of the weld about its centre of gravity. The polar moment of inertia about an axis passing through G is determined by the parallel axis theorem.

$$J_G = J_{G1} + Ar_1^2$$

where r_1 is the distance between G and G_1.

$$J_G = A\left[\frac{l^2}{12} + r_1^2\right]$$

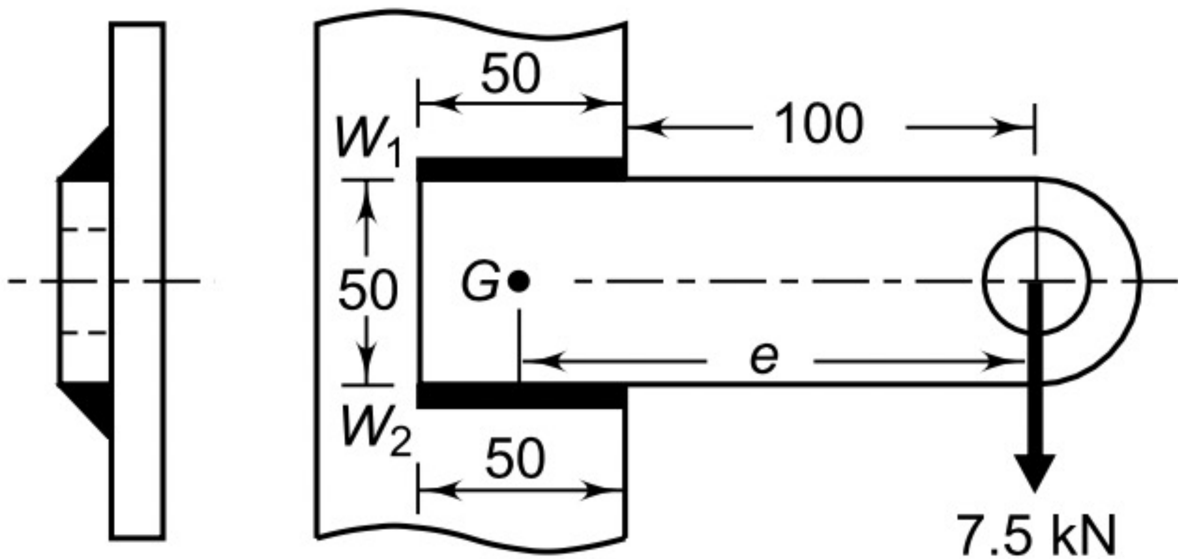
When there are number of welds, then in that case:

$$J = J_1 + J_2 + J_3 \ldots\ldots\ldots J_n$$

The above value of J is to be used to calculate secondary stress.

Eccentric Load in The Plane of Welds

A welded connection, is subjected to an eccentric force of 7.5 kN. Determine the size of welds if the permissible shear stress for the weld is 100 N/mm2. Assume static conditions.



Eccentric Load in The Plane of Welds

Given $P = 7.5$ kN $\tau = 100$ N/mm^2

Step I *Primary shear stress*

Suppose t is the throat of each weld. There are two welds W_1 and W_2 and their throat area is given by,

$$A = 2(50t) = (100t) \text{ mm}^2$$

From Eq. (8.21), the primary shear stress is given by,

$$\tau_1 = \frac{P}{A} = \frac{7500}{(100t)} = \left(\frac{75}{t}\right) \text{N/mm}^2 \qquad \text{(a)}$$

Step II *Secondary shear stress*

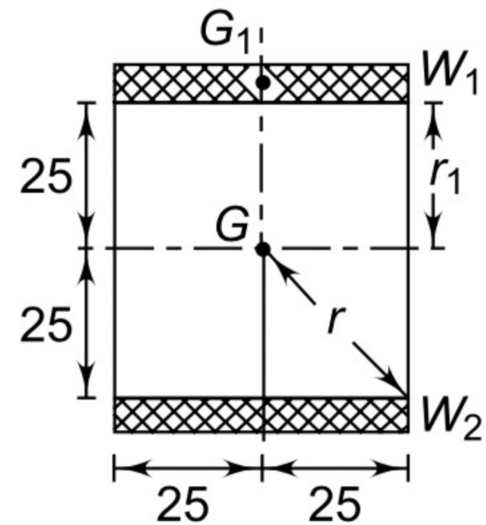
The two welds are symmetrical and G is the centre of gravity of the two welds.

$$e = 25 + 100 = 125 \text{ mm}$$

$$M = P \times e = (7500)\,(125) = 937\,500 \text{ N-mm} \qquad \text{(i)}$$

The distance r of the farthest point in the weld from the centre of gravity is given by (Fig. 8.23),

$$r = \sqrt{(25)^2 + (25)^2} = 35.36 \text{ mm} \qquad \text{(ii)}$$



Eccentric Load in The Plane of Welds

From Eq. (8.25), the polar moment of inertia J_1 of the weld W_1 about G is given by

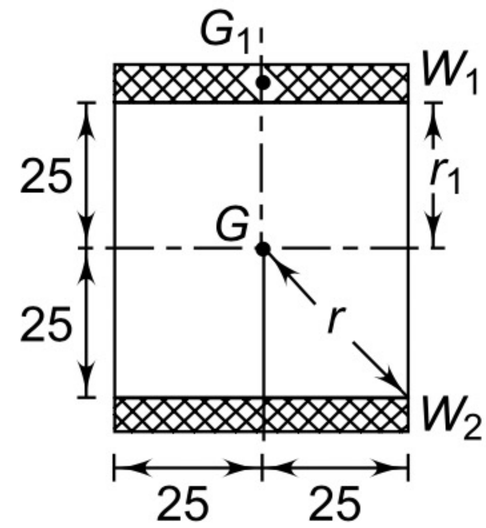
$$J_1 = A\left[\frac{l^2}{12} + r_1^2\right] = (50t) \times \left[\frac{50^2}{12} + 25^2\right]$$
$$= (41\ 667t)\ \text{mm}^4$$

Due to symmetry, the polar moment of inertia of the two welds (J) is given by

$$J = J_1 + J_2 = 2J_1 = 2(41\ 667t) = (83\ 334t)\ \text{mm}^4$$

From Eq. (8.22), the secondary shear stress is given by

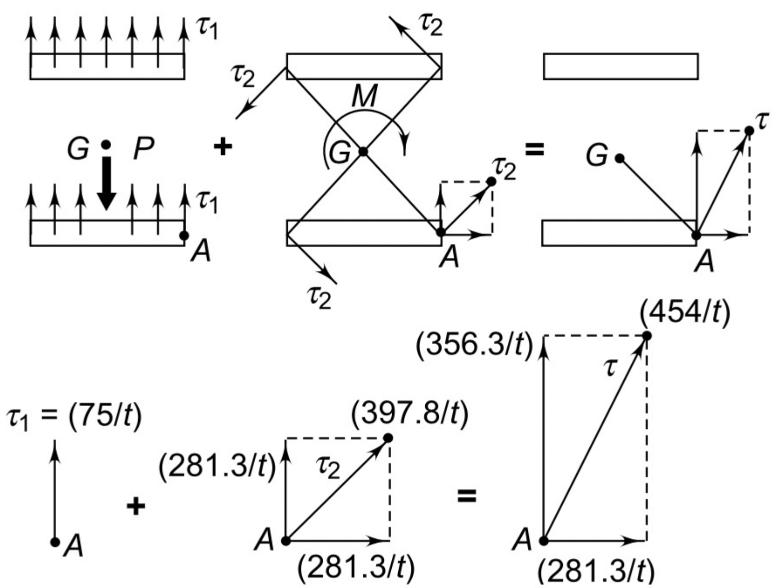
$$\tau_2 = \frac{Mr}{J} = \frac{(937\ 500)(35.36)}{(83\ 334t)} = \left(\frac{397.8}{t}\right)\ \text{N/mm}^2$$



Eccentric Load in The Plane of Welds

Step III *Resultant shear stress*
Figure 8.24 shows the primary and secondary shear stresses. The vertical and horizontal components of these shear stresses are added and the resultant shear stress is determined. Therefore, from the figure,

$$\tau = \left(\frac{454}{t}\right) \text{ N/mm}^2$$



Step IV *Size of weld*
Since the permissible shear stress for the weld material is 100 N/mm^2,

$$\left(\frac{454}{t}\right) = 100 \quad \text{or} \quad t = 4.54 \text{ or } 5 \text{ mm}$$