Lecture # 16

Welded Joints - Eccentric Loading

Welded Joints – Eccentric Loading

Eccentrically Loaded Welded Joints

An eccentric load may be imposed on welded joints in many ways.

The stresses induced on the joint may be of different nature or of the same nature.

The induced stresses are combined depending upon the nature of stresses.

When the shear and bending stresses are simultaneously present in a joint (see case 1), then maximum stresses are as follows:

$$\sigma_{b(\max)} = \frac{\sigma_b}{2} + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

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and maximum shear stress,

$$\tau_{(\max)} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

where σ_{b} = bending Stress, and

τ = Shear stress

When the stresses are of the same nature, these may be combind vectorially (case 2).

Lets discuss the two cases of eccentric loading as follows:

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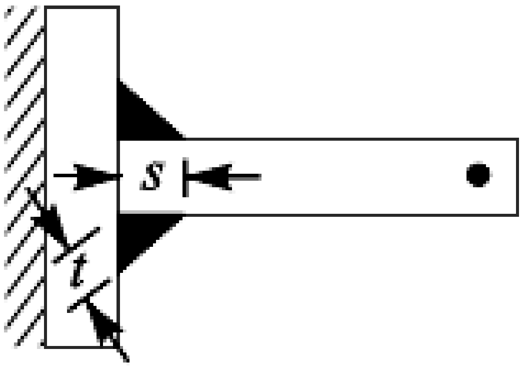
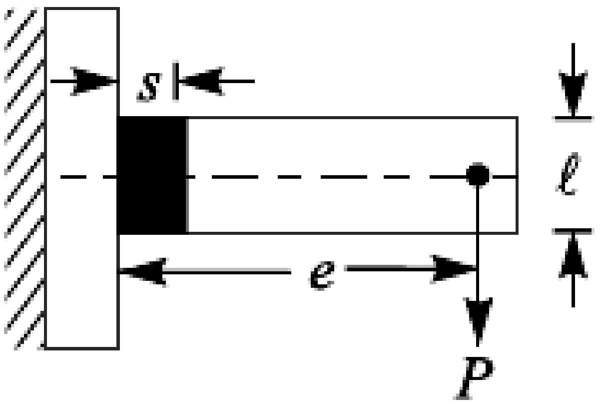
Eccentrically Loaded Welded Joints case 1

Consider a T-joint fixed at one end and subjected to an eccentric load P at a distance e,





Let s = Size of weld,

l = Length of weld, and t = Throat thickness.

The joint will be subjected to the following two types of stresses:

1. Direct shear stress due to the shear force P acting at the welds, and

2. Bending stress due to the bending moment P × e.

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Eccentrically Loaded Welded Joints (case 1)

We know that area at the throat,

A = Throat thickness × Length of weld

(For double fillet weld)

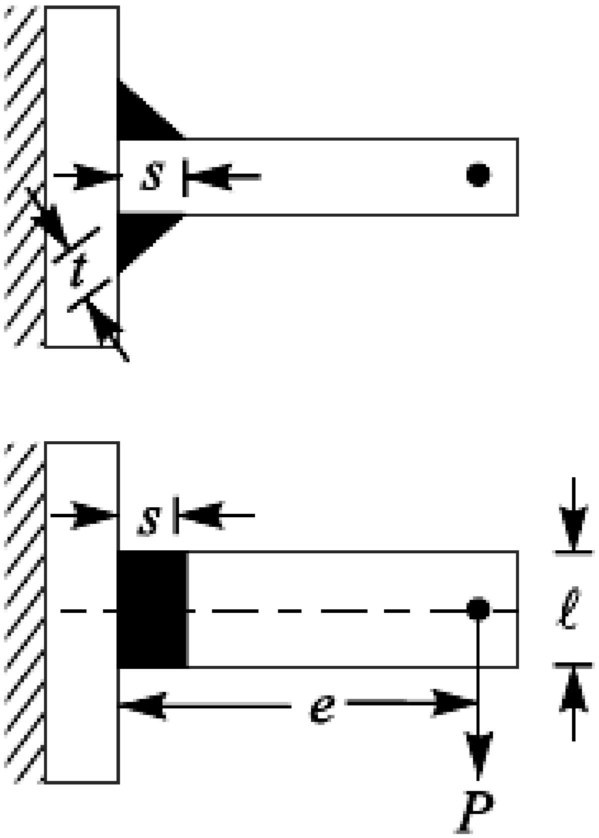
$A = t \times l \times 2$ or $A = 2\,t \times l$

$A = 2 \times 0.707\,s \times l = 1.414\,s \times l$

therefore Shear stress in the weld

(assuming uniformly distributed).

$$\tau = \frac{P}{A} = \frac{P}{1.414\,s \times l}$$



Section modulus of the weld metal through the throat,

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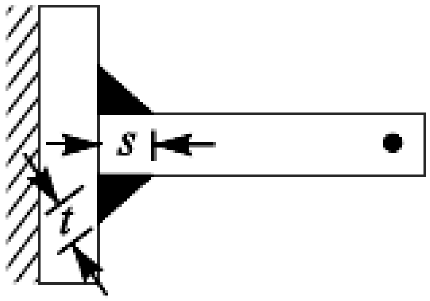
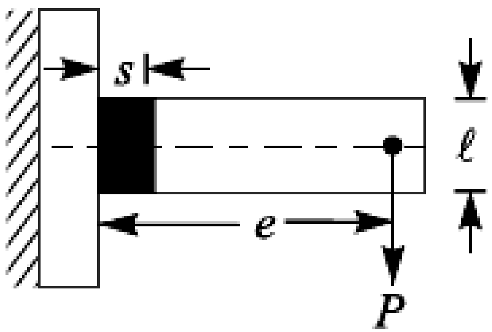
Eccentrically Loaded Welded Joints (case 1)



$$Z = \frac{t \times l^2}{6} \times 2 \quad .....(\text{For both sides weld})$$

$$= \frac{0.707 s \times l^2}{6} \times 2 = \frac{s \times l^2}{4.242}$$



Bending moment, M = P x e

$$\therefore \text{Bending stress } \sigma_b = \frac{M}{Z} = \frac{P \times e \times 4.242}{s \times l^2}$$

The maximum normal stress, is given as

$$\sigma_{b(\max)} = \frac{\sigma_b}{2} + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

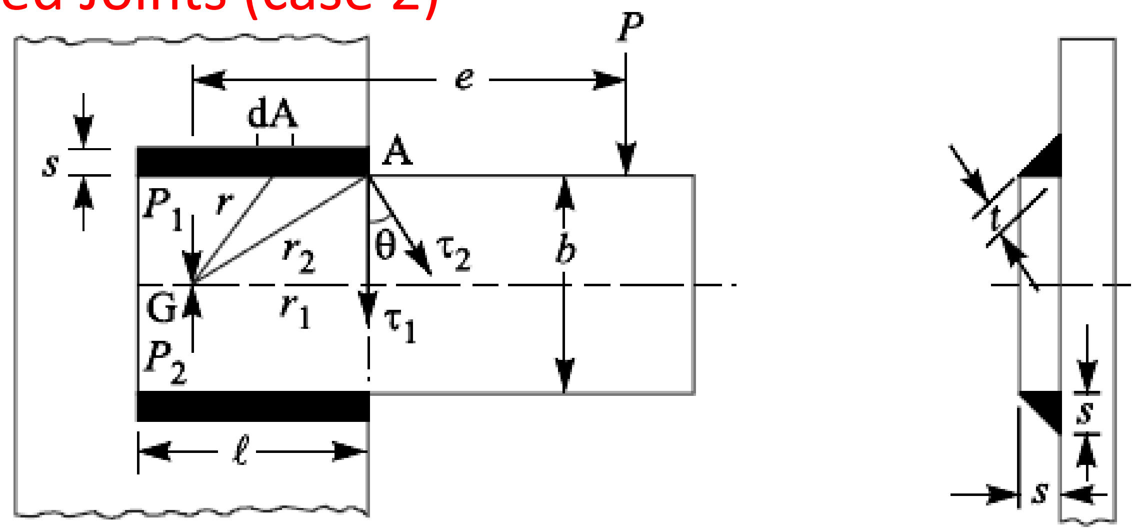
and maximum shear stress,

$$\tau_{(\max)} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

Welded Joints – Eccentric Loading

Eccentrically Loaded Welded Joints (case 2)

When a welded joint is loaded eccentrically as shown in Fig., the following two types of the stresses are induced:



1. Direct or primary shear stress, and
2. Shear stress due to turning moment.

Let P = Eccentric load,

e = Eccentricity i.e. perpendicular distance between the line of action of load and centre of gravity (G) of the throat section or fillets,

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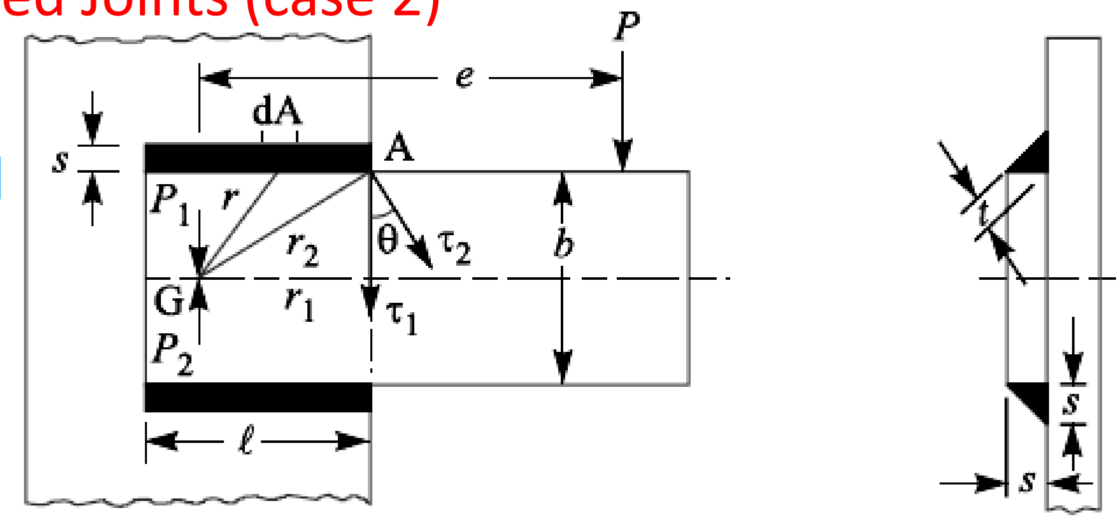
Eccentrically Loaded Welded Joints (case 2)



l = Length of single weld,

s = Size or leg of weld, and

t = Throat thickness.

Let two loads P_1 and P_2 (each equal to P) are introduced at the centre of gravity 'G' of the weld system.

The effect of load P_1 = P is to produce direct shear stress which is assumed to be uniform over the entire weld length.

The effect of load P_2 = P is to produce a turning moment of magnitude P × e which tends to rotate the joint about the centre of gravity 'G' of the weld system.

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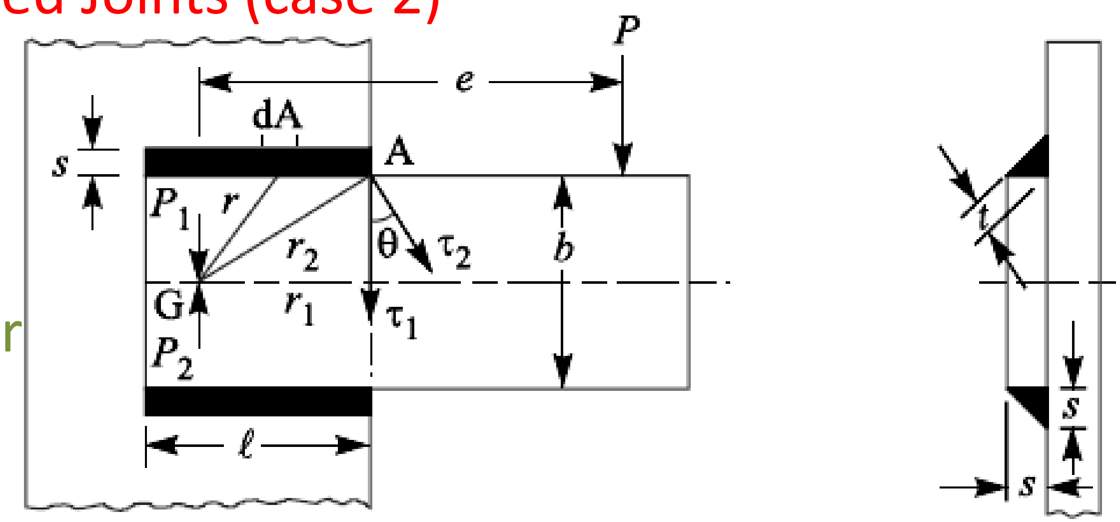
Eccentrically Loaded Welded Joints (case 2)

Due to the turning moment, secondary shear stress is induced.



We know that the direct or primary shear stress is

$$\tau = \frac{Load}{Throat\ Area} = \frac{P}{2 \times 0.707\, s \times l} = \frac{P}{1.414\, s \times l}$$

Since the shear stress produced due to the turning moment (T = P × e) at any section is proportional to its radial distance from G, therefore stress due to (P × e) at the point A is proportional to AG (r_2) and is in a direction at right angles to AG.

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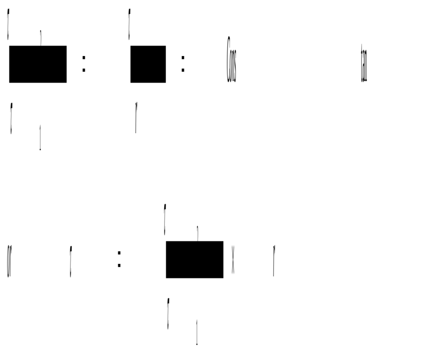
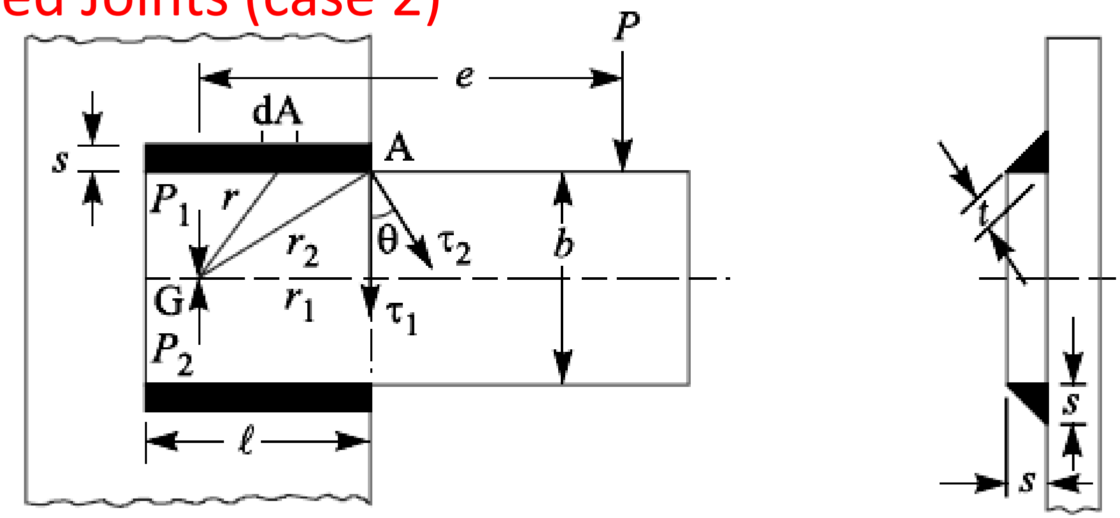
Eccentrically Loaded Welded Joints (case 2)

In other words,





where τ_2 is the shear stress at the maximum distance (r_2) and τ is the shear stress at any distance r.

Consider a small section of the weld having area dA at a distance r from G.

∴ Shear force on this small section = $\tau \times dA$

and turning moment of this shear force about G,

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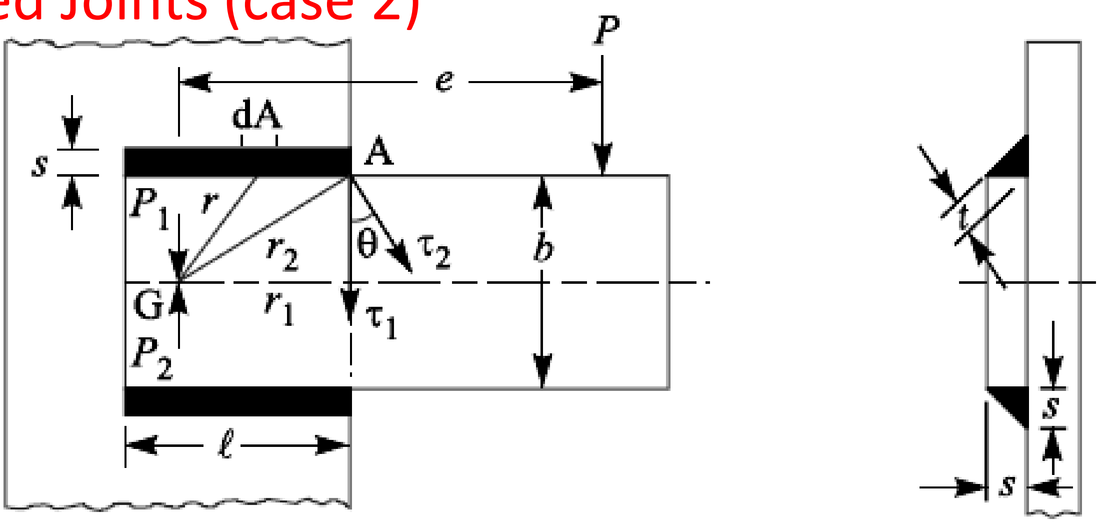
Eccentrically Loaded Welded Joints (case 2)

$$dT = \tau \times dA \times r = \frac{\tau_2}{r_2} \times dA \times r^2$$

total turning moment over the whole weld area,

T = P x e



$$T = \int \frac{\tau_2}{r_2} \times dA \times r^2 = \frac{\tau_2}{r_2} \int dA \times r^2 = \frac{\tau_2}{r_2} \times J$$

where J = Polar moment of inertia of the throat area about G.

therefore shear stress due to the turning moment i.e secondary shear stress, is given as $\tau_2 = \frac{T \times r_2}{J} = \frac{P \times e \times r_2}{J}$

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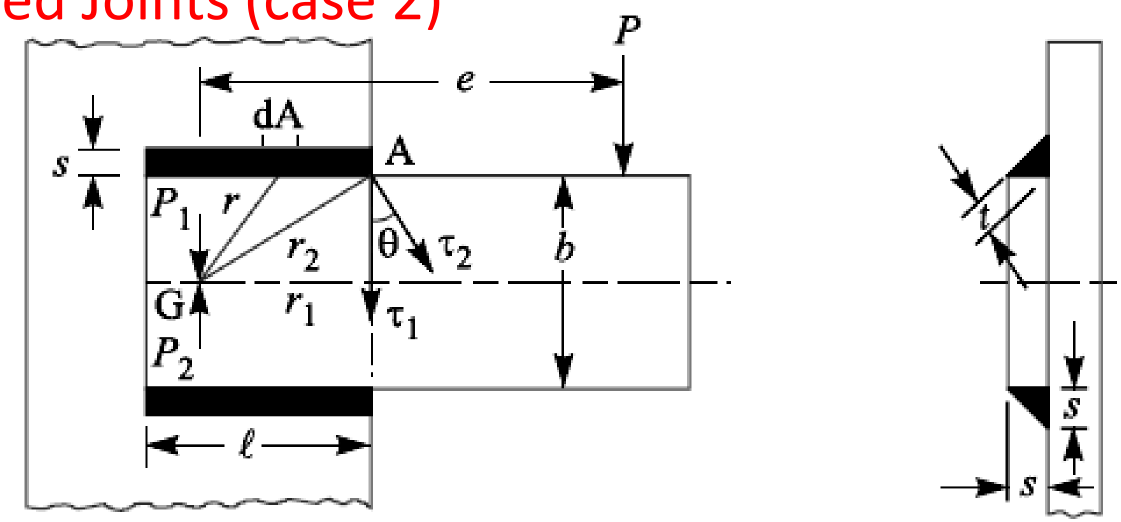
Eccentrically Loaded Welded Joints (case 2)

In order to find the resultant stress, the primary and seconary shear stresses are combined vectorially.



$\therefore$ Resulted shear stress at A

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

where θ = Angle between τ_1 and τ_2, $\cos\theta = \frac{r_1}{r_2}$

Welded Joints – Eccentric Loading

Eccentrically Loaded Welded Joints (case 2)

The polar moment of inertia of the throat area (A) about the center of gravity (G) is obtained by the parallel axis theorem, i.e.

$$J = 2\left[I_{xx} + A\times x^2\right] = 2\left[\frac{A\times l^2}{12} + A\times x^2\right] = 2A\left(\frac{l_2}{12} + x^2\right)$$

where $A = \text{Throat Area} = \text{t}\times l = 0.707s\times l,$

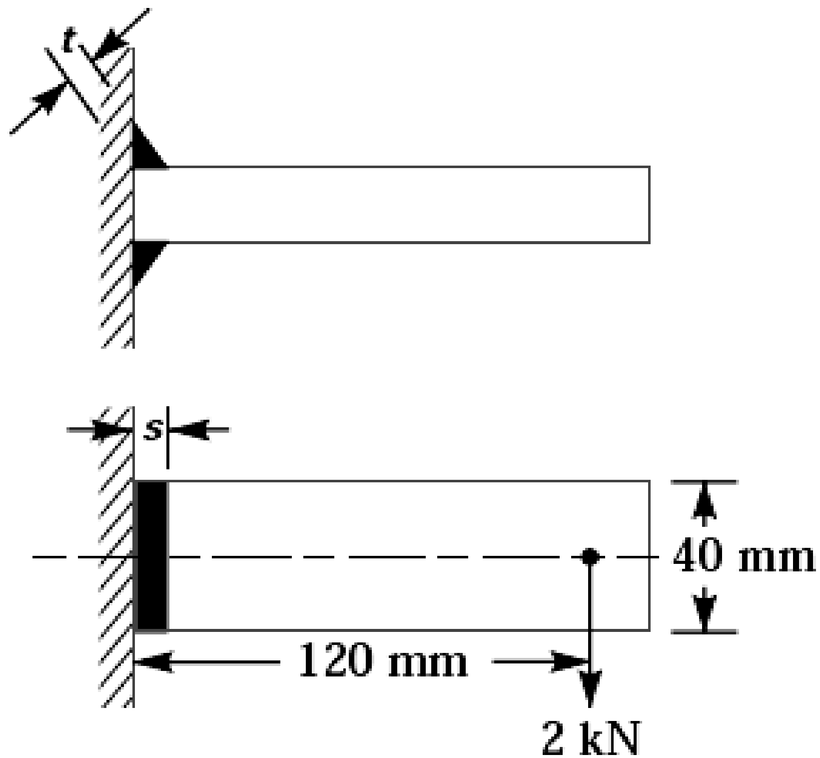
$l = \text{Length of weld, and}$

$x = \text{Perpendicular distance between the two parallel axes.}$

Welded Joints – Eccentric Loading

Example 8.

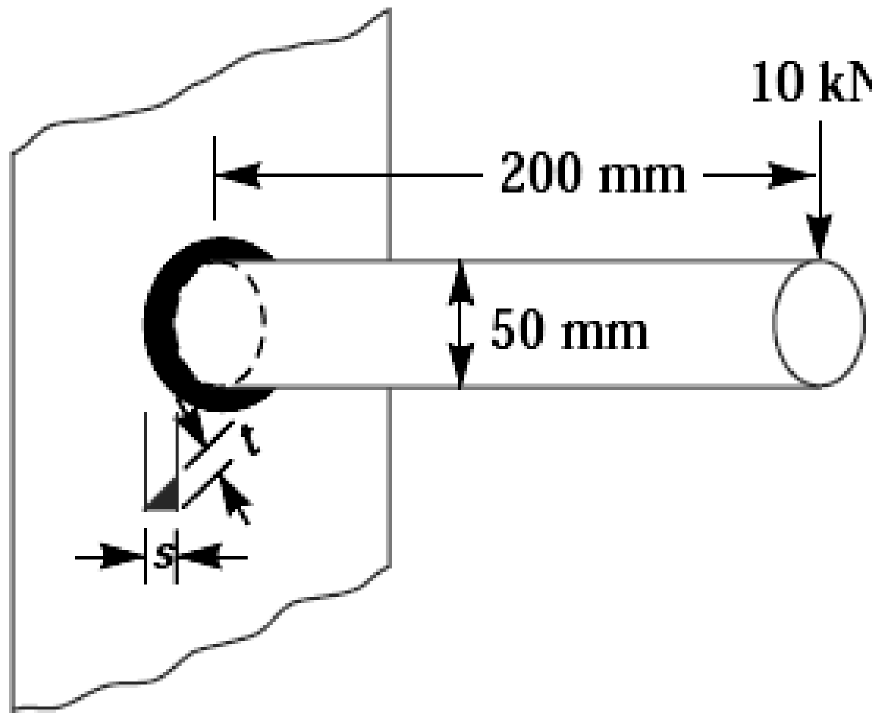
A welded joint as shown in Fig., is subjected to an eccentric load of 2 kN. Find the size of weld, if the maximum shear stress in the weld is 25 MPa.



Welded Joints – Eccentric Loading

Example 9.

A 50 mm diameter solid shaft is welded to a flat plate as shown in Fig. If the size of the weld is 15 mm, find the maximum normal and shear stress in the weld.



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