III UNIT
DESIGN OF TEMPORARY AND PERMANENT JOINTS

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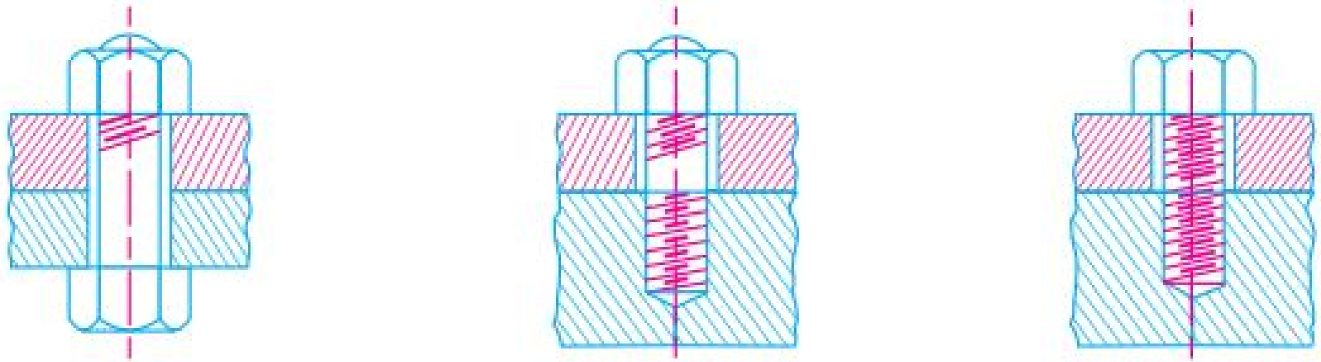
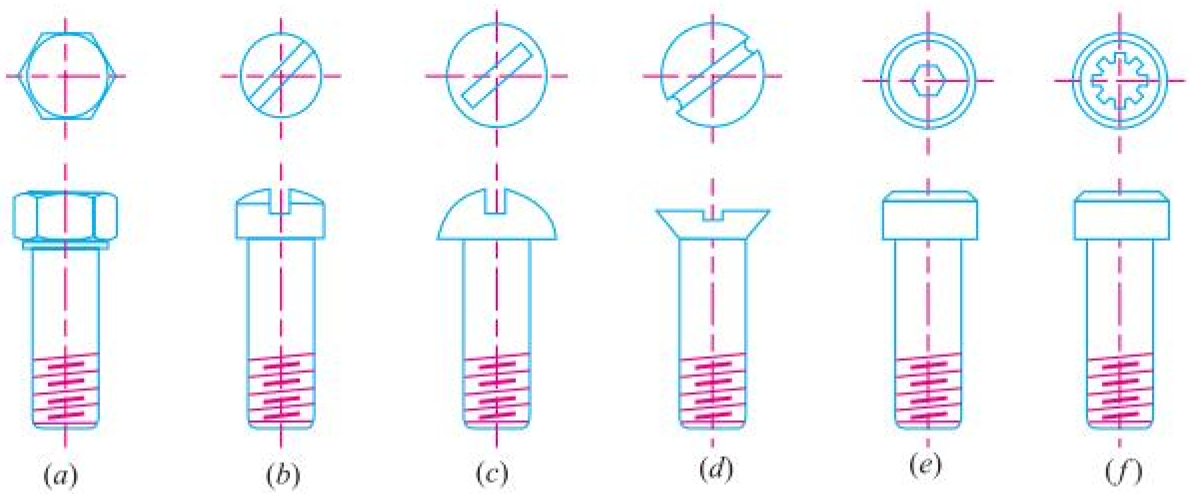
Syllabus

THREADED FASTNERS – DESIGN OF BOLTED JOINTS INCLUDING ECCENTRIC LOADING, KNUCKLE JOINTS, COTTER JOINTS – DESIGN OF WELDED JOINTS, RIVETED JOINTS FOR STRUCTURES – THEORY OF BONDED JOINTS.

BOLTS:-

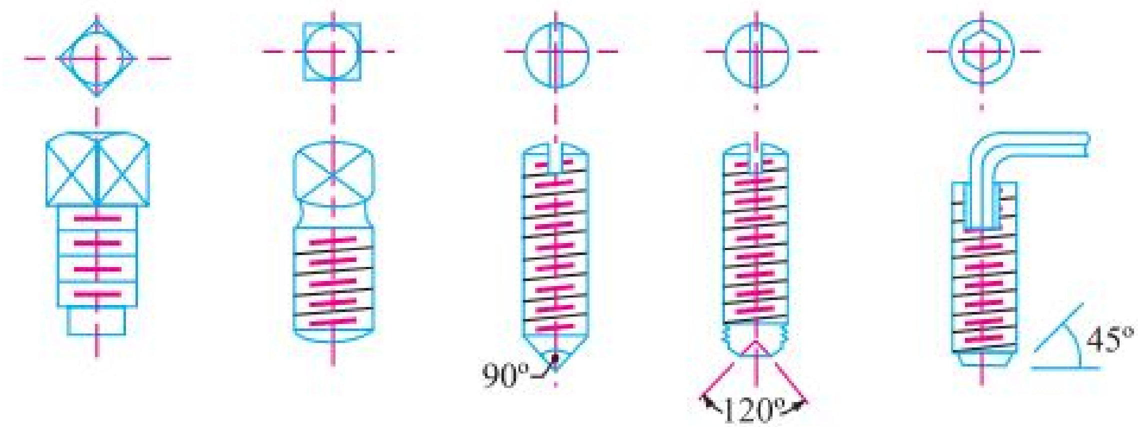


(*a*) Through bolt. (*b*) Tap bolt. (*c*) Stud.



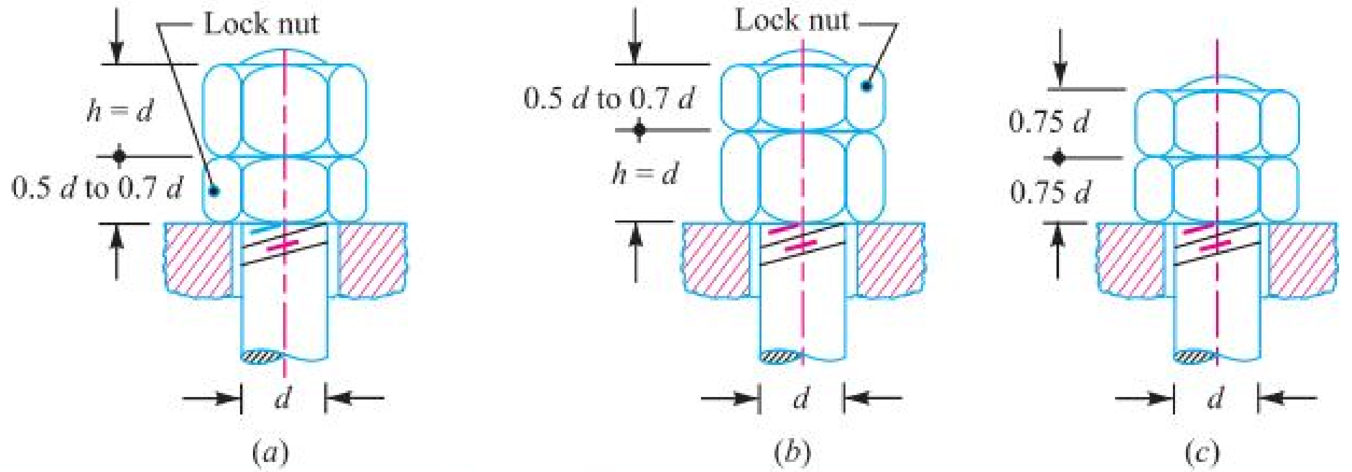
(*a*) Hexagonal head; (*b*) Fillister head; (*c*) Round head; (*d*) Flat head;
(*e*) Hexagonal socket; (*f*) Fluted socket.

Types of cap screws.

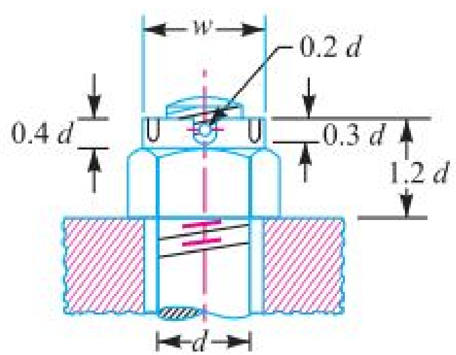


Set screws.

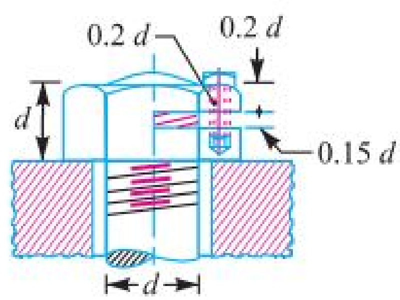
NUTS



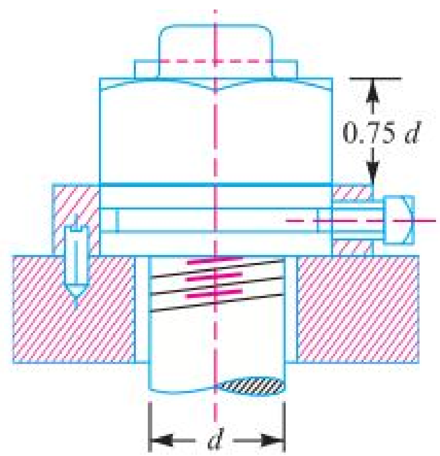
Jam nut or lock nut.



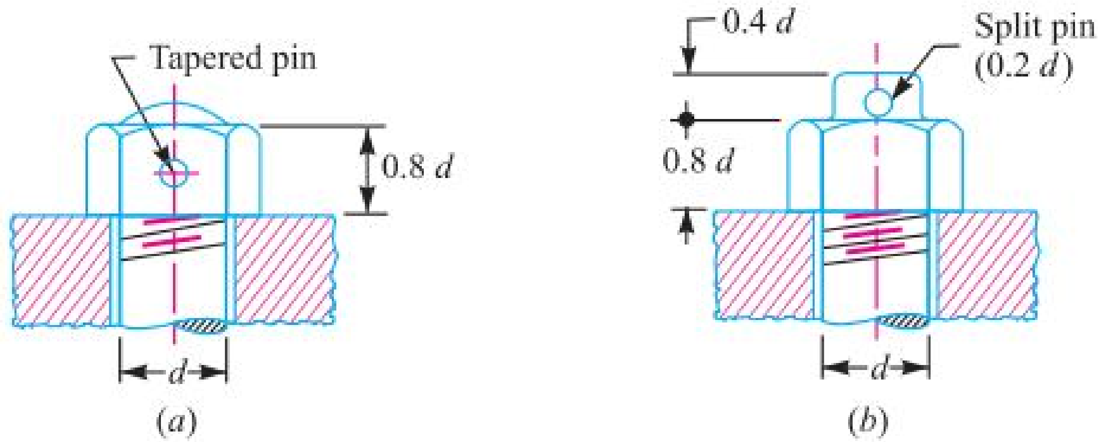
Castle nut.



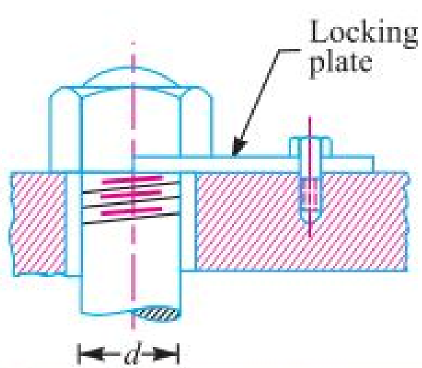
Sawn nut.



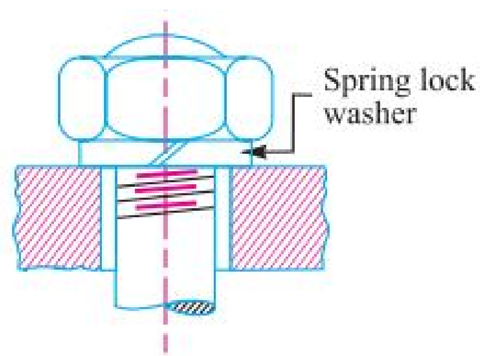
Penn, ring or grooved nut.



Locking with pin.



Locking with plate.



Locking with washer.

Problems

1. A steam engine cylinder has an effective diameter of 350 mm and the maximum steam pressure acting on the cylinder cover is 1.25 N/mm^2. Calculate the number and size of studs required to fix the cylinder cover. Assuming the permissible stress in the studs as 33 MPa.
2. The head of a steam engine cylinder 500 mm diameter is subjected to a pressure of 1 N/mm^2. The head is held in position by 16 numbers of M30 bolts. A copper gasket is used to make the joint steam tight. Determine the stress induced in the bolt. Assume k=0.5.

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3. Find the size of 14 bolts required for a C.I steam engine cylinder head. The diameter of the cylinder is 400 mm and the steam pressure is 1.5 N/mm^2. Take the permissible tensile stress as 35 N/mm^2.
4. The cylinder head of a steam engine with 250 mm bore is fastened by eight stud bolts made of 30C8 steel. Maximum pressure inside the cylinder is 1 MPa. Determine the bolt size and approximate tightening torque. Take 20% overhead. Assume σy = 300 MPa for bolt material.

Eccentrically loaded bolted joints

1. A bracket as shown in figure. It is fitted to a wall with 5 bolts, three at the top and two at the bottom, with all the bolts equally spaced. A load of 20000 N is acting at an eccentricity of 200 mm vertical distances of first and second rows from the hinge point are 50 mm and 250 mm respectively. Select a suitable bolt size for this application

2. A bracket is fitted to a channel with 4 bolts as shown in figure. Distance between bolts 1 and 3 is equal to the distance between bolts 2 & 4 which is 150 mm, eccentricity is 300 mm. Find a suitable bolt.
3. A steel plate subjected to a force of 5 kN and fixed to a channel by means of three identical bolts is shown in figure. The bolts are made from plain carbon steel 45C8 and the factor of safety is 3. Specify the size of bolts. **(N/D 2010)**

3. A machine member has circular flange, which is connected to the frame by means of 8 bolts and loaded as shown in fig. Assuming that the bolt material has a allowable shear stress of 30 Mpa, find the bolt size required.

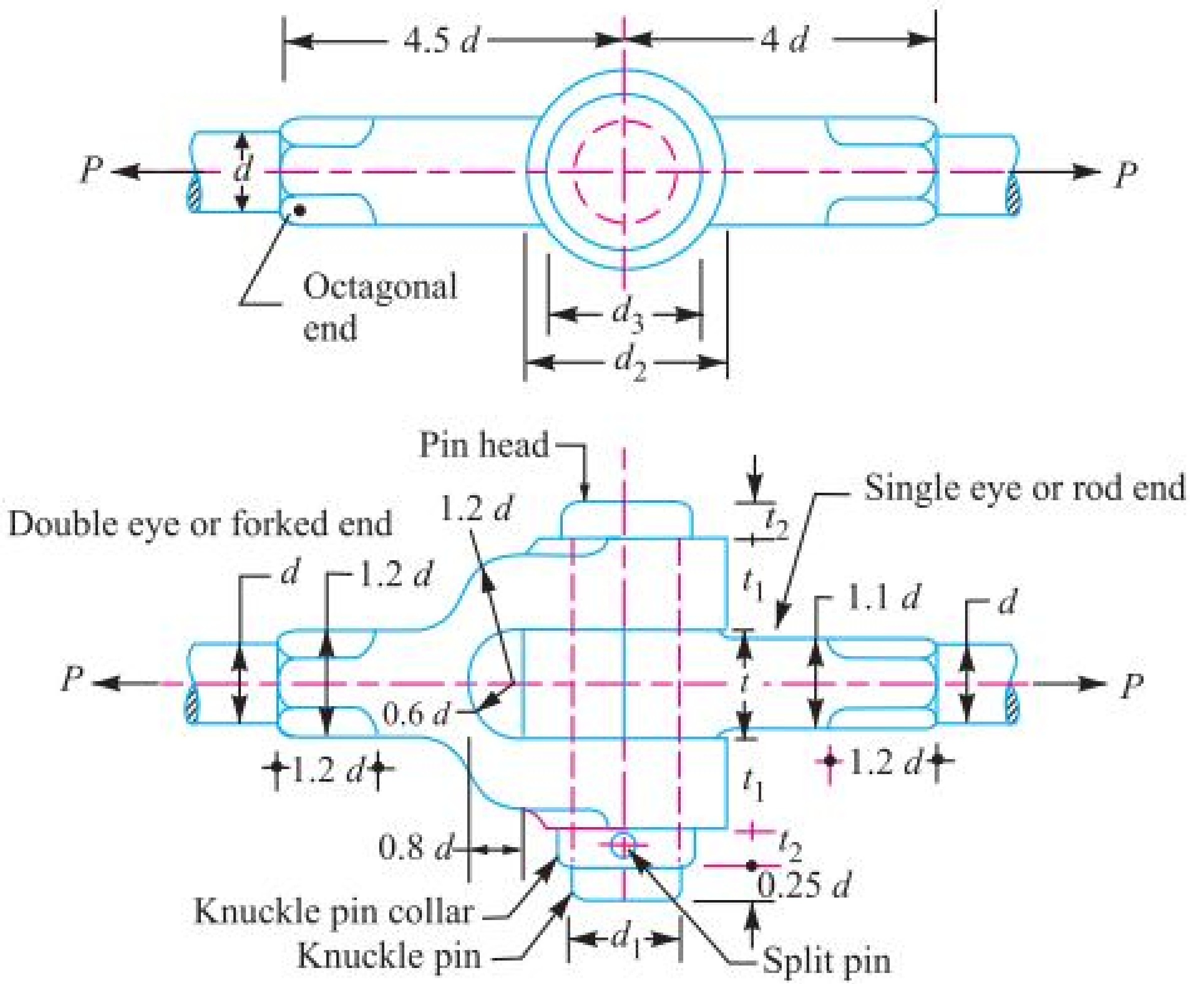
Knuckle Joint

A knuckle joint is used to connect two rods which are under the action of tensile loads. However, if the Joint is guided, the rods may support a compressive load.

Application:

1. Link of a cycle chain
2. Tie rod Joint for roof truss
3. Valve rod joint with eccentric rod
4. Pump rod joint
5. Tension link in bridge structure

Design of Knuckle Joint



Let,

d- diameter of the rod

d_1 – diameter of the pin

d_2 – outer diameter of the eye

d_3 – diameter of knuckle pin head and collar

t – thickness of single eye

t_1 – thickness of fore

t_2 – thickness of pin head

(σ_t) – permissible tensile stress in the joint

(τ) – permissible shear stress in the joint

(σ_c) – permissible crushing stress in the joint

Problem

Design a knuckle joint to connect two mild steel bars under a tensile load of 25 kN. The allowable stresses are 65 Mpa in tension, 50 Mpa in shear and 83 Mpa in crushing.

Sleeve and Cotter Joint

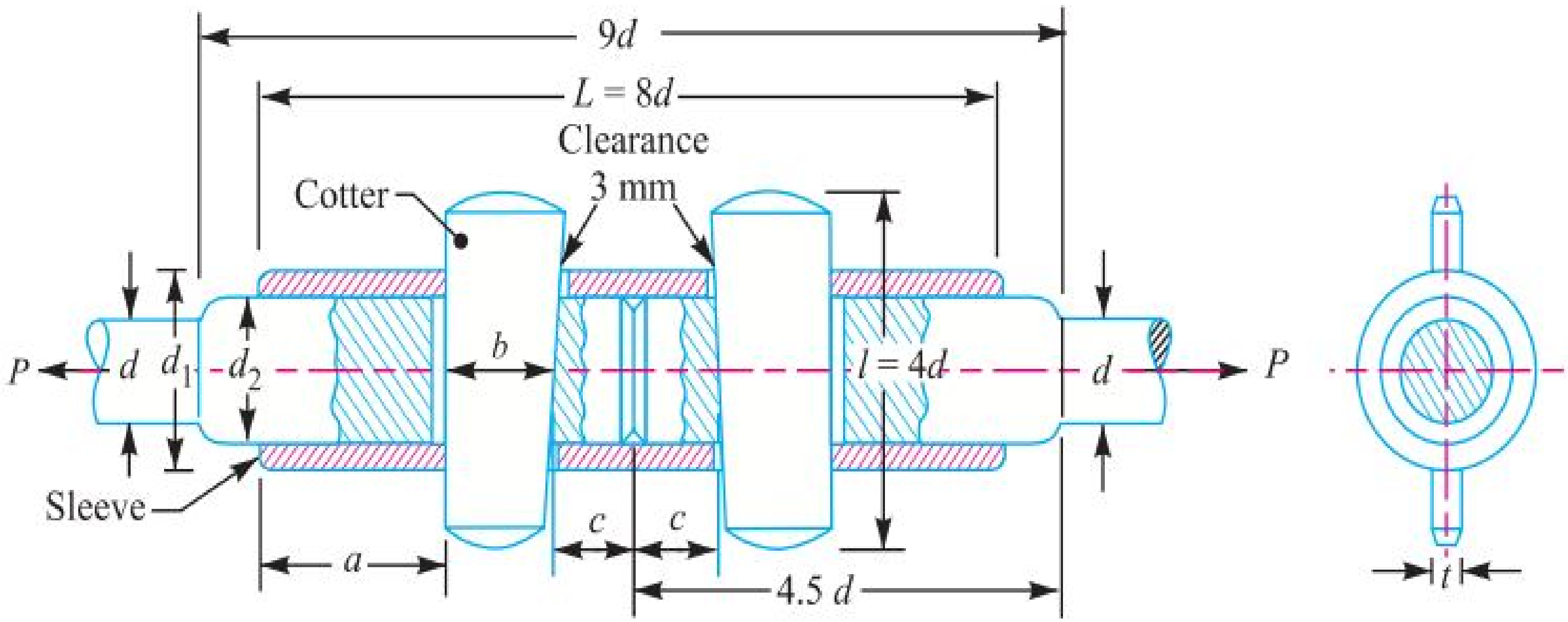


Fig. 12.9. Sleeve and cotter joint.

Design of sleeve and cotter Joint

Let P = Load carried by the rods,

d = Diameter of the rods,

d_1 = Outside diameter of sleeve,

d_2 = Diameter of the enlarged end of rod,

t = Thickness of cotter,

l = Length of cotter,

b = Width of cotter,

a = Distance of the rod end from the beginning to the cotter hole (inside the sleeve end),

c = Distance of the rod end from its end to the cotter hole,

σ_t, τ and σ_c = Permissible tensile, shear and crushing stresses respectively for the material of the rods and cotter.

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The various proportions for the sleeve and cotter joint in terms of the diameter of rod (d) are as follows :

Outside diameter of sleeve,

$$d_1 = 2.5\,d$$

Diameter of enlarged end of rod,

$$d_2 = \text{Inside diameter of sleeve} = 1.25\,d$$

Length of sleeve, $L = 8\,d$

Thickness of cotter, $t = d_2/4 \text{ or } 0.31\,d$

Width of cotter, $b = 1.25\,d$

Length of cotter, $l = 4\,d$

Distance of the rod end (a) from the beginning to the cotter hole (inside the sleeve end)

= Distance of the rod end (c) from its end to the cotter hole

$= 1.25\,d$

1. *Failure of the rods in tension*

The rods may fail in tension due to the tensile load P. We know that

$$\text{Area resisting tearing} = \frac{\pi}{4} \times d^2$$

$\therefore$ Tearing strength of the rods

$$= \frac{\pi}{4} \times d^2 \times \sigma_t$$

Equating this to load (P), we have

$$P = \frac{\pi}{4} \times d^2 \times \sigma_t$$

From this equation, diameter of the rods (d) may be obtained.

2. Failure of the rod in tension across the weakest section (i.e. slot)

Since the weakest section is that section of the rod which has a slot in it for the cotter, therefore area resisting tearing of the rod across the slot

$$= \frac{\pi}{4}(d_2)^2 - d_2 \times t$$

and tearing strength of the rod across the slot

$$= \left[\frac{\pi}{4}(d_2)^2 - d_2 \times t\right]\sigma_t$$

Equating this to load (P), we have

$$P = \left[\frac{\pi}{4}(d_2)^2 - d_2 \times t\right]\sigma_t$$

From this equation, the diameter of enlarged end of the rod (d_2) may be obtained.

Note: The thickness of cotter is usually taken as $d_2 / 4$.

3. *Failure of the rod or cotter in crushing*

We know that the area that resists crushing of a rod or cotter

$$= d_2 \times t$$

$$\therefore \quad \text{Crushing strength} = d_2 \times t \times \sigma_c$$

Equating this to load (P), we have

$$P = d_2 \times t \times \sigma_c$$

From this equation, the induced crushing stress may be checked.

4. *Failure of sleeve in tension across the slot*

We know that the resisting area of sleeve across the slot

$$= \left[\frac{\pi}{4}(d_1)^2 - (d_2)^2\right] - (d_1 - d_2)\, t$$

$\therefore$ Tearing strength of the sleeve across the slot

$$= \left[\frac{\pi}{4}[(d_1)^2 - (d_2)^2] - (d_1 - d_2)\, t\right]\sigma_t$$

Equating this to load (P), we have

$$P = \left[\frac{\pi}{4}[(d_1)^2 - (d_2)^2] - (d_1 - d_2)\, t\right]\sigma_t$$

From this equation, the outside diameter of sleeve (d_1) may be obtained.

5. *Failure of cotter in shear*

Since the cotter is in double shear, therefore shearing area of the cotter

$$= 2b \times t$$

and shear strength of the cotter

$$= 2b \times t \times \tau$$

Equating this to load (P), we have

$$P = 2b \times t \times \tau$$

From this equation, width of cotter (b) may be determined.

6. *Failure of rod end in shear*

Since the rod end is in double shear, therefore area resisting shear of the rod end

$$= 2\, a \times d_2$$

and shear strength of the rod end

$$= 2\, a \times d_2 \times \tau$$

Equating this to load (P), we have

$$P = 2\, a \times d_2 \times \tau$$

From this equation, distance (a) may be determined.

7. *Failure of sleeve end in shear*

Since the sleeve end is in double shear, therefore the area resisting shear of the sleeve end

$$= 2\,(d_1 - d_2)\, c$$

and shear strength of the sleeve end

$$= 2\,(d_1 - d_2)\, c \times \tau$$

Equating this to load (P), we have

$$P = 2\,(d_1 - d_2)\, c \times \tau$$

From this equation, distance (c) may be determined.

Problem

Design a sleeve and cotter joint to withstand a tensile load of 70 kN. All parts of the joint are made of saame material and the permissible stresses are $(\sigma_t) = 60\ N/mm^2$, $(\sigma_c) = 120\ N/mm^2$, $(\tau) = 70\ N/mm^2$.

Socket and Spigot cotter Joint

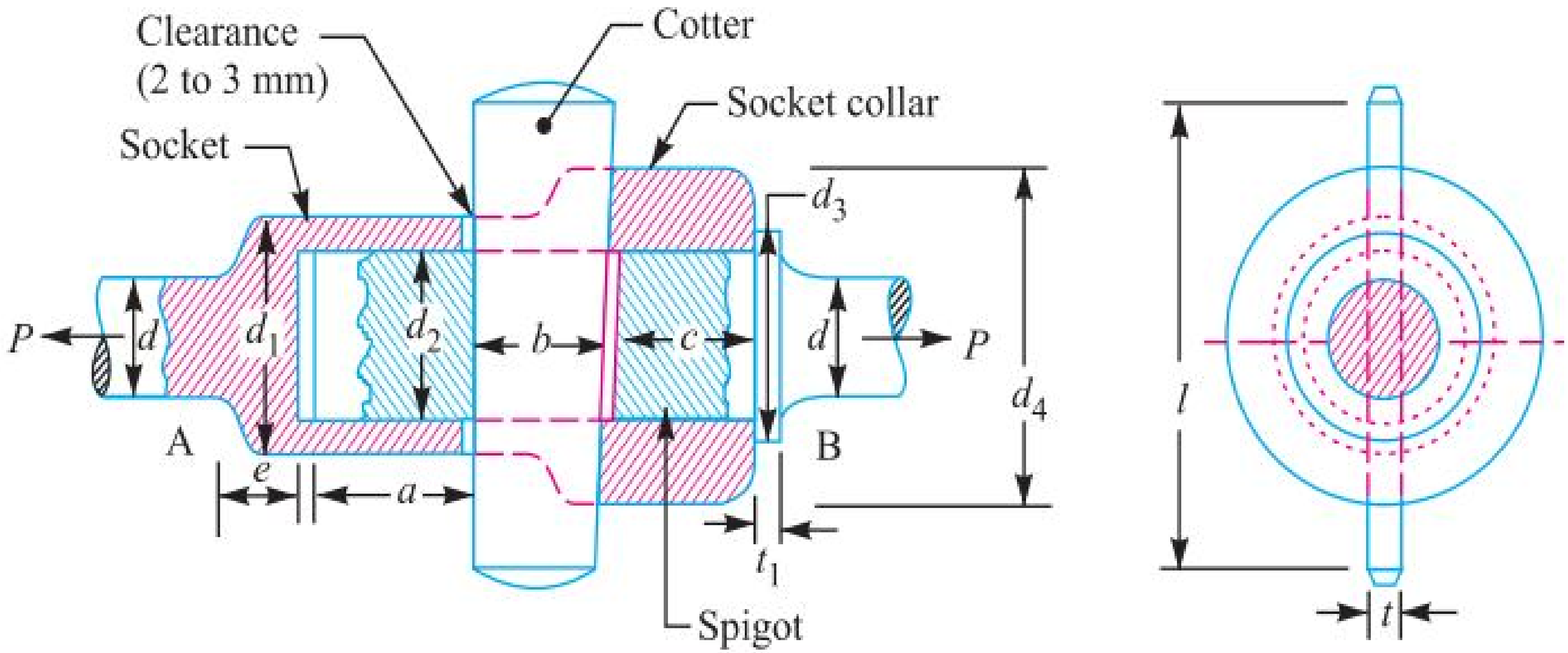


Fig. 12.1. Socket and spigot cotter joint.

Let P = Load carried by the rods,

d = Diameter of the rods,

d_1 = Outside diameter of socket,

d_2 = Diameter of spigot or inside diameter of socket,

d_3 = Outside diameter of spigot collar,

t_1 = Thickness of spigot collar,

d_4 = Diameter of socket collar,

c = Thickness of socket collar,

b = Mean width of cotter,

t = Thickness of cotter,

l = Length of cotter,

a = Distance from the end of the slot to the end of rod,

σ_t = Permissible tensile stress for the rods material,

τ = Permissible shear stress for the cotter material, and

σ_c = Permissible crushing stress for the cotter material.

1. *Failure of the rods in tension*

The rods may fail in tension due tc the tensile load P. We know that

Area resisting tearing

$$= \frac{\pi}{4} \times d^2$$

∴ Tearing strength of the rods,

$$= \frac{\pi}{4} \times d^2 \times \sigma_t$$

Equating this to load (P), we have

$$P = \frac{\pi}{4} \times d^2 \times \sigma_t$$

From this equation, diameter of the rods (d) may be determined.

2. *Failure of spigot in tension across the weakest section (or slot)*

Since the weakest section of the spigot is that section which has a slot in it for the cotter, as shown in Fig. 12.2, therefore

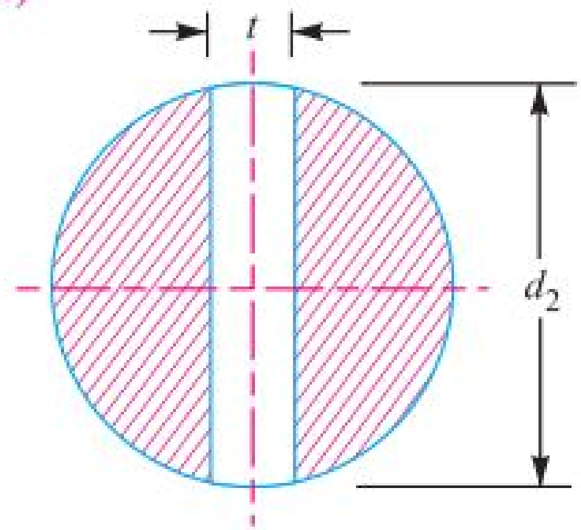


Fig. 12.2

Area resisting tearing of the spigot across the slot

$$= \frac{\pi}{4}(d_2)^2 - d_2 \times t$$

and tearing strength of the spigot across the slot

$$= \left[\frac{\pi}{4}(d_2)^2 - d_2 \times t\right]\sigma_t$$

Equating this to load (P), we have

$$P = \left[\frac{\pi}{4}(d_2)^2 - d_2 \times t\right]\sigma_t$$

From this equation, the diameter of spigot or inside diameter of socket (d_2) may be determined.

Note : In actual practice, the thickness of cotter is usually taken as $d_2 / 4$.

3. *Failure of the rod or cotter in crushing*

We know that the area that resists crushing of a rod or cotter

$$= d_2 \times t$$

$\therefore$ Crushing strength $= d_2 \times t \times \sigma_c$

Equating this to load (P), we have

$$P = d_2 \times t \times \sigma_c$$

From this equation, the induced crushing stress may be checked.

4. *Failure of the socket in tension across the slot*

We know that the resisting area of the socket across the slot, as shown in Fig. 12.3

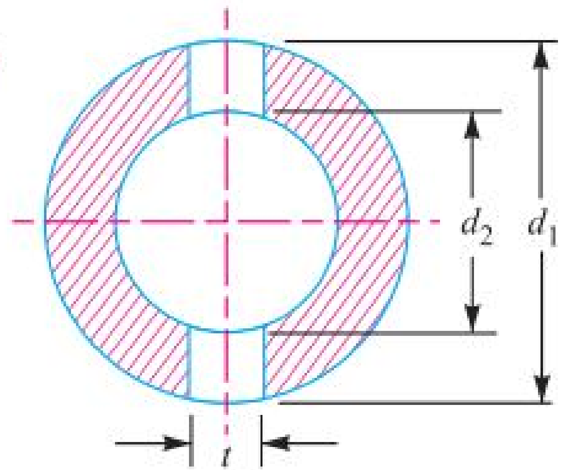
$$= \frac{\pi}{4}\left[(d_1)^2 - (d_2)^2\right] - (d_1 - d_2)\, t$$

$\therefore$ Tearing strength of the socket across the slot

$$= \left\{\frac{\pi}{4}\left[(d_1)^2 - (d_2)^2\right] - (d_1 - d_2)\, t\right\} \sigma_t$$

Equating this to load (P), we have

$$P = \left\{\frac{\pi}{4}\left[(d_1)^2 - (d_2)^2\right] - (d_1 - d_2)\, t\right\} \sigma_t$$



From this equation, outside diameter of socket (d_1) may be determined.

5. *Failure of cotter in shear*

Considering the failure of cotter in shear as shown in Fig. 12.4. Since the cotter is in double shear, therefore shearing area of the cotter

$$= 2\,b \times t$$

and shearing strength of the cotter

$$= 2\,b \times t \times \tau$$

Equating this to load (P), we have

$$P = 2\,b \times t \times \tau$$

From this equation, width of cotter (b) is determined.

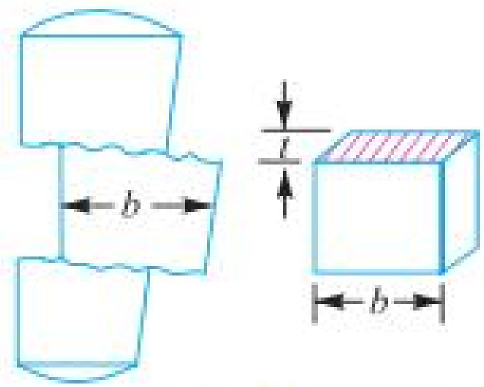


Fig. 12.4

6. *Failure of the socket collar in crushing*

Considering the failure of socket collar in crushing as shown in Fig. 12.5.

We know that area that resists crushing of socket collar

$$= (d_4 - d_2)\,t$$

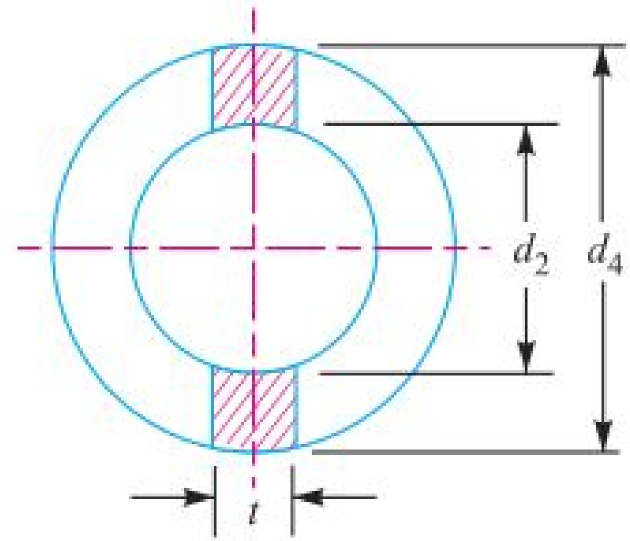
and crushing strength $= (d_4 - d_2)\,t \times \sigma_c$

Equating this to load (P), we have

$$P = (d_4 - d_2)\,t \times \sigma_c$$

From this equation, the diameter of socket collar (d_4) may be obtained.

7. *Failure of socket end in shearing*



Since the socket end is in double shear, therefore area that resists shearing of socket collar

$$= 2\,(d_4 - d_2)\,c$$

and shearing strength of socket collar

$$= 2\,(d_4 - d_2)\,c \times \tau$$

Equating this to load (P), we have

$$P = 2\,(d_4 - d_2)\,c \times \tau$$

From this equation, the thickness of socket collar (c) may be obtained.

8. *Failure of rod end in shear*

Since the rod end is in double shear, therefore the area resisting shear of the rod end

$$= 2\,a \times d_2$$

and shear strength of the rod end

$$= 2\,a \times d_2 \times \tau$$

Equating this to load (P), we have

$$P = 2\,a \times d_2 \times \tau$$

From this equation, the distance from the end of the slot to the end of the rod (a) may be obtained.

9. *Failure of spigot collar in crushing*

Considering the failure of the spigot collar in crushing as shown in Fig. 12.6. We know that area that resists crushing of the collar

$$= \frac{\pi}{4}\left[(d_3)^2 - (d_2)^2\right]$$

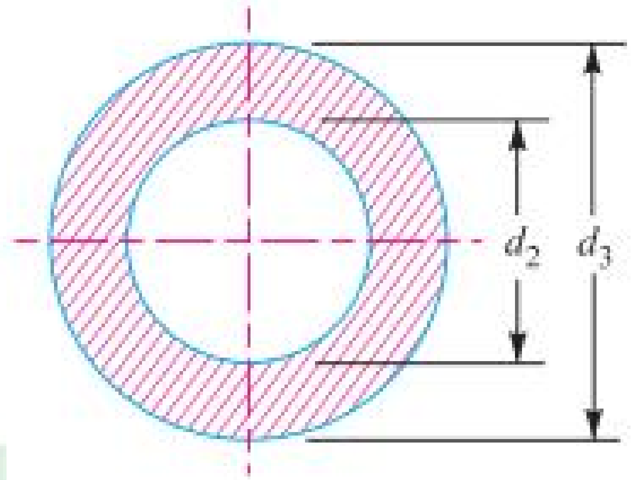
and crushing strength of the collar

$$= \frac{\pi}{4}\left[(d_3)^2 - (d_2)^2\right]\sigma_c$$

Equating this to load (P), we have

$$P = \frac{\pi}{4}\left[(d_3)^2 - (d_2)^2\right]\sigma_c$$

From this equation, the diameter of the spigot collar (d_3) may be obtained.



10. *Failure of the spigot collar in shearing*

Considering the failure of the spigot collar in shearing as shown in Fig. 12.7. We know that area that resists shearing of the collar

$$= \pi\, d_2 \times t_1$$

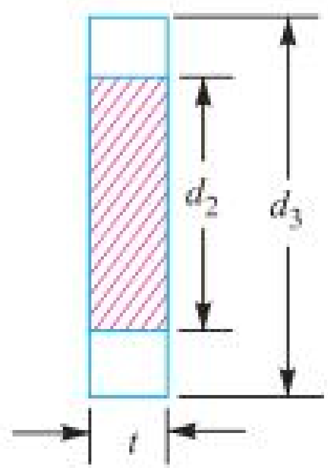
and shearing strength of the collar,

$$= \pi\, d_2 \times t_1 \times \tau$$

Equating this to load (P) we have

$$P = \pi\, d_2 \times t_1 \times \tau$$

From this equation, the thickness of spigot collar (t_1) may be obtained.



12. The length of cotter (l) in taken as 4 d.

13. The taper in cotter should not exceed 1 in 24. In case the greater taper is required, then a locking device must be provided.

Problem

Design a socket and spigot cotter joint to transmit an axial load of 30 kN which alternately changes from tensile to compressive. The permissible stresses are 50 Mpa in tension, 35 Mpa in shear, and 90 Mpa in crushing.

Welded Joints

Welding:

Welding can be defined as a process of joining two similar or disimilar metals by heating to a suitable diameter with or without the application of pressure.

Advantages:

1. Lighter in weight
2. Leak proof Joint
3. Production time is less

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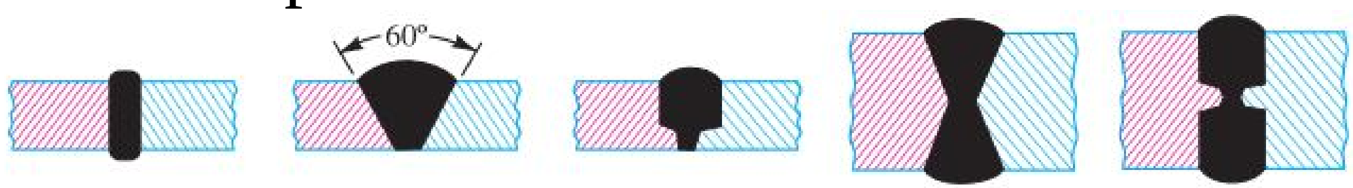
Limitations:

1. Poor vibration damping charecteristics
2. Residual stresses introduced
3. Highly skilled welder required

Types of welded Joints:

Butt Joint:

It is used to join the ends (or) edges of two plates. The surfaces of plates are located in the same plane.

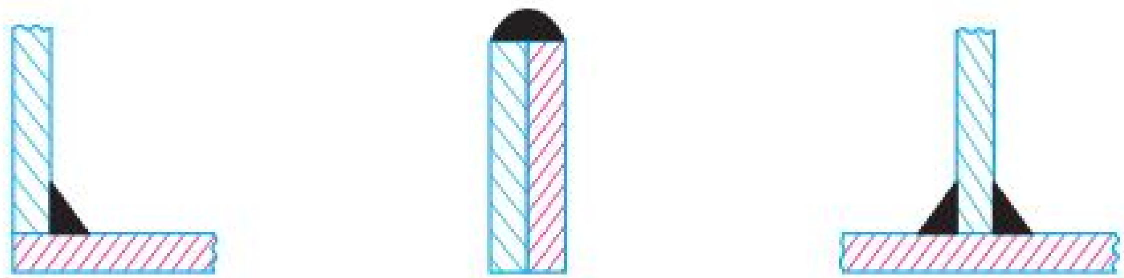


(*a*) Square butt joint. (*b*) Single *V*-butt joint. (*c*) Single *U*-butt joint. (*d*) Double *V*-butt joint. (*e*) Double *U*-butt joint.

Fig. 10.3. Types of butt joints.

Lap Joint:

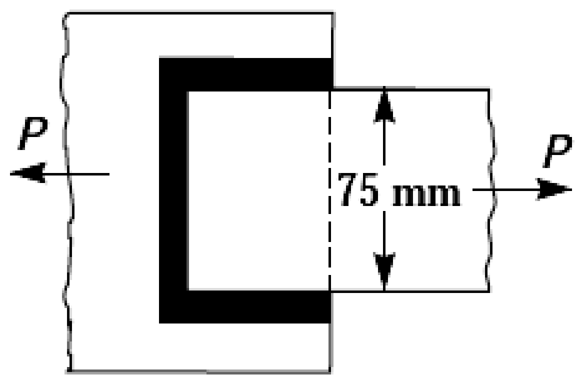
In a lap joint, two plates are over lapped each other for a certain distance.



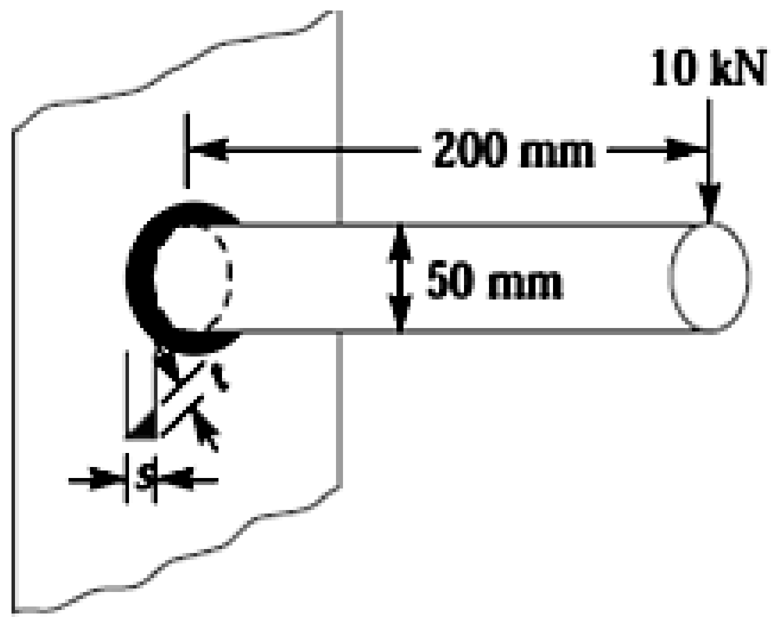
(a) Corner joint. (b) Edge joint. (c) T-joint.

Problems

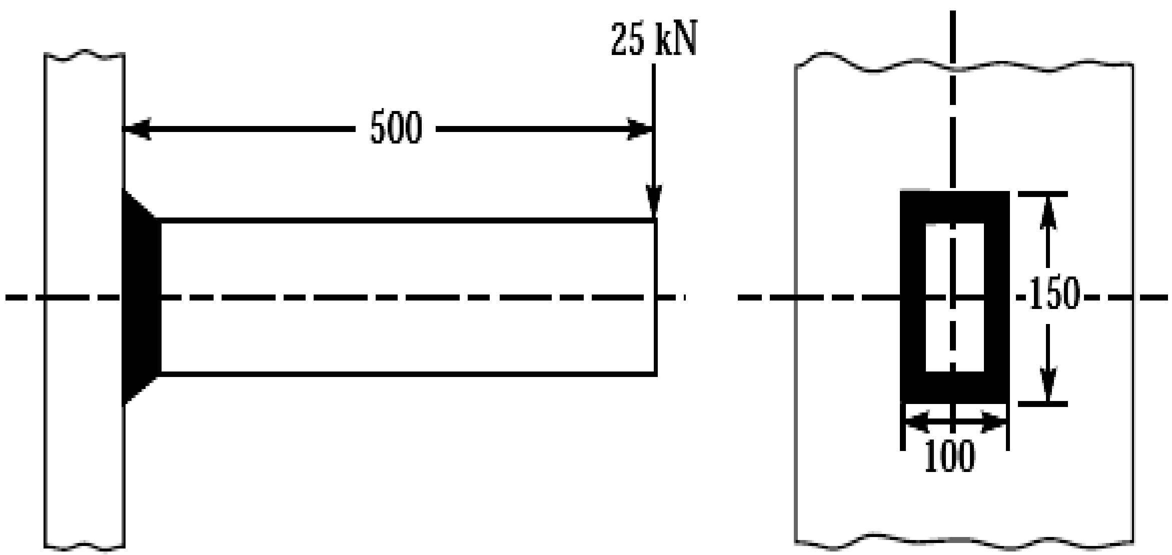
1. A plate 75 mm wide and 12.5 mm thick is joined with another plate by a single transverse weld and a double parallel fillet weld as shown in Fig. the maximum tensile and shear stresses are 70 MPa and 56 MPa respectively. Find the length of each parallel fillet weld, if the joint is subjected to both static and fatigue loading. **(N/D 2010)**



2. 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. **(NOV/DEC 2006/2007)**

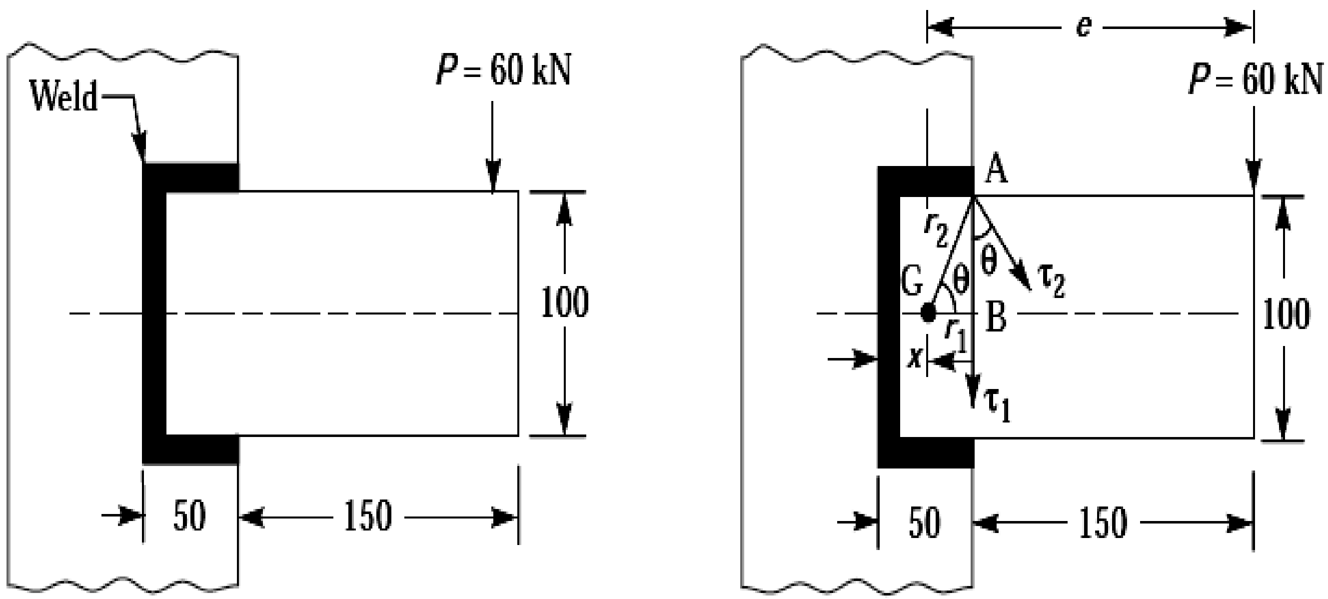


3. A rectangular cross-section bar is welded to a support by means of fillet welds as shown in Fig. Determine the size of the welds, if the permissible shear stress in the weld is limited to 75 MPa. **(NOV/DEC 2011)**



All dimensions in mm

4. A rectangular steel plate is welded as a cantilever to a vertical column and supports a single concentrated load P, as shown in Fig. Determine the weld size if shear stress in the same is not to exceed 140 MPa. **(NOV/DEC 2012, MAY/JUNE 2013)**



All dimensions in mm.

5. A plate of 200 mm width and 600 mm long is welded to a vertical plate by placing it on the vertical plate to form a cantilever with projecting length of 480 mm and overlap between the plates as 120 mm. Fillet weld is done on all three sides. A vertical load 30 kN is applied at the free end of the cantilever plate parallel to its width of 200 mm. If the allowable weld stress is 95 Mpa. Determine the weld size.
6. A rectangular steel plate is welded as a cantilever to a vertical column and supports a single concentrated load P, as shown in fig. Determine the weld size if shear stress in the same is not to exceed 140 Mpa. **(N/D 2012)**