THREADED FASTNERS

In threaded joints two or more machine members are joined together with the help of threaded fastening e.g. a nut and bolt. These are non-permanent type joints. Threads are formed by cutting a helical groove on the surface of a cylindrical rod or cylindrical hole.

Terminology of Screw Threads

Figure 1 shows some important terms used in screw threads

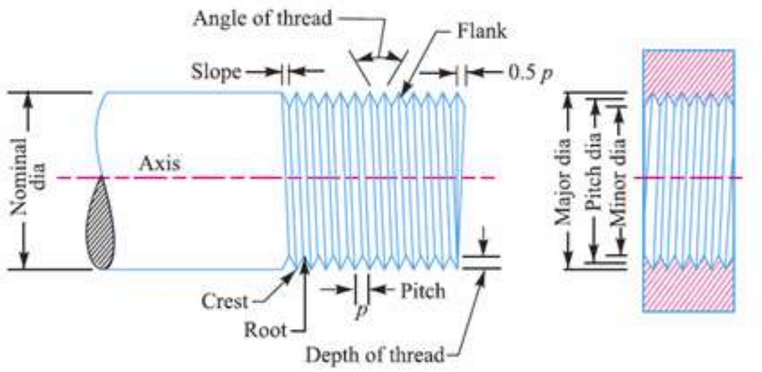


Figure 1 Terms used in Screw Threads

Major diameter: It is the largest diameter of an external or internal screw thread. The screw is specified by this diameter. It is also known as outside or nominal diameter.

Minor diameter: It is the smallest diameter of an external or internal screw thread. It is also known as core or root diameter.

Pitch diameter: It is the diameter of an imaginary cylinder, on a cylindrical screw thread, the surface of which would pass through the thread at such points as to make equal the width of the thread and the width of the spaces between the threads.

Pitch: It is the distance from a point on one thread to the corresponding point on the next. This is measured in an axial direction between corresponding points in the same axial plane.

Mathematically, Pitch = 1/ No. of threads per unit length of screw

Lead: It is the distance between two corresponding points on the same helix. It may also be defined as the distance which a screw thread advances axially in one rotation of the nut. Lead is equal to the pitch in case of single start threads; it is twice the pitch in double start and so on.

Crest: It is the top surface of the thread.

Root: It is the bottom surface created by the two adjacent flanks of the thread.

Depth of thread: It is the perpendicular distance between the crest and root.

Flank: It is the surface joining the crest and root.

Angle of thread: It is the angle included by the flanks of the thread.

Slope: It is half the pitch of the thread.

Types of Screw Fasteners

Bolt (Through Bolt): It is a cylindrical bar with threads for the nut at one end and head at the other end. The cylindrical part of the bolt is known as shank. It is passed through drilled holes in the two parts to be fastened together and clamped them securely to each other as the nut is screwed on to the threaded end. Bolts have hexagonal or square heads.

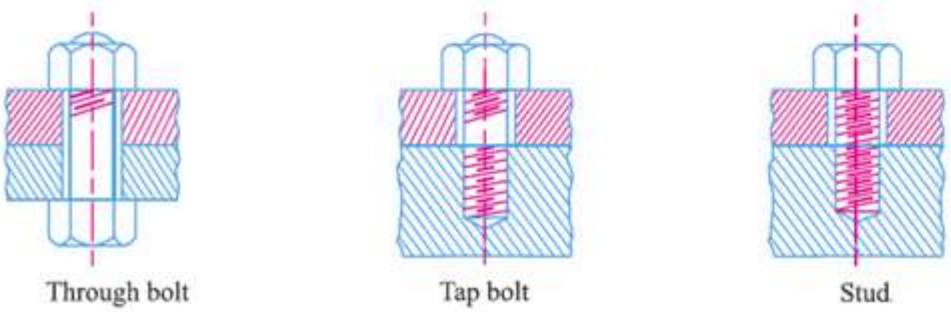


Figure.2 Through Bolt, Tap Bolt and Stud

Tap bolts: Tap bolt is screwed into a tapped hole of one of the parts to be fastened and nut is not used with it.

Studs: A stud is a round bar threaded at both ends. One end is screwed into a tapped hole of the parts to be fastened, while the other end receives a nut on it.

DESIGN OF THREADED FASTNERS

Modes of Failure

Consider a bolted joint subjected to tensile load as shown in Figure 3. Possible modes of failure of bolt under this loading are as follows:

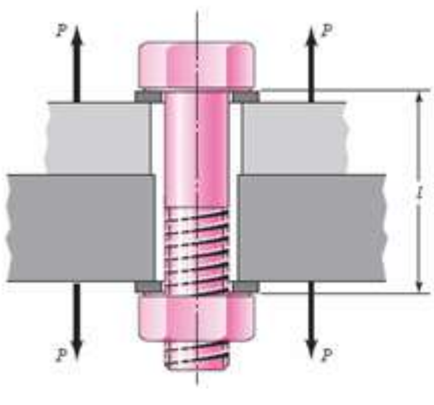


Figure 3 Bolt subjected to tensile load

Tensile Failure of Bolt

Maximum tensile stress induced in the bolt is given by,

$$\sigma_t = \frac{P}{A} = \frac{P}{\frac{\pi}{4}d_C^2} \leq \sigma_t$$

Where, d_c = core diameter of the bolt.

In addition to this, threads of the bolt can also fail in shear and crushing. For analysing that, it is assumed that each turn of the thread supports equal load and failure occurs in the threads of the bolt and not in the threads of the nut. Also stress concentration is neglected in the analysis of the bolts.

<u>Shear Failure of Threads</u>

Maximum shear stress developed in the threads is given by,

$$\tau = \frac{\frac{P}{n}}{\pi d_C b} = \frac{P}{\pi d_C h} \leq \tau$$

Where n = no. of turns, b = width of thread section at the root

h = n × b = height of the bolt

<u>Crushing Failure of Threads</u>

Maximum crushing stress developed in the threads is given by,

$$\sigma_C = \frac{\frac{P}{n}}{\frac{\pi}{4}\left(d^2 - d_C^2\right)} \leq \sigma_C$$

Where, n = no. of turns, d = outer diameter of the bolt

Shear Failure of Bolt

In addition to the above case of tensile loading, bolts may also be subjected to shear loads. In such case the maximum shear stress is given by,

$$\tau = \frac{P}{\frac{\pi}{4}d_C^2} \leq \tau$$

Where P, in this case, is the force acting on the joint perpendicular to the axis of bolt.

Using above relations, core diameter of the bolt can be calculated for a given material and type of loading. Approximate relation d_c = 0.8 d is generally used to find the nominal diameter of the bolt.

Pre-stress in Bolts

Stress develops in the threaded joint because of initial tightening torque. Stress developed is compressive in the members and tensile in nature in the bolts. Value of initial tension in the bolts is calculated using an empirical relation.

Initial Tension, F_i = 2840 d (N) (for fluid tight joints)

= 1420 d (N) (for other joints)

Where, d is nominal diameter of the bolt in mm. Initial Stress in the bolt can be calculated from F_i.

Eccentrically Loaded Bolted Joints

Eccentric Load acting in the plane of the Bolts

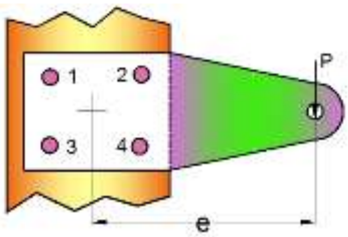


Figure 4 Eccentric load acting in plane of bolts

Consider the joint shown in Figure 4. Let a force P is acting at a distance e from the centre of gravity. This eccentric force can be considered as equivalent to an imaginary force P acting at the centre of gravity and a moment ‛ P_e′ about the centre of gravity.

Primary shear force developed in the bolts, because of the direct load,

$$P_1' = P_2' = P_3' = P_4' = \frac{P}{No. of\ bolts}$$

Secondary shear force because of the moment can be determined as follows.

$$P_e = P_1''.r_1 + P_2''.r_2 + P_3''.r_3 + P_4''.r_4$$

It is assumed that the secondary shear force in any bolt is proportional to its distance from the centre of gravity.

$$P_1'' \propto r_1,\ P_2'' \propto r_2, P_3'' \propto r_3\ and\ P_4'' \propto r_4$$

Considering C as a proportionality constant,

$$P_1'' = Cr_1, \qquad P_2'' = Cr_2, P_3'' = Cr_3 \; and \; P_4'' = Cr_4$$

So, $P_e = C.r_1^2 + C.r_2^2 + C.r_3^2 + C.r_4^2$

$$C = \frac{P_e}{r_1^2+r_2^2+r_3^2+r_4^2}$$

$$P_1'' = \frac{P_e.r_1}{r_1^2 + r_2^2 + r_3^2 + r_4^2}$$

Similarly P''_2, P''_3 and P''_4 values can be calculated. Primary and secondary shear forces are then vectorially added to get the resultant shear force in each bolt, which can then be used to find the stresses.

Eccentric Load acting perpendicular to the plane of the Bolts

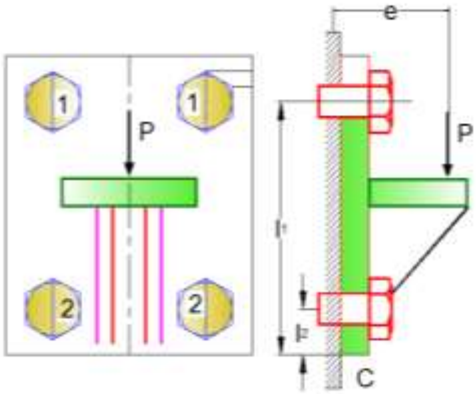


Figure 5 Eccentric load acting perpendicular to the plane of bolts

Consider a bracket bolted to a structure as shown in Figure 5. Let an eccentric force P be acting at a distance e from the structure. Lower two bolts are denoted by 2 and upper two by 1. P is acting perpendicular to the axes of the bolts and leads to a direct shear load, which can be given by,

$$P_1' = P_2' = \frac{P}{No.\ of\ bolts}$$

Also, because of eccentricity, P leads to a moment Pe, which tends to tilt the bracket about the edge C. This leads to resisting tensile forces in all the bolts, which are proportional to their distance from C. If and are the resisting tensile forces developed in bolts at position 1 and 2 respectively,

$$P_1'' = C\, l_1 \;\; and \;\; P_2'' = Cl_2$$

Considering C as a proportionality constant, Equating the moments due to P and due to the resisting forces,

$$Pe = 2\,P_1''.l_1 + 2\,P_2''.l_2$$

$$Pe = 2\,C\,l_1^2 + 2\,C\,l_2^2$$

Or

$$\therefore C = \frac{Pe}{2(l_1^2 + l_2^2)}$$

$$\therefore P_1'' = \frac{P\,e\,l_1}{2(l_1^2 + l_2^2)}$$

and

$$P_2'' = \frac{P\,e\,l_2}{2(l_1^2 + l_2^2)}$$

Bolts farthest from the tilting edge have maximum value of resisting tensile force. Therefore stresses in the bolts denoted by 1 will have maximum stresses which can be determined as follows:

Maximum principal stresses developed in the bolts can then be found and compared with the allowable values or bolt dimensions can be found for a given material.

Eccentric Load acting parallel to the plane of the Bolts

Consider the bracket bolted to structure shown in Figure 6. Let an eccentric force P be acting at a distance e from the edge C about which it tends to tilt the bracket. There are two bolts at each position i.e. 1 & 2. As P, in this case, is acting parallel to the axes of the bolts, it leads to a primary tensile force and a secondary tensile force due to the moment.

Primary tensile forces are given by,

$$P_1' = P_2' = \frac{P}{No.\ of\ bolts}$$

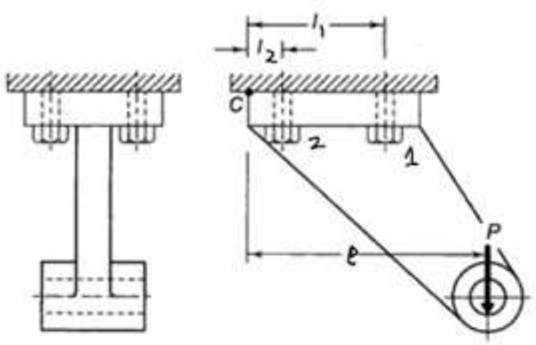


Figure 6 Eccentric load acting parallel to the plane of bolts

As discussed in the previous case, secondary tensile forces are given by,

$$P_1'' = \frac{P\,e\,l_1}{2(l_1^2 + l_2^2)} \text{ and } P_2'' = \frac{P\,e\,l_2}{2(l_1^2 + l_2^2)}$$

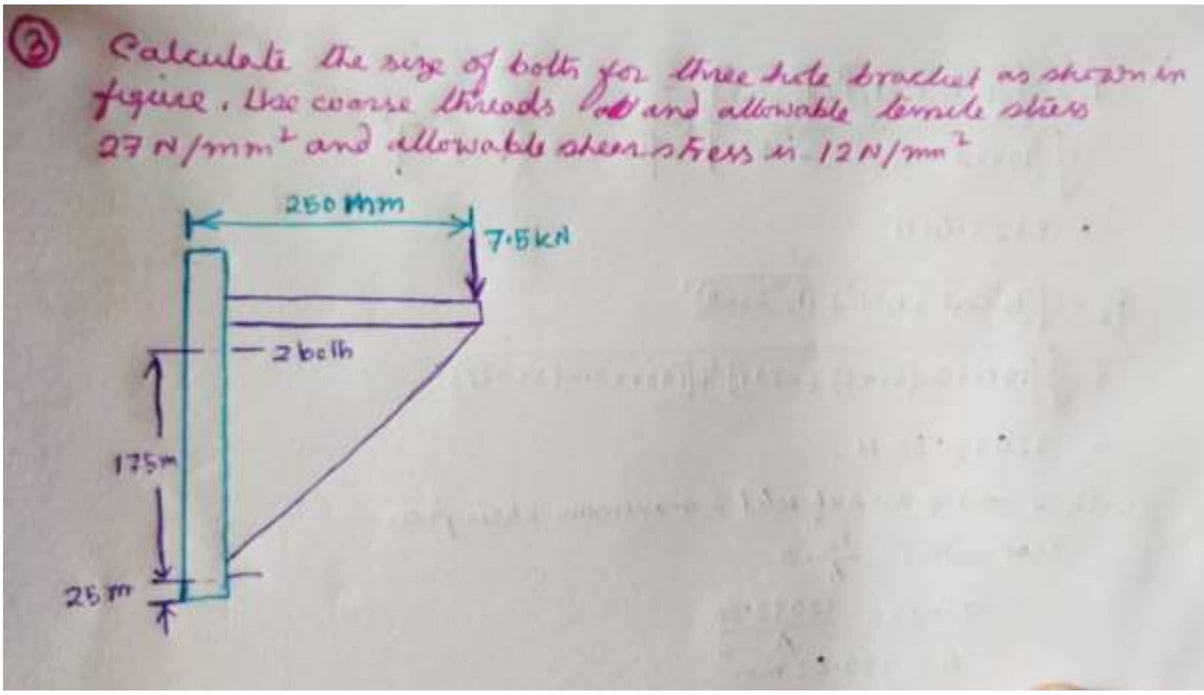
Total tensile force in each bolt at position 1 & 2 are given by,

$$P_1 = P'_1 + P''_2 \quad \text{and} \quad P2 = P'_2 + P''_2$$

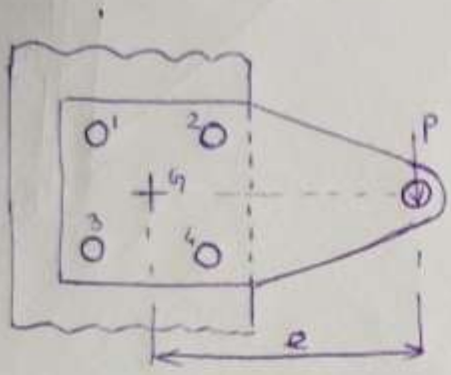
As bolts at 1 are farthest from the edge about which the bracket tends to tilt, maximum resisting force is developed in those. Maximum tensile stress in bolts at position 1 is given by,

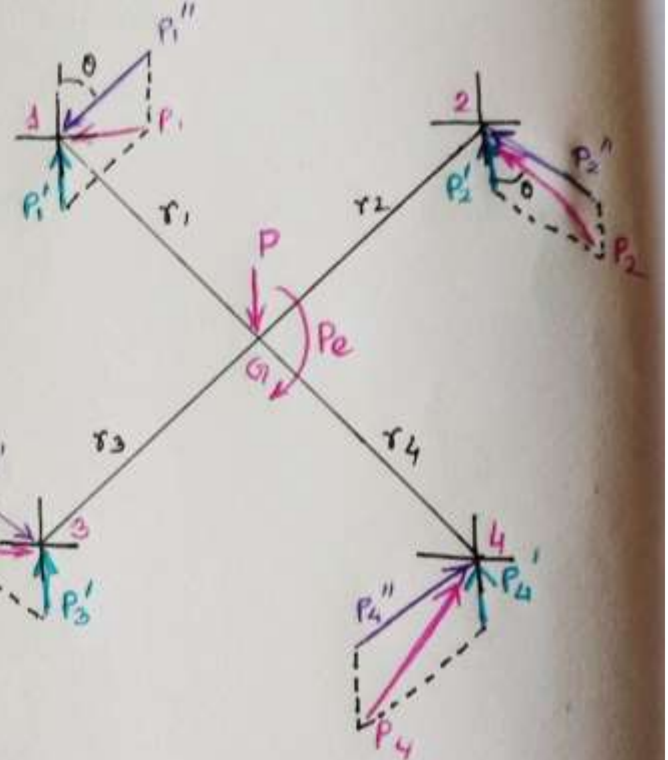
$$\sigma_{t_1} = \frac{P_1}{\frac{\pi}{4} d_c^2}$$

This can be compared with the allowable values of tensile stress.



1. The structural connection shown in figure below is subjected to an eccentric force P of 10 kN with an eccentricity of 500 mm. The centre distance between bolts 1 and 2 is 200 mm and the centre distance between bolt 1 and 3 is 150 mm. All the bolts are identical. The bolts are made from plain carbon steel 30C8 ($S_{yt} = 400 N/mm^2$) and the factor of safety is 2.5. Determine the size of the bolt.

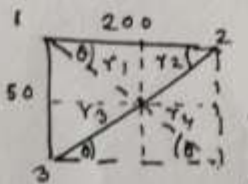




Permissible shear stress

$$\tau = \frac{S_{sy}}{f.o.s} = \frac{0.577 S_{yt}}{2.5}$$

$$\tau = \frac{0.577 \times 400}{2.5} = 92.32 \ N/mm^2$$



$$(r_2 + r_3)^2 = 200^2 + 150^2 = 62500$$

$$r_2 + r_3 = 250$$

$$r = r_1 = r_2 = r_3 = r_4 = \frac{250}{2} = 125 \ mm.$$

Primary shear force, $P_1' = P_2' = P_3' = P_4' = \frac{10000}{4} = 2500 N$.

Secondary shear force, $P_1'' = \frac{(Pe) r_1}{(r_1^2 + r_2^2 + r_3^2 + r_4^2)} = \frac{P.e}{4r} = \frac{10000 \times 500}{4 \times 125} = 10000 N$

Similarly $P_1'' = P_2'' = P_3'' = P_4'' = 10000 N$.

$\tan\theta = \frac{75}{100}$ or $\theta = 36.87°$.

$$P_1 = \sqrt{(P_1''\cos\theta - P_1')^2 + (P_1''\sin\theta)^2}$$

$$= \sqrt{[10000\cos(36.87) - 2500]^2 + [10000\sin(36.87)]^2}$$

$$= 8139.41\,N$$

$$P_2 = \sqrt{(P_2''\cos\theta + P_2')^2 + (P_2''\sin\theta)^2}$$

$$= \sqrt{[10000\cos(36.87) + 2500]^2 + [10000\sin(36.87)]^2}$$

$$= 12093.38\,N$$

Bolts 2 and 4 are subjected to maximum shear forces.

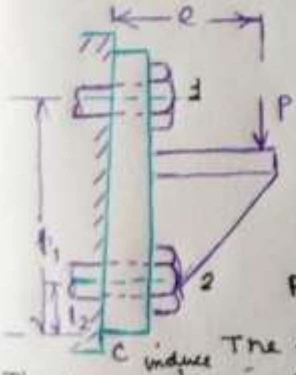
Thus $\tau = \frac{P_2}{A}$

$$92.32 = \frac{12093.38}{A}$$

$$A = 130.99\ mm$$

From table, bolts with thread M16 are suitable.

2. The following data is given for the bracket as shown in figure
$P = 25\,kN$, $e = 100\,mm$, $l_1 = 150\,mm$, $l_2 = 25\,mm$.
There is no pre load in the bolts. The bolts are made of plain carbon steel 45C8 ($S_{yt} = 380\,N/mm^2$) and the factor of safety is 2.5. Using maximum shear stress theory, specify size of bolt.



Soln

Permissible shear stress $\tau = \frac{S_{yt}}{F.O.S} = \frac{0.55\,S_{yt}}{2.5} = 76\,N/mm^2$

Primary shear force $P_1' = P_2' = \frac{P}{\text{No. of bolts}} = \frac{25\times10^3}{4} = 6250\,N$

The direct shear stress induce, $\tau = \frac{6250}{A}\,N/mm^2$

The force, tensile stress in bolt, $P_1'' = \frac{P e l_1}{2(l_1^2 + l_2^2)} = \frac{25\times10^3\times100\times150}{2[150^2 + 25^2]} = 8108.11\,N$

The bolts 1 are subjected to maximum forces.

Therefore the tensile stress in this bolt, $\sigma_t = \frac{P_1''}{A} = \frac{8108.11}{A}\,N/mm^2$

So, $\tau_{max} = \sqrt{\left(\frac{\sigma_t}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{8108.11}{2A}\right)^2 + \left(\frac{6250}{A}\right)^2} = \frac{7449.69}{A}\,N/mm^2$

Now, $\frac{7449.69}{A} = 76$; $A = 98.02\,mm^2$

From Table bolts with thread M16 are suitable.

WELDED JOINTS

Introduction

Welding is a process for joining two similar or dissimilar metals by fusion and provides a permanent joint. In welding, the parts are coalesced at their contacting surfaces by a suitable application of heat and/or pressure, with or without the addition of a filler metal. Welding provides a permanent joint but it normally affects the metallurgy of the components. It is therefore usually accompanied by post weld heat treatment for most of the critical components. The welding is widely used as a fabrication and repairing process in industries. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, bridges, welded pipes, sealing of nuclear fuel and explosives, etc.

Advantages

- Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
- Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
- Large number of metals and alloys both similar and dissimilar can be joined by welding.
- General welding equipment is not very costly.
- Portable welding equipment's can be easily made available.
- Welding permits considerable freedom in design.
- Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
- Welding can also be mechanized.

Disadvantages

- It results in residual stresses and distortion of the work pieces.
- Welded joint needs stress relieving and heat treatment.
- Welding gives out harmful radiations (light), fumes and spatter.
- Jigs and fixtures may also be needed to hold and position the parts to be welded
- Edges preparation of the welding jobs are required before welding
- Skilled welder is required for production of good welding
- Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

Types of Welding

Welding processes can be broadly classified in two groups:

- fusion welding and
- solid-state welding.

Fusion Welding Processes

Fusion Welding processes use heat to melt the base metals. In fusion welding operations, a filler metal is generally added to the molten pool. Fusion welding processes can further be subdivided into following types:

Arc Welding: Arc welding refers to a group of welding processes in which heating of the metals is accomplished by an electric arc.

Resistance welding: Resistance welding achieves coalescence using heat from electrical resistance to the flow of a current passing between the faying surfaces of two parts held together under pressure.

Oxy-fuel Gas Welding: These joining processes use an oxyfuel gas, such as a mixture of oxygen and acetylene, to produce a hot flame for melting the base metal.

Other welding processes that produce fusion of the metals joined include electron beam welding and laser beam welding.

Solid-State Welding

Solid-state welding refers to joining processes in which coalescence results from application of pressure alone or a combination of heat and pressure. If heat is used, the temperature in the process is below the melting point of the metals being welded. No filler metal is utilized. Some welding processes in this group are:

Diffusion welding: Two surfaces are held together under pressure at an elevated temperature and the parts coalesce by solid-state fusion.

Friction welding: Coalescence is achieved by the heat of friction between two surfaces.

Ultrasonic welding: Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces. The combination of normal and vibratory forces results in shear stresses that remove surface films and achieve atomic bonding of the surfaces.

Types of Welded Joints

Welded joints are primarily of two types:

1. Lap joint or fillet joint, and
2. Butt joint.

Lap Joint

The lap joint or the fillet joint is obtained by overlapping the plates and then welding the edges of the plates. The cross-section of the fillet is approximately triangular. The fillet joints are of three types: - Single transverse fillet, Double transverse fillet and Parallel fillet joints. These are shown in Figure 1.

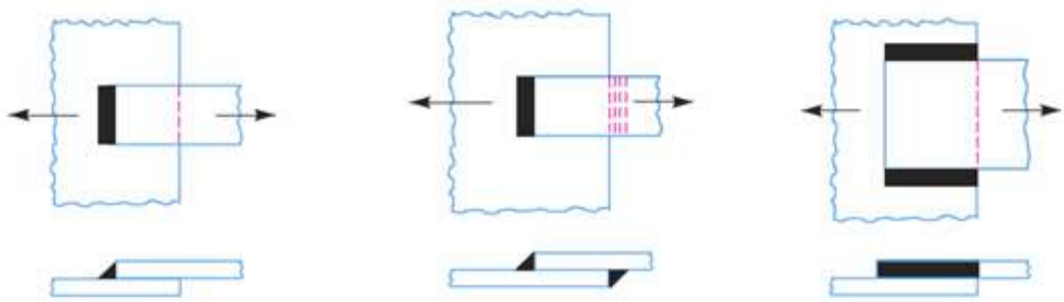


Figure 1 Types of Lap or Fillet Joint

Butt Joint

The butt joint is obtained by placing the plates edge to edge as shown in figure. In butt welds, the plate edges do not require bevelling if the thickness of plate is less than 5 mm. On the other hand, if the plate thickness is 5 mm to 12.5 mm, the edges should be bevelled to V or U-groove on both sides. Figure 2 shows the types of butt joints.

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

Figure 2 Types of Butt Joint

Corner joint, edge joint and T-joint (shown in Figure 3) are some other types of welded joints.

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

Figure 3 Some Other Types of Welded Joints

DESIGN OF WELDED JOINTS

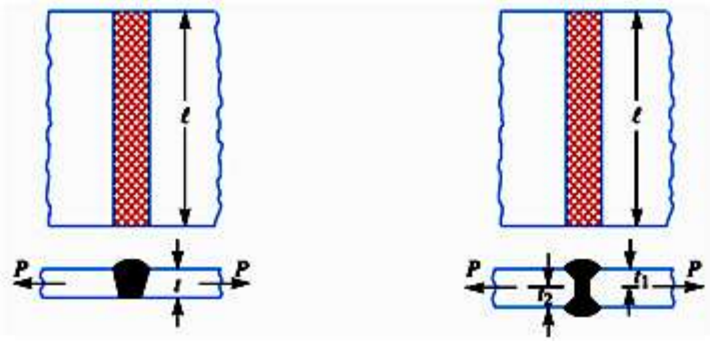
Design of a Butt Joint

The butt joints are designed for tension or compression. Average Tensile Stress in a butt welded joint subjected to tensile load, P is given by, $\sigma_T = \frac{P}{A} = \frac{P}{t.l}$

where, A is throat area, t is throat thickness and l is length of the weld.

σ_t must be ≤ [σ_t] for the joint to be safe.

Similarly Average Compressive Stress in a butt welded joint subjected to compressive load, P is given by, $\sigma_C = \frac{P}{t.l}$, which must be ≤ [σ_C].



i. Single V-Butt Joint ii. Double V-Butt Joint

Figure 4 Butt Joint

For double V-butt joint, throat area is (t_1+t_2) l, where t_1 and t_2 are throat thickness at top and bottom.

Design of a Fillet Joint

Transverse Fillet Weld

Transverse Fillet welds are designed for tensile strength. For strength calculations, the section of fillet is assumed to be a right angled triangle, with hypotenuse making equal angles with the two sides as shown in Figure 5.

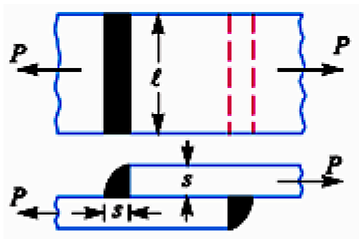


Figure 5 Single & Double Transverse Fillet Weld

Length of each side (AB=BC) is known as size or leg of the weld (s) and the distance of the hypotenuse from the intersection of two legs (BD) is known as throat thickness (t). Minimum area is obtained at the throat. If l is the length of the weld,

Throat area, A = t l = s. sin 45°. l = 0.707 s l

Tensile Stress of single transverse fillet weld subjected to tensile load, P is given by,

$$\sigma_t = \frac{P}{A} = \frac{P}{0.707\ s\ l} \leq [\sigma_t]$$

And that for a double transverse fillet weld is given by,

$$\sigma_t = \frac{P}{2\ A} = \frac{P}{1.414\ s\ l} \leq [\sigma_t]$$

Parallel Fillet Weld

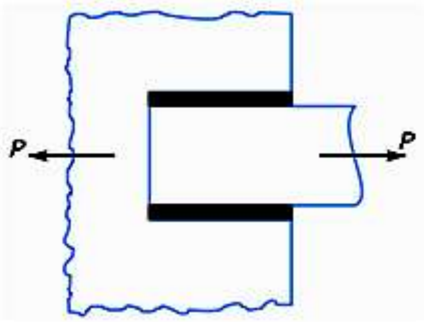


Figure 6 Parallel Fillet Weld

Parallel fillet welds are designed for shear strength. Consider a parallel fillet weld as shown in Figure 6. Throat Area, A = 0.707 s l, where s and l are size and length of the weld. For a parallel fillet weld subjected to tensile load, P, shear stress is given by,

$$\tau = \frac{P}{2\ A} = \frac{P}{1.414\ s\ l} \leq [\tau]$$

Combination of Transverse and Parallel Fillet Welds

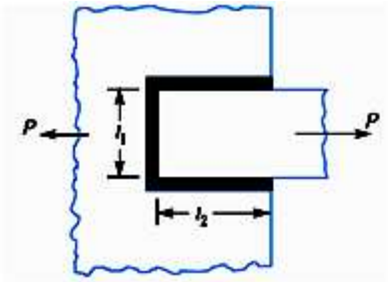


Figure 7 Combination of Transverse & Parallel Fillet Weld

If a tensile load, P is applied on a combination of transverse and parallel fillet weld, shear stress will develop in the parallel fillet welds and tensile stress will develop in the transverse fillet weld such that the maximum load that the weld can withstand is given by,

$$P_{max} = 1.414\ s\ l_1\ [\sigma_t] + 1.414\ s\ l_2\ [t]$$

$$= 1.414\, s\, (l_1\, [\sigma_t] + l_2\, [t])$$

l_1 and l_2 are weld lengths on two sides, as shown in Figure 7.While designing any fillet weld, 11.5 mm length must be left on each side of the weld to allow for the start and stop of the bead.

11.3 Unsymmetrical Welded Sections

For unsymmetrical welded sections subjected to tensile loads as shown in Figure 8, the length of welds should be so proportioned that the resisting moment of the welds about the gravity axis is zero.

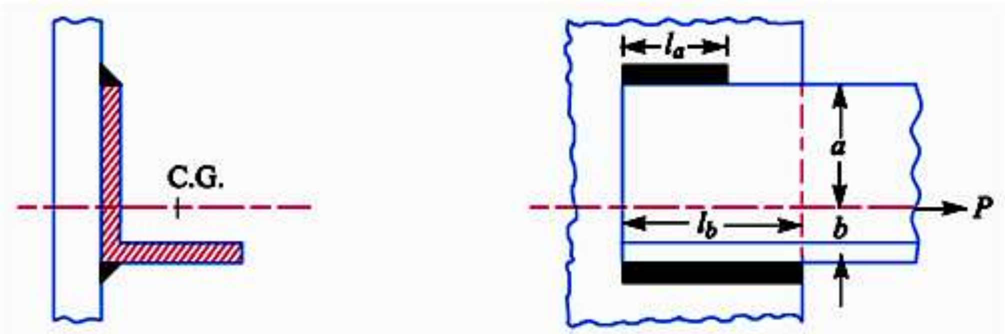


Figure 8 Axially Loaded Unsymmetrical Welded Sections

Let.

l_a, l_b = Length of welds on two sides

a , b = Distance of welds from gravity axis

l = Total length of weld = $l_a + l_b$

P = Axial load,

f = Resistance offered by the weld per unit length.

Moment of resistance offered by weld on side A about gravity axis = $l_a \times f \times a$

Moment of resistance offered by weld on side B about gravity axis = $l_b \times f \times b$

For the moments about the gravity axis to be zero,

$$l_a \times f \times a = l_b \times f \times b \Rightarrow l_a \times a = l_b \times b$$

Also, $l = l_a + l_b$

Therefore, $l_a = \dfrac{l\, b}{a + b}$ and $l_b = \dfrac{l\, a}{a + b}$

Eccentrically Loaded Welded Joints

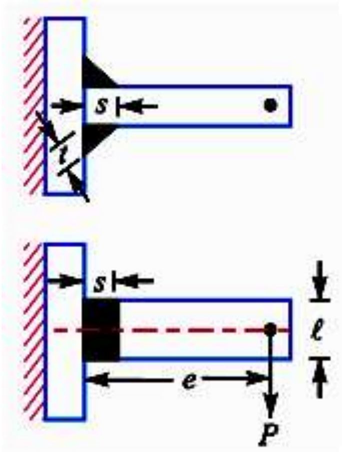


Figure 9 Bending Stress due to Eccentricity

In many cases the welded joints are eccentrically loaded. Different stresses may get induced depending upon the type of joint and loading. If the stresses are of same nature, those may be vectorially added but for those of different nature, resultant maximum tensile and shear stresses may be calculated. Depending upon the type of joint, eccentricity may lead to bending stress or torsional shear stress in the joint in addition to the direct shear stress induced by applied load.

Eccentricity leading to Bending Stress

Consider a T-joint subjected to loading as shown in figure 9. Let s and l be the size and length of the weld and t be the throat thickness.

Throat area = A = 2 t l

This applied load may be considered as a load P directly acting on the joint through the CG and a bending moment of magnitude P.e acting on the joint. 1st one will lead to direct shear stress and the 2nd will lead to a bending stress.

Direct Shear Stress, $\sigma_T = \frac{P}{A} = \frac{P}{t.l}$ and $\sigma_B = \frac{M.y}{I}$ Bending Stress,

Where, y = distance of the point on the weld from the neutral axis

I = Moment of inertia of the weld section

Maximum tensile and shear stress may be calculated as:

$$\sigma_{t_{max.}} = \left(\frac{\sigma_b}{2}\right)^2 + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + (\tau)^2}$$ and $$\tau_{max.} = \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + (\tau)^2}$$

Eccentricity Leading to Torsional Shear Stress

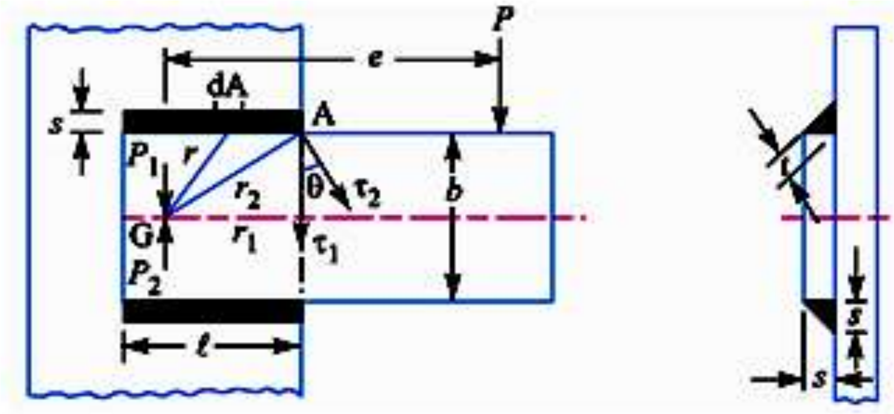


Figure 10 Shear Stress due to Eccentricity

Let us consider a double parallel fillet weld subjected to an eccentric load P acting at a distance e from the CG of the welds as shown in Figure 10.

Eccentric force P may be considered as a force P acting on the CG of the joint and a torque equivalent to P.e acting on the joint. The force P through the CG leads to direct shear stress, called primary shear stress and is assumed to be uniformly distributed over the throat area of all welds. The torque P.e causes torsional shear stress called secondary shear stress.

Primary Shear Stress, $\sigma_T = \frac{P}{A} = \frac{P}{t.l}$ and Secondary Shear Stress,

$$\tau_2 = \frac{M.r}{J} = \frac{P.e}{J}.r$$

where r = distance of the point on the weld from the CG

J = Polar moment of inertia of the weld section

$$[\bar{X} = \frac{2XlX\frac{l}{2}+bX0}{2Xl+b} = \frac{l^2}{2l+b} \text{ and } \bar{y} = \frac{b}{2}]$$

$$J = I_{XX} + I_{YY}$$

$$I_{XX} = 2X\frac{lXb^2}{4} + \frac{b^3}{12} = \frac{b^2 l}{2} + \frac{b^3}{12}$$

$$I_{YY} = 2X\left[\frac{l^3}{12} + l\,X\left(\frac{l}{2} - \bar{x}\right)^2\right] + b.\bar{x}^2$$

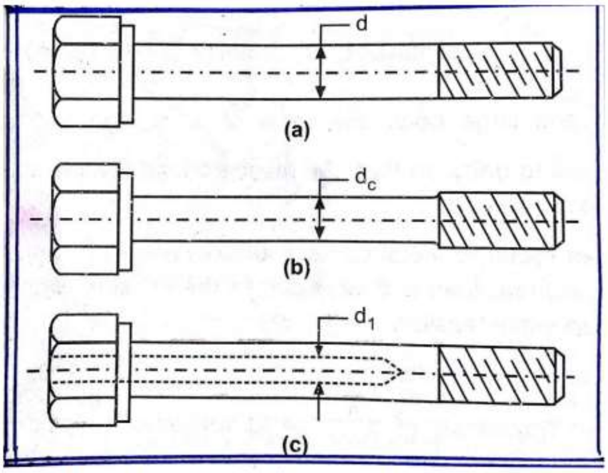
r is calculated from the geometry for the farthest point of the weld from the CG.

Question:

Describe ‘bolt of uniform strength’ with neat sketch

Answer:

When an ordinary bolt of uniform diameter is subjected to shock load stress concentration across at the weakest part of the bolt i.e. threaded portion (as shown in figure a), it means that greater portion of energy will be absorbed at the region of threaded part and it may cause the failure of threaded portion

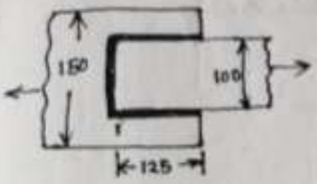


There are two methods to achieve bolts of uniform strength i. Turn down shank diameter of bolt equal or lesser than the core diameter of thread (dc) as shown in figure (b) and it gives bolt of uniform strength. ii. In this method an axial hole is drilled to the head as far as threaded portion such that area of shank become equal to the root area of thread as shown in figure (c). Where,d_1= Diameter of hole to be drill do= Nominal diameter dc= Core diameter

$$\frac{\pi}{4} \times d_1^{\,2} = \frac{\pi}{4} \times (d_o^{\,2} - d_c^{\,2})$$

$$d_1 = \sqrt{(d_o^{\,2} - d_c^{\,2})}$$

Pbm1. A fillet welded joint connecting 10 mm thick plate as shown in figure. Calculate the maximum load to which the joint can be subjected. Weld size = 8 mm, working stress in the weld and plate = 110 MPa.



weld size = 8 mm

Working stress = 110 N/mm^2

Length of the weld (l) = 2×125 + 100 + 2×8 = 366 mm.

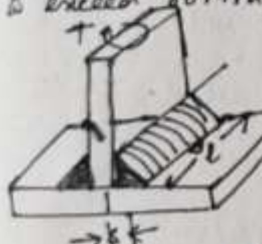
Shear strength of the joint = $\frac{\tau \cdot s \cdot l}{\sqrt{2}} = \frac{110 \times 8 \times 366}{\sqrt{2}}$

= 227750 N = 227.75 kN

Also the strength of the smaller plate = 110×100×10 = 110000 N = 110 kN

∴ Maximum load to which the joint can be subjected is the lesser value i.e. 110 kN.

2. A plate one meter long 60 mm thick is welded to another plate at right angles to each other by 15 m fillet weld. Find the maximum torque that the welded joint can sustain if the permissible shear stress intensity in the weld material is not to exceed 80 MPa.



Let T = maximum torque that the weld joint can sustain.

τ_{max} = Maximum shear stress = 80 MPa.

J = polar moment of inertia of the weld section

$= 2 \times \frac{t \times l^3}{12} = \frac{t \times l^3}{6}$

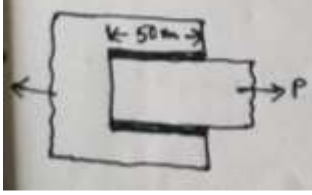
Shearing stress, $\tau = \frac{T \times l/2}{t \times \frac{l^3}{6}} = \frac{3T}{t \times l^2} = \frac{3T}{0.707 \times s \times l^2}$

So, $80 = \frac{3T}{0.707 \times 15 \times (1000)^2}$

or $T = \frac{80 \times 0.707 \times 15 \times 10^6}{3} = 282.8 \times 10^6$ Nmm

= 282.8 kN-m.

3. A structural steel plate 75 mm wide × 10 mm thick is welded to a plate by means of double parallel fillet welded joint as shown in figure. The plates are subjected to a static load of 55 kN. Find the stress produced in the weld metal and state the nature of the stress.



$P = 2 \times 0.707 \times s \times l \times \tau_s$

$55 \times 10^3 = 2 \times 0.707 \times 10 \times 50 \times \tau_s$

$\tau_s = \frac{55 \times 10^3}{1.414 \times 500} = 77.8$ N/mm^2 (Shear stress)

4. A plate 100 mm wide and 12.5 mm thick is to be welded to another plate by means of a single transverse and double parallel fillet welds. Determine the length of weld run in each case if the joint is subjected to varying loads. The recommended design stress in tension is not to exceed 70 N/mm² and in shear 56 N/mm² for static loading

Permissible tensile stress $(\sigma_t) = \frac{70}{1.5} = 46.7\ N/mm^2$

Permissible shear stress $(\tau_s) = \frac{56}{2.7} = 20.74\ N/mm^2$

max^m load, $P = 100 \times 12.5 \times 70 = 87500\ N$.

Effective length for single transverse load $= 100 - 12.5 = 87.5$ mm

$$P = P_{transverse} + P_{parallel}$$

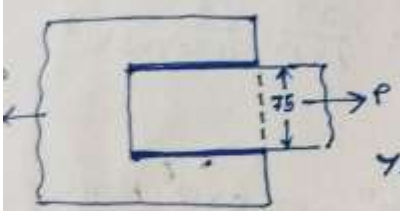
$$= 0.707 \times 87.5 \times 12.5 \times 46.7 + 2 \times 0.707 \times 12.5 \times l_2 \times 20.74$$

$$87500 = 36112.23 + 366.58\, l_2$$

$$\therefore\ l_2 = \frac{87500 - 36112.23}{366.58} = 140\ mm$$

$\therefore$ Effective length of parallel weld for each leg $= 140 + 12.5 = 152.5$ mm

5. A plate 75 mm wide × 12.5 mm thick is joined with another plate by a single transverse weld and a double parallel fillet weld as shown in figure. The maximum tensile and shear stresses are 70 N/mm² and 56 N/mm² respectively. Find the length of each parallel fillet weld, if the joint is subjected to static loading



The effective length of weld (l_1) for the transverse weld $= l - 12.5 = 75 - 12.5 = 62.5$ mm

Let, l_2 = length of each parallel fillet.

The maximum load, plate can carry $= 75 \times 12.5 \times 70 = 65625\ N$

Load carried by single transverse weld, $P_1 = 0.707 \times s \times l_1 \times \sigma_t$

$$P_1 = 0.707 \times 12.5 \times 62.5 \times 70 = 38664\ N$$

Load carried by double parallel fillet weld $P_2 = 2 \times 0.707 \times s \times l_2 \times \tau_s$

$$P_2 = 1.414 \times 12.5 \times l_2 \times 56 = 990.\,l_2\ N$$

$\therefore$ Load carried by the joint, $P = P_1 + P_2$

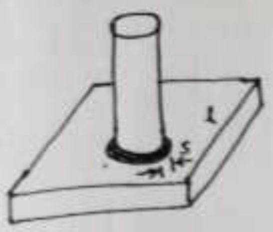
$$65625 = 38664 + 990\, l_2$$

$$l_2 = 27.2\ mm.$$

Adding 12.5 mm for starting and stopping of weld run, we get

$$l_2 = 27.2 + 12.5 = 39.7 \simeq 40\ mm.$$

6. A 50 mm diameter solid shaft is welded to a flat plate by 10mm fillet weld as shown in figure. Find the maximum torque that the welded joint can sustain if the maximum shear stress intensity in the weld material is not to exceed $80\ N/mm^2$



By torsion formula $\frac{T}{J} = \frac{\tau}{r}$

$$\tau = \frac{T \cdot r}{J} = \frac{T \times d/2}{\frac{\pi}{4} t d^3} = T \times \frac{d}{2} \times \frac{4}{\pi t d^3}$$

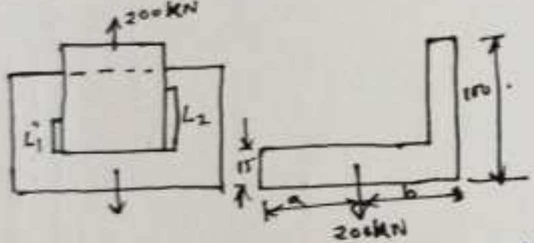
$$\tau = \frac{2T}{\pi t d^2} = \frac{2T}{\pi \times 0.707 S \cdot d^2}$$

$$80 = \frac{2T}{\pi \times 0.707 \times 10 \times (50)^2}$$

$$T = 80 \times \pi \times 0.707 \times 5 \times (50)^2$$

$$T = 2.22 \times 10^6\ N\text{-}mm.$$

7. A mild steel angle 150×100×15 mm is to be welded to a mild steel plate by fillet welds along the edge of 150 mm leg. A tensile load of 200 kN acts through the gravity axis of the angle. Determine the weld length if the centre of gravity of angle is a distance of 50 mm from end be as shown in figure. The allowable shear stress in weld material is $70\ N/mm^2$.



Given $b = 50$ mm

$\therefore a = 150 - 50 = 100$ mm

Total length of the weld required

$$l = L_1 + L_2 = \frac{P}{0.707 \times 15 \times 70}$$

$$l = \frac{200 \times 10^3}{0.707 \times 15 \times 70} = 270\ mm$$

Individual welded lengths are

$$L_1 = 270 \times \frac{b}{a+b} = 270 \times \frac{50}{150} = 90\ mm$$

$$L_2 = 270 \times \frac{a}{a+b} = 270 \times \frac{100}{150} = 180\ mm$$

Allowing for weld run effective $L_1 = 90 + 15 = 105$ mm

effective $L_2 = 180 + 15 = 195$ mm