Module
10
Design of Permanent Joints

Lesson
4
Design of Welded Joints

Instructional Objectives:

At the end of this lesson, the students should be able to understand:

- Possible failure mechanisms in welded joints.
- How to design various kinds of welding joints.

1.Design of a butt joint:

The main failure mechanism of welded butt joint is tensile failure. Therefore the strength of a butt joint is

$$P = s_T lt$$

where s_T =allowable tensile strength of the weld material.

t =thickness of the weld

l =length of the weld.

For a square butt joint t is equal to the thickness of the plates. In general, this need not be so (see figure 1).

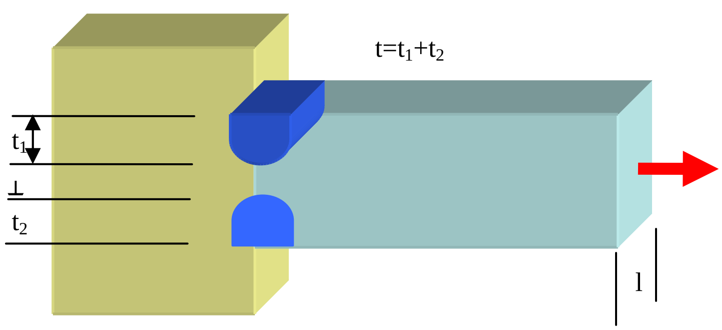

Figure 10.4.1: Design of a butt joint

2.Design of transverse fillet joint:

Consider a single transverse joint as shown in figure 10.4.2. The general stress distribution in the weld metal is very complicated. In design, a simple procedure is used assuming that entire load *P* acts as shear force on the throat area, which is the smallest area of the cross section in a fillet weld. If the fillet weld has equal base and height, (*h*, say), then the cross section of the throat is easily seen to be $\frac{hl}{\sqrt{2}}$. With the above consideration the permissible load carried by a transverse fillet weld is

$$P = s_s A_{throat}$$

where s_s -allowable shear stress

A_{throat} =throat area.

For a double transverse fillet joint the allowable load is twice that of the single fillet joint.

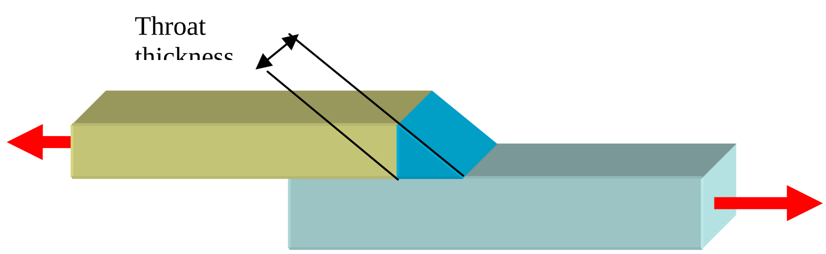

Figure 10.4.2: Design of a single transverse fillet

3.Design of parallel fillet joint:

Consider a parallel fillet weld as shown in figure 10.4.3. Each weld carries a load $P/2$. It is easy to see from the strength of material approach that the maximum shear occurs along the throat area (try to prove it). The allowable load carried by each of the joint is $s_s A_t$ where the throat area $A_t = \frac{lh}{\sqrt{2}}$. The total allowable load is

$$P = 2 s_s A_t.$$

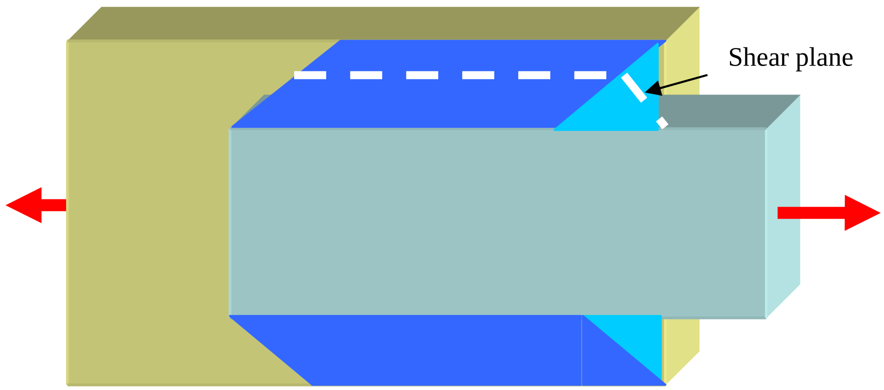

Figure 3: Design of a parallel fillet joint

In designing a weld joint the design variables are h and l. They can be selected based on the above design criteria. When a combination of transverse and parallel fillet joint is required (see figure-10.4.4) the allowable load is

$$P = 2s_s A_t + s_s A_t'$$

where A_t =throat area along the longitudinal direction.

A_t' =throat area along the transverse direction.

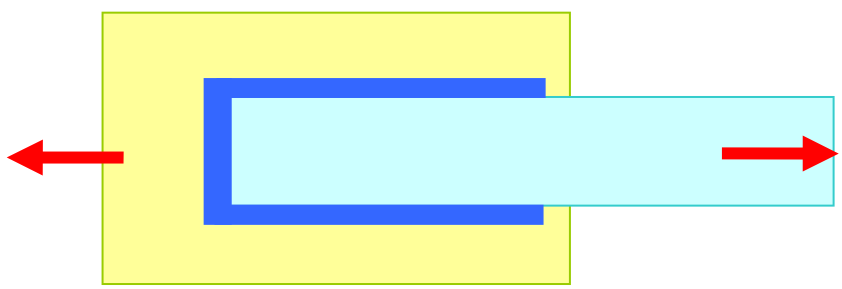

Figure 10.4.4: Design of combined transverse and parallel fillet joint

4.Design of circular fillet weld subjected to torsion:

Consider a circular shaft connected to a plate by means of a fillet joint as shown in figure-10.4.5. If the shaft is subjected to a torque, shear stress develops in the weld in a similar way as in parallel fillet joint. Assuming that the weld thickness is very small compared to the diameter of the shaft, the maximum shear stress occurs in the throat area. Thus, for a given torque the maximum shear stress in the weld is

$$\tau_{\max} = \frac{T(\frac{d}{2} + t_{throat})}{I_p}$$

where T =torque applied.

d =outer diameter of the shaft

t_{throat} = throat thickness

I_p =polar moment of area of the throat section.

$$= \frac{\pi}{32}[(d + 2t_{throat})^4 - d^4]$$

When $t_{throat} << d$, $\tau_{\max} = \dfrac{T\frac{d}{2}}{\frac{\pi}{4} t_{throat} d^3} = \dfrac{2T}{\pi t_{throat} d^2}$

The throat dimension and hence weld dimension can be selected from the equation

$$\frac{2T}{\pi t_{throat} d^2} = s_s$$

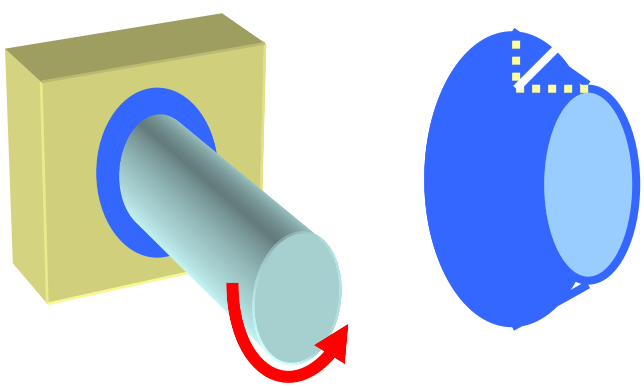

Figure 10.4.5: Design of a fillet weld for torsion

5.Design stresses of welds:

Determination of stresses in a welded joint is difficult because of

- inhomogeneity of the weld joint metals
- thermal stresses in the welds
- changes of physical properties due to high rate of cooling etc.

The stresses in welded joints for joining ferrous material with MS electrode are tabulated below.

Table 1.

Type of load		Bare electrodes (Static load)	Covered electrodes (Static load)
Butt weld	Tension (MPa)	91.5	112.5
	Compression (MPa)	105.4	126.5
	Shear (MPa)	56.2	70.3
Fillet weld	Shear (MPa)	79.5	98.5

Welded joints are also subjected to eccentric loading as well as variable loading. These topics will be treated separately in later lessons.

Review questions and answers:

Q. 1. A plate 50 mm wide and 12.5 mm thick is to be welded to another plate by means of parallel fillet welds. The plates are subjected to a load of 50 kN. Find the length of the weld. Assume allowable shear strength to be 56 MPa.

Ans. In a parallel fillet welding two lines of welding are to be provided. Each line shares a load of $P = \frac{50}{2}\,\mathrm{kN} = 25\,\mathrm{kN}$. Maximum shear stress in the parallel fillet weld is $\frac{P}{lt}$, where t=throat length=$\frac{12.5}{\sqrt{2}}\,\mathrm{mm}$. Since $\frac{P}{lt} \le s_s = 56\times10^6$. Hence the minimum length of the weld is $\frac{25\times10^3\times\sqrt{2}}{56\times12.5\times10^3}$=50.5 mm. However some extra length of the weld is to be provided as allowance for starting or stopping of the bead. An usual allowance of 12.5 mm is kept. (Note that the allowance has no connection with the plate thickness)

Q. 2. Two plates 200 mm wide and 10 mm thick are to be welded by means of transverse welds at the ends. If the plates are subjected to a load of 70 kN, find the size of the weld assuming the allowable tensile stress 70 MPa.

Ans. According to the design principle of fillet (transverse) joint the weld is designed assuming maximum shear stress occurs along the throat area. Since tensile strength is specified the shear strength may be calculated as half of tensile strength, i.e., $s_s = 35\,\mathrm{MPa}$. Assuming there are two welds, each weld carries a load of 35 kN and the size of the weld is calculated from

$$35\times10^3 = l\times(\frac{10\times10^{-3}}{\sqrt{2}})\times35\times10^6$$

or $l = 141.42$ mm.

Adding an allowance of 12.5 mm for stopping and starting of the bead, the length of the weld should be 154 mm.

Q. 3. A 50 mm diameter solid shaft is to be welded to a flat plate and is required to carry a torque of 1500 Nm. If fillet joint is used foe welding what will be the minimum size of the weld when working shear stress is 56 MPa.

Ans. According to the procedure for calculating strength in the weld joint,

$$\frac{2T}{\pi t_{throat} d^2} = s_s\ ,$$

where the symbols have usual significance. For given data, the throat thickness is 6.8 mm. Assuming equal base and height of the fillet the minimum size is 9.6 mm. Therefore a fillet weld of size 10 mm will have to be used.