

Lecture 25

DESIGN OF WELDED JOINTS IV

This chapter describes basic principle and methodology of weld joints design for static and dynamic loading to develop groove and fillet weld joints besides the information required for developing said designs.

Keywords: Design of weld joint, static and dynamic loading, load resisting cross sectional area, allowable stress, throat thickness, leg length, class of weld, stress range

25.1 Design of weld joint for static loading

As mentioned in section 24.6 for designing of a weld joint, it is required to determine the throat thickness and length of the weld. Measurement of throat thickness is easier for groove butt weld joint than fillet weld joint because root is not accessible in case of fillet weld. Throat thickness of fillet welds is obtained indirectly (mathematically) from leg length: $2^{1/2} \times \text{leg length}$. Leg length of fillet weld can be measured directly using metrological instruments. Further, for a particular plate thickness, minimum throat thickness values have been fixed by American welding society in view of cracking tendency of fillet weld due to tensile residual stresses in weld joints. Small fillet weld developed on thick plate exhibits cracking tendency appreciably due to inability of small fillet to sustain heavy residual tensile stresses which develop in small fillet weld. It is important to note that depending upon the expected service load, a weld joint can be designed by considering tensile, compressive and shear stresses.

A weldment joint design program starts with recognition of a need to design expected to be induced during the service.(new design or failure of existing design) a weld joints followed by main steps of weldment design procedure including:

1. Determination or estimation of expected service load on the weld joint
2. Collecting information about working condition and type of stresses
3. Based on the requirement identify design criteria (ultimate strength, yield strength, modulus of elasticity)
4. Using suitable design formula calculate length of weld or throat thickness as per need or data given
5. Determine length and throat thickness required to take up given load (tensile, shear bending load etc.) during service

Methodology

- Depending upon the service requirements, select the type of weld joint and edge preparation for design
- Establish the maximum load for which a weld joint is to be designed
- For a given thickness of the plate usually throat thickness is generally fixed. For full penetration fillet weld, throat thickness is about 0.707 time of leg length of the weld and that of groove weld generally is equal to thickness of thinner plate (in case of dissimilar thickness weld) or thickness of any plate (Fig. 25.1).
- Using suitable factor of safety and suitable design criteria determine the allowable stress for the weld joint.
- Subsequently calculate length of the weld using external maximum load, allowable stress, throat thickness and allowable stress.

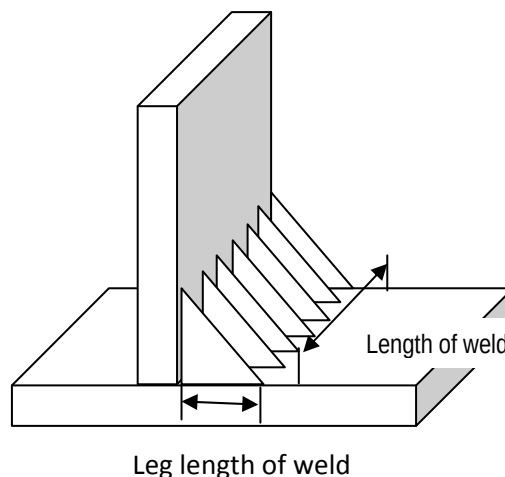
25.2 Design of fillet welds

- (a) Stress on fillet weld joint can be obtained by using following relationship:

Load/weld throat cross sectional area

Load/(throat thickness X length of weld joint X number of welds)

Load/0.707 X leg length of the weld X length of the weld X number of welds



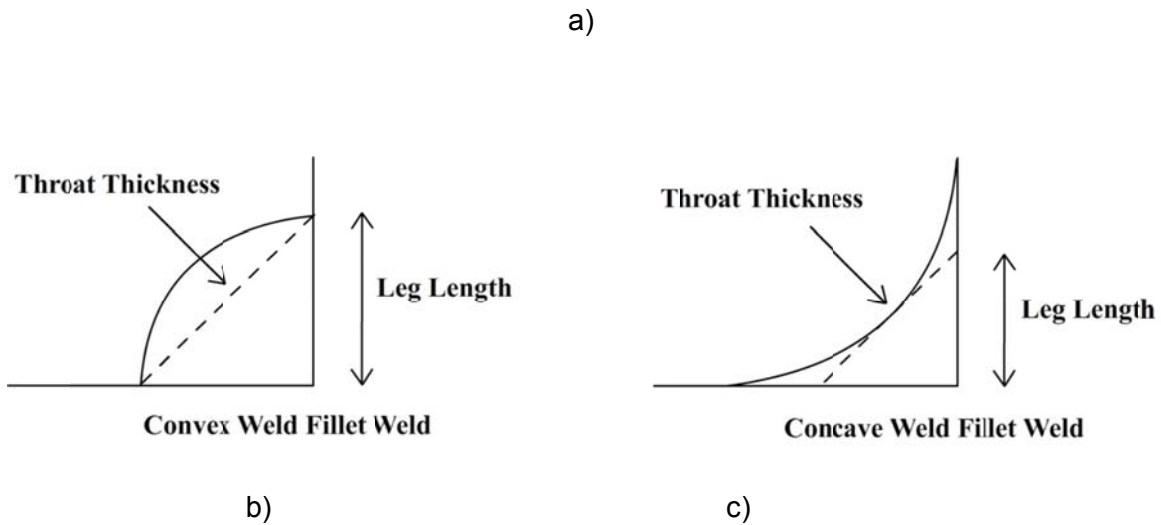


Fig. 25.1 Schematic diagram showing a) leg length and length of weld, b) throat thickness for convex and c) throat thickness for concave fillet welds

25.3 Design of butt weld joint

Stress on butt weld joint between equal thickness plates (Fig. 25.2) is obtained using following relationship: Stress: $\text{Load} / \text{weld throat cross sectional area} = \text{Load} / (\text{throat thickness} \times \text{length of weld joint} \times \text{number of welds}) = \text{Load} / (\text{thickness of any plate} \times \text{length of the weld} \times \text{number of welds})$

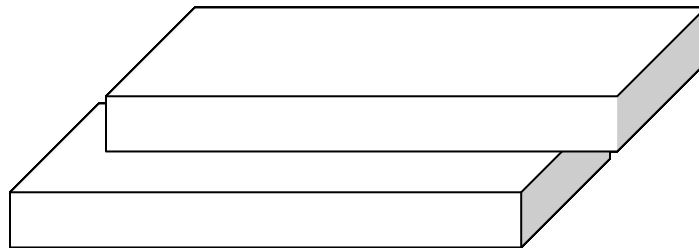


Fig. 25.2 Schematic diagram of butt weld between plates of equal thickness

Stress (σ) on the butt weld joint between plates of different thicknesses (T_1 and T_2) subjected to external load (P) experiences eccentricity (e) owing to difference in thickness of plates and T_1

thickness of thinner plate of the joint (Fig. 25.3). Even axial loading due to eccentricity causes the bending stress in addition to axial stress. Therefore, stress on the weld joint becomes sum of axial as well as bending stress and can be calculated as under.

Stress in weld = Axial Stress + Bending Stress

$$\sigma_{total} = \frac{P}{T_1} + \frac{P \cdot e \cdot \frac{1}{2} \cdot T_1}{\frac{T_1^3}{12}}$$

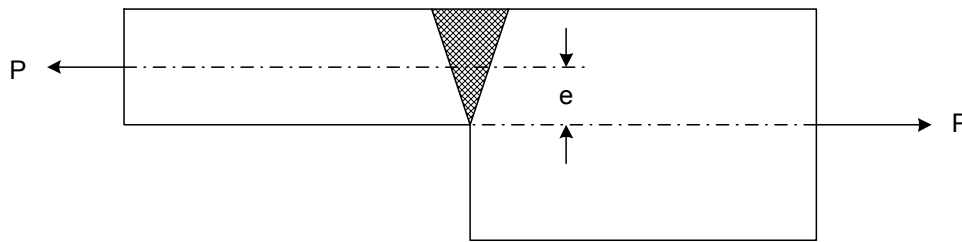


Fig. 25.3 Schematic diagram of butt weld when both the plates are of different thickness

25.4 Design of weld joints for fatigue loading

The approach for designing weld joints for fatigue load conditions is different from that of static loading primarily due to high tendency of the fracture by crack nucleation and growth phenomenon. A weld joint can be categorized in a specific class depending upon the severity of stress concentration, weld penetration (full or partial penetration weld), location of weld, type of weld and weld constraint. The class of a weld joint to be designed for fatigue loading is used to identify allowable stress range for a given life of weld joint (number of fatigue load cycles) from stress range vs. number of load cycle curves developed for different loading conditions and metal system (Fig. 25.4). Thus, allowable stress range obtained on the basis of the class of the weld and fatigue life of weld (for which it is to be designed) is used to determine the weld-throat-load-resisting cross-sectional area (throat thickness, length of weld and number of weld).

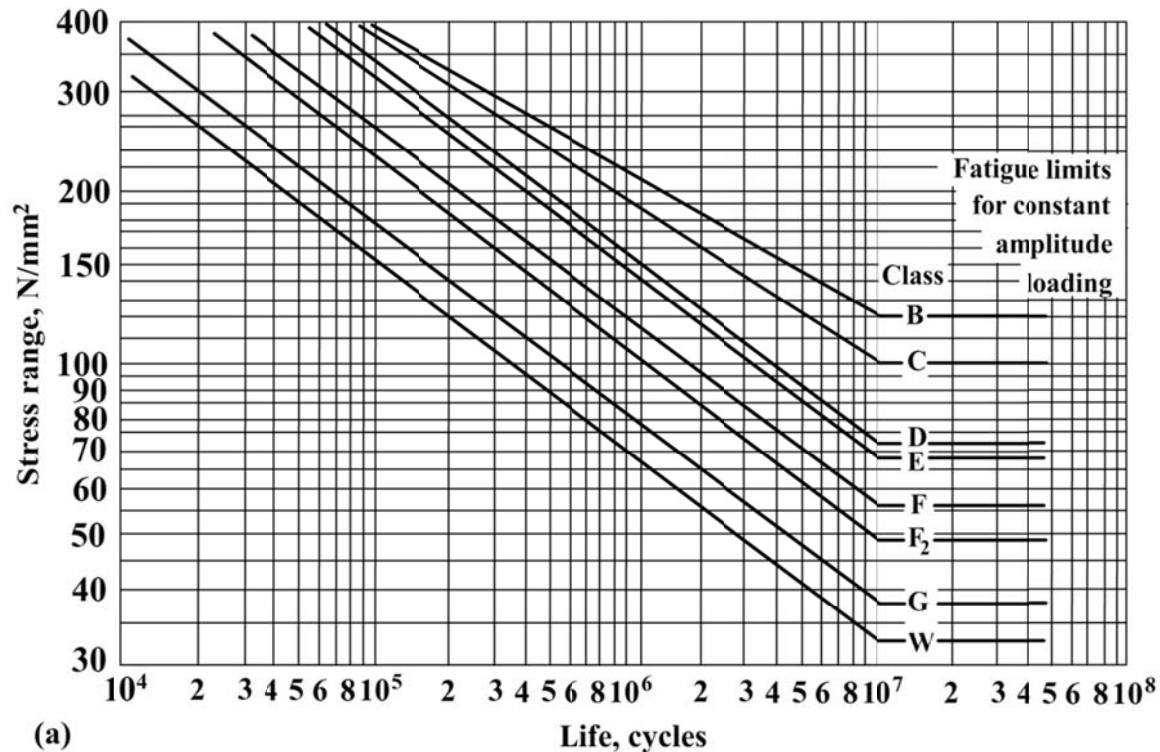
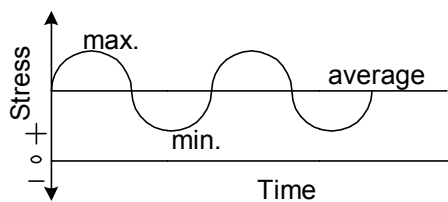


Fig. 25.4 S-N curves for different classes of weld joints (Madox, S K, 1991)

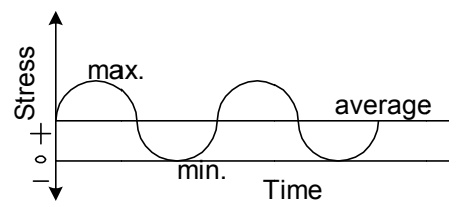
Procedure of weld joint design for fatigue loading

Weld joints for fatigue loading condition are designed using following steps:

- Identify the class of the weld joint based on severity of loading, type of weld, penetration and criticality of the joint for the success of the assembly
- For identified class of the weld joint, obtain a value of the allowable stress range using fatigue life (number of cycles) for which it is to be designed.
- The allowable stress range and service loading condition (maximum and minimum load) are used to determine load resisting cross sectional area of the weld joint (Fig. 25.5)



a) Tension-Tension



b) 0-Tension

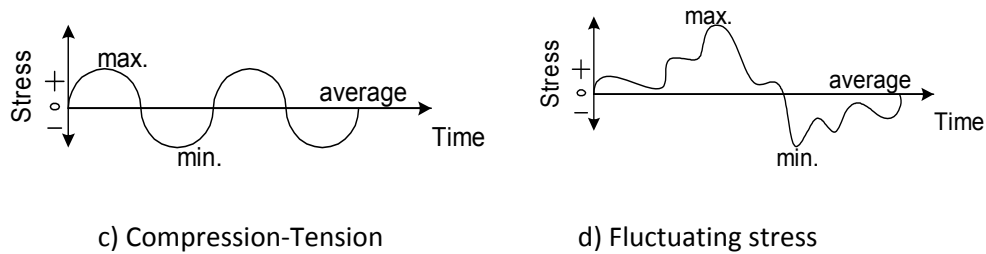


Fig. 25.5 Common fatigue load patterns

- For given set of loading condition and identified class of the weld joint various details like throat thickness, length of weld joint and number of welds can be obtained from calculated load resisting cross sectional area desired.
- Generally, the maximum length of the weld becomes same as the length of the plate to be welded and maximum number of welds for butt welding is one and that for fillet weld can be two for uninterrupted welds. This suggests that primarily throat thickness of the weld is identified if length and number of weld are fixed else any combination of the weld parameters such as throat thickness, length of weld and number of welds can be obtained in such a way that their product is equal to the required load resisting cross sectional area.
- Strength of weld metal doesn't play any big role on fatigue performance of the weld joints as under severe stress conditions (which generally exist in weld joint owing to the presence of notches and discontinuities) fatigue strength and life are marginally affected by strength of weld metal.

25.4.1 Information required for designing

- The fatigue life (number of load cycles) for which a weld is to be designed e.g. 2×10^6 cycles
- Class of the weld joint based on type and penetration and other conditions (Fig. 6)
- Allowable stress range on the basis of class of weld and life required from the figure
- Value of the maximum and minimum service load expected on weld joint

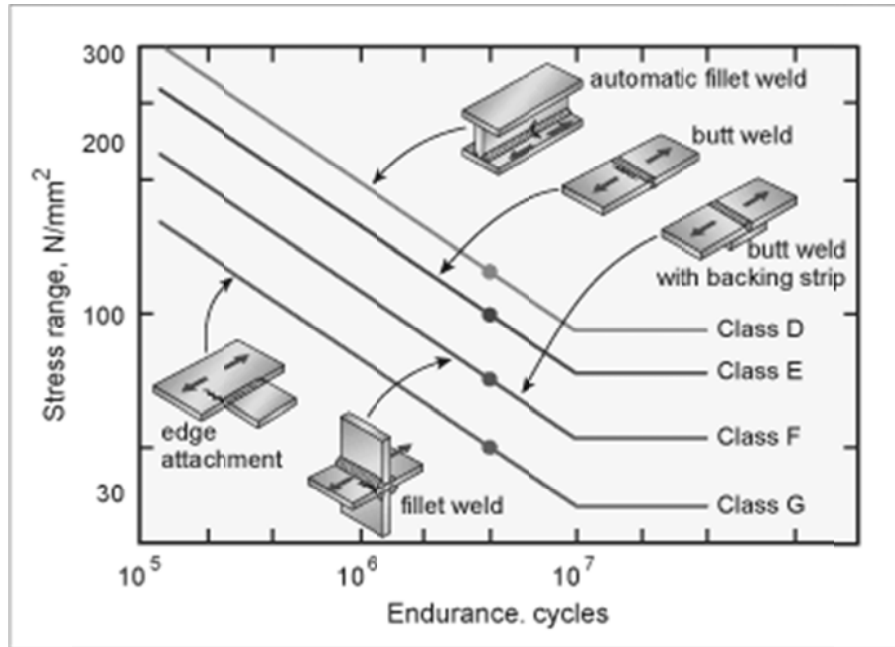


Fig. 25.6 Schematics of weld joints of different classes

Example

A T joint of steel plates is subjected to 350 kN load is developed using intermitted 4 double fillet welds of length each of 40 mm at an interval of 100 mm. Allowable shear strength of the weld metal is 100 MPa. Determine the leg length of the weld.



Solution

Weld load resisting cross sectional area: throat thickness X length of each weld X No. of weld

: weld throat thickness X 40 X 4 X 2

: weld throat thickness X 320

Load carrying capability: load resisting cross sectional area X allowable shear stress

350,000 : weld throat thickness X 320 X 100

Weld throat thickness: $350000/320 \times 100$

Weld throat thickness: 10.93 mm

Leg length of weld: weld throat thickness X $(2)^{1/2}$

Leg length of weld : $10.92 \times 1.414 = 15.45$ mm

Example

A full penetration butt weld joint made of two steel plates each of 10 mm X 100 mm X 300 mm is subjected load fluctuation from 150 kN to 350 kN load. Determine if weld is safe for 10^6 or 10^5 load cycle.

Solution

Assuming class of the weld for given service condition is E

Load resisting cross sectional area of weld: length X width: $10 \times 100 = 1000$ mm²

Assuming throat thickness of weld is equal to min. thickness of plate

Max stress: $350000/1000$: 350 MPa

Min. stress: $150000/1000$: 150 MPa

Stress range: 200 MPa

The allowable stress range for 10^6 and 10^5 load cycle for E class is obtained from standard table/plots: 180 and 260 MPa

References and books for further reading

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