

FATIGUE STRENGTH OF LONGITUDINAL FILLET WELDED ATTACHMENTS AND JOINTS IN STEELS UNDER AXIAL LOADING

1. NOTATION

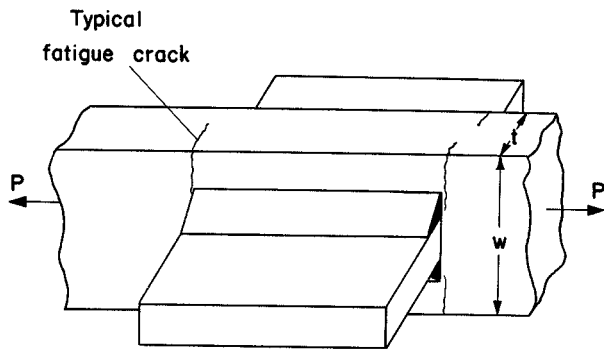
a	throat depth (see Sketch 2.5)	m	in
d	distance of weld end from end of loaded plates	m	in
E	modulus of elasticity of plate material	N/m ²	lbf/in ²
l	length of weld run of loaded plate	m	in
N	endurance		
P	load applied to joint	N	lbf
S_a	nominal alternating stress (half range) in loaded plate	N/m ²	lbf/in ²
s	weld leg length (see Sketch 2.5)	m	in
t	thickness of loaded plate	m	in
w	width of loaded plate	m	in

Both SI and British units are quoted.

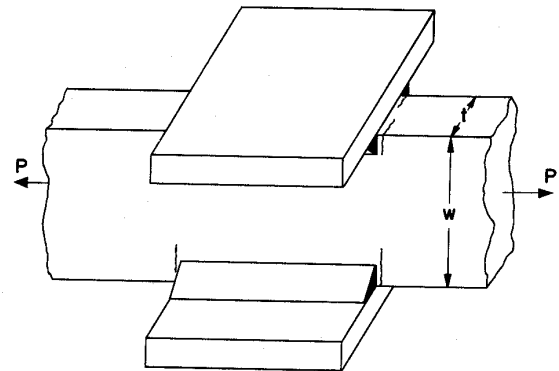
2. NOTES

This Item presents data on the fatigue strength of longitudinal fillet welded attachments and joints between steel members of the types shown in Sketch 2.1 to 2.4 tested in the *as-welded* condition. The data are obtained from specimens welded in the laboratory. The range of sizes of the test specimens is quoted on the relevant figure.

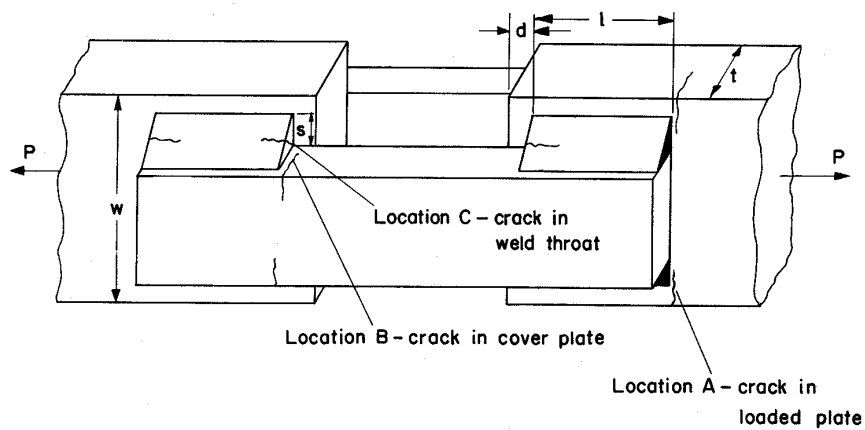
Provided that the welds are sound and free from major defects, the fatigue strength of longitudinal fillet welds in the untreated and unmachined condition is independent of the properties of the plate and weld materials (except in the low cycle fatigue region, that is, when $2S_a$ is greater than about 85 per cent of the material tensile strength, at which the endurance is about 4×10^3 cycles). The fatigue strength is also independent of the applied mean stress. This is because as-welded longitudinal joints contain a system of highly localised residual stresses in the direction of loading which result from the internal constraints applied during cooling of the weld, and which are of the order of the material yield strength. Hence, any applied loading will cause local yielding in the region of the end of the weld run during the first few load cycles. The actual stress experienced in the critical region will thereafter cycle between the yield strength and the yield strength less the applied stress range, irrespective of applied mean stress, except in cases of high compressive mean stress.



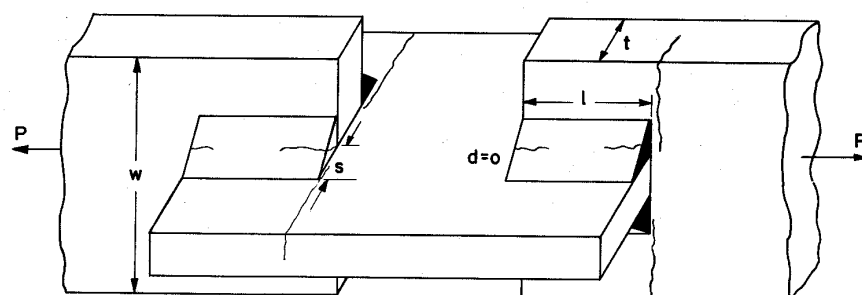
Sketch 2.1 Non-load-carrying joint
(stiffener type)



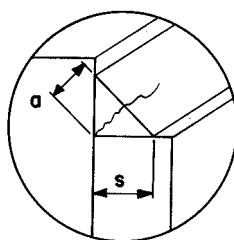
Sketch 2.2 Non-load-carrying joint
(flange type)



Sketch 2.3 Load-carrying joint
(double strap type)



Sketch 2.4 Load-carrying joint
(egg-box type)



Sketch 2.5 Illustrating the assumed throat
depth of a fillet weld and showing
a type C failure

Provided the weld run is continuous and without severe ripples or defects, all fatigue failures start at one or both ends of the weld run. Two modes of failure can be distinguished. The fatigue crack may be initiated at a small defect in the transition region between the plate and the weld bead, and subsequently propagate transversely through the plate. Alternatively, a crack in the weld throat may begin at the end of the weld in the weld bead and propagate to cause failure along the weld bead or turn to run transversely through the loaded plates. The mode of failure is influenced by the throat area of the weld bead relative to the plate sizes and by the length of the weld run.

Data for non-load-carrying stiffener type attachments are given in Figure 1. These data are for a wide range of steels and a wide range of applied stress conditions. Figure 2 shows data for non-load-carrying joints of the flange type and compares these with the data of Figure 1. Figure 3 shows data for asymmetric joints of the non-load-carrying stiffener type, for example stiffeners welded on one side of the plate only. Data for load-carrying joints of these types are given in Figures 4 and 5.

3. NON-LOAD-CARRYING JOINTS

3.1 Stiffener-type Attachments

The data for this type of joint, shown in Sketch 2.1, are given in Figure 1. The data show no positive knee and can be represented by a straight line when plotted on a log/log basis. The mean line of Figure 1 can be expressed by the equation $N = 3.65 \times 10^{-4} (E/2S_a)^{2.9*}$ over a wide range of tensile mean stress. All failures begin in the plate at the ends of the weld run, see Sketch 2.1, and fatigue cracks propagate through and across the loaded plate perpendicular to the stressing direction. Joints with attachments that have been welded all round, that is, with transverse end welds, have fatigue strengths that are well within the scatter of the data but are lower on average than those with only longitudinal welds. The reduced fatigue strength may be due to an increased stress concentration at the ends of the weld runs.

The distribution of the data about the mean is sensibly Gaussian and statistical analysis has led to the confidence limits shown on the figure. The inner limits give bounds within which there is 95 per cent confidence that 95 per cent of the population will occur and the outer limits give bounds within which there is 99 per cent confidence that 99 per cent of the population will occur.

3.2 Flange-type Attachments

This type of joint is shown in Sketch 2.2. The data, given on Figure 2, indicate that the fatigue strength falls slightly below that of stiffener-type specimens although remaining within the 99 per cent confidence limits of Figure 1. The lower fatigue strength is thought to be due to the proximity of the weld ends to the edges of the loaded plate. The location of failure is through the loaded plate from the weld ends as indicated in Sketch 2.2.

The dashed line in Figure 2 is the mean line for the data.

3.3 Non-load-carrying Asymmetric Joints

The fatigue strength of asymmetric joints is not necessarily lower than that of symmetric joints and may even be higher as shown in Figure 3, where the dashed line is a mean line through data relating to stiffener-type joints with attachments on one side of the plate only. This strengthening effect may not exist for long stiffeners as it may be due to compression at the ends of the stiffener caused by secondary bending.

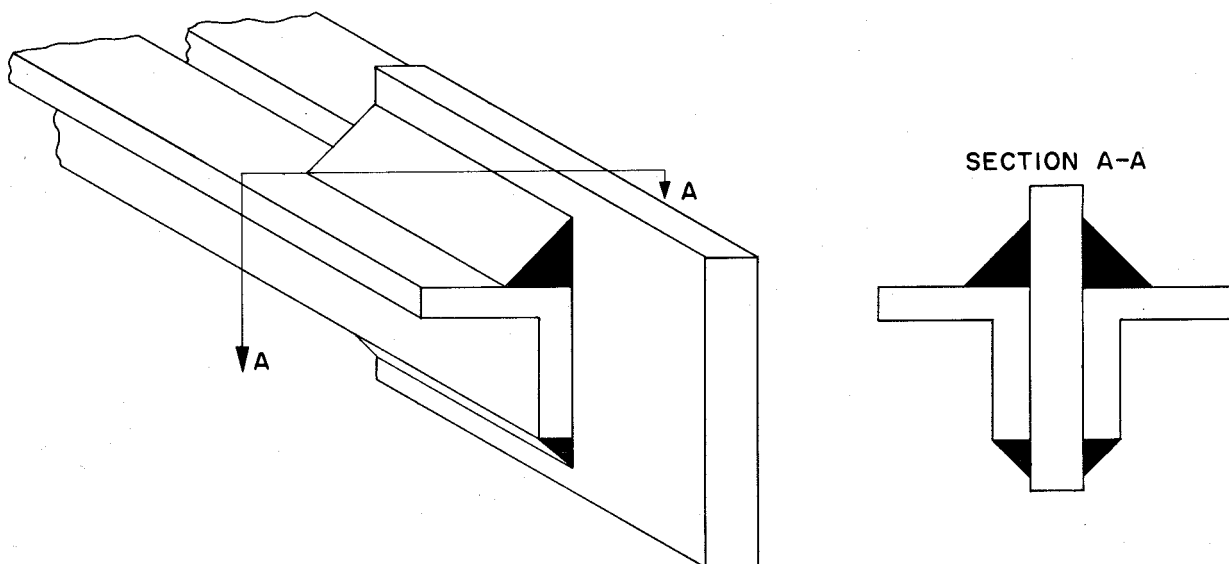
* The value of E is taken as $207\,000\text{ MN/m}^2$ ($30 \times 10^6\text{ lbf/in}^2$).

4. LOAD-CARRYING JOINTS

4.1 Double Strap Joints

Fatigue data for this type of joint are given in Figures 4 and 5. Failures started in either the loaded plate or the cover plate at locations A and B respectively, see Sketch 2.3, or in the weld throat at location C, see Sketch 2.5. Figure 4 presents the failures at location A based on the area of the loaded plate and failures at location B based on the area of the cover plates. In cases where weld failures at location C preceded failure at locations A or B the lower of the stresses in the loaded plate and the cover plates is also plotted on Figure 4 indicating that plate failure had not occurred at this endurance. Figure 5 presents the same data as Figure 4 but with the stresses based on the weld throat area, $P/4al$.

In cases of plate failure, failure may occur from either end of the weld run. The actual method of pick up of stress by the cover plates leads to peak stresses at locations A and B, the relative magnitude of which determines the location at which failure will occur. The magnitude of these local stresses depends mainly on the applied stress in both the load and the cover plates and on l , the length of the weld runs. If l is increased, the peak local stress decreases asymptotically towards a minimum value and the fatigue strength will correspondingly tend to increase. There are insufficient data available to give guidance on this effect. If the stress applied to the loaded plates is significantly higher than that in the cover plate, failure will begin at location A and the crack will run across and through the loaded plate to cause failure. Failure will occur through the cover plates from location B if the opposite is true. Lower fatigue strengths will occur in the cover plates if the ends of the weld runs coincide with the end of the loaded plates, that is, $d = 0$. Joints made using double angle pieces may show fatigue strengths comparable to those made with simple symmetric plates but may exhibit higher fatigue strengths if the weld length or weld throat are altered such that the bending stresses are minimised, for example as in Sketch 4.1. Data for this type of joint are included in Figures 4 and 5.



Sketch 4.1 Load-carrying joint – double angle type – see Derivation 3

4.2 Egg-box Type Joints

This type of joint is shown in Sketch 2.4 and failure may occur in either of the two plates, as mentioned in Section 4.1, starting from the ends of the welds. The fatigue strengths are the same as for the double strap joints. Data for both types are given in Figures 4 and 5.