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The effect of post-weld treatments on fatigue at fillet welded attachments

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Dr C.E. Turner	— Imperial College of Science and Technology.

* Corresponding Member

The construction and subsequent development of the Data Item was undertaken by

Mr R.P. Sharp	— Senior Engineer.
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The person with overall responsibility for the work in this subject area is Mr M.E. Grayley, Head of Strength Analysis Group.

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THE EFFECT OF POST-WELD TREATMENTS ON FATIGUE AT FILLET WELDED ATTACHMENTS

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THE EFFECT OF POST-WELD TREATMENTS ON FATIGUE AT FILLET WELDED ATTACHMENTS

1. INTRODUCTION

This Item provides information on the effect of post-weld treatments on the as-welded fatigue strength of non-load-carrying longitudinal and transverse fillet welded attachments to steel plates subjected to axial fatigue loading. The attachments covered by this Item are transverse fillet welded attachments, longitudinal stiffener and flange type attachments and wing butt welds, as illustrated in Sketch 3.1.

The fatigue strengths at fillet welded attachments in the as-welded condition are given in ESDU 75016 and ESDU 76007. Where the as-welded fatigue strength is unsatisfactory, redesign is the best solution, and post-weld treatment should be used only when redesign to give improved geometry and/or lower stresses is not practically or economically feasible.

2. NOTATION

K	elastic stress concentration factor based on stress in loaded plate (at weld toe for transverse attachments and at end of weld run for longitudinal attachments)		
P	load applied to plate (see Sketch 3.1)	N	lbf
R	stress ratio = $S_{min}/S_{max} = (S_m - S_a)/(S_m + S_a)$		
S_a	alternating stress (half range) in loaded plate	N/m ²	lbf/in ²
S_m	applied mean stress in loaded plate	N/m ²	lbf/in ²
S_{min}	minimum stress ($S_m - S_a$) in loaded plate	N/m ²	lbf/in ²
S_{max}	maximum stress ($S_m + S_a$) in loaded plate	N/m ²	lbf/in ²
S_y	yield stress	N/m ²	lbf/in ²

Both SI and British units are quoted.

3. GENERAL PRINCIPLES

As-welded joints contain a highly localised system of residual stresses resulting from internal constraints arising during cooling of the weld. Experience shows that these stresses in the critical regions at the weld toe and the ends of weld runs are often tensile. Residual stresses in the direction of welding are high, usually of the order of the material yield strength, whereas stresses at 90 degrees to the direction of welding are not necessarily of this magnitude but depend on plate thickness. In thin plate the temperature during cooling is reasonably uniform through the thickness of the plate and the resulting transverse and through thickness stresses are likely to be small although stresses along the weld may be high. In thicker plates the temperature differences are more pronounced and the larger is the section that remains relatively cool during welding

the higher are the residual stresses in the region of the weld. Therefore in very thick joints the transverse and through thickness stresses will be of the order of the material yield strength. Because of this the plate thicknesses are given on the figures.

Longitudinal fillet welded attachments are stressed along the line of the weld. Since the residual stress in this direction is of the order of yield, any applied loading will cause local yielding in the region of the stress concentration at the end of the weld run during the first few load cycles. This causes the actual stress experienced in the critical region to cycle between the yield stress and the yield stress less the local stress range, that is from S_y to $(S_y - 2KS_a)$.

In transverse fillet welded attachments the joint is loaded at 90 degrees to the welding direction. The maximum stress developed at the stress concentration at the weld toe is the sum of the residual stress and $K(S_m + S_a)$. If this sum exceeds the yield stress, S_y , local yielding will occur and, locally, subsequent cycles will range from S_y to $(S_y - 2KS_a)$. In thinner joints the residual stresses tend to be low and hence low applied stresses may not cause local stresses to exceed yield.

The condition where the residual and applied stresses are high enough to cause local yielding in critical regions is termed the yield limited condition. Where this condition applies the stress experienced at stress concentrations will cycle between the yield stress and the yield stress less the applied stress range irrespective of applied mean stress or the material yield strength. If however the residual stresses are low, as in the case of transverse fillet welded joints in thin plate, or can be brought to a low level by post-weld treatment, then the effects of mean stress may become evident. If the mean stress is such that, at the stress range applied, the maximum local stress is less than yield the fatigue life will be greater than that found if the same stress had caused the yield limited condition. If the yield limited condition does not apply then lowering the mean stress applied will give an increase in endurance; the effect of mean stress will be more noticeable at lower alternating stresses. The effect of the joint being out of the yield limited condition is to rotate the fatigue curve for as-welded joints anticlockwise, see Sketch 5.1. The point about which this rotation occurs is dependent upon the residual and applied stress but for cases where the applied stress cycle is fully tensile this rotation is about the material's yield stress, see Sketch 5.2.

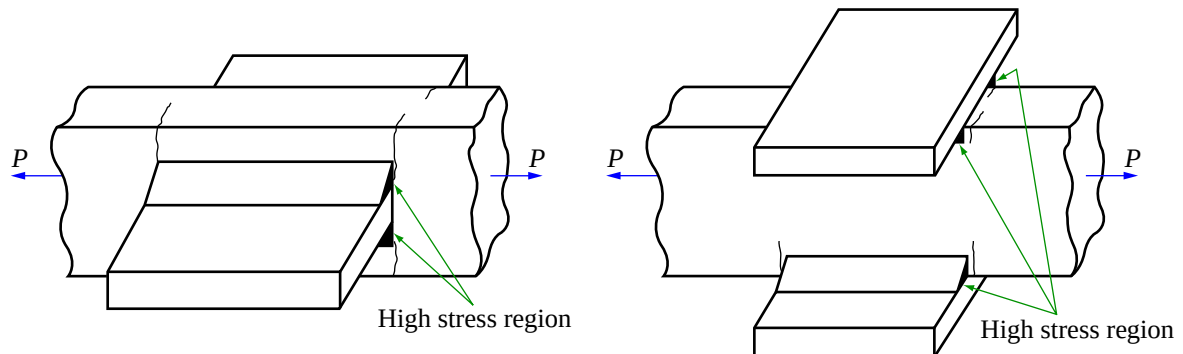
Improvements in fatigue strength can be brought about both by reducing the stress concentration factor, K , and/or reducing the residual stress. The fatigue strength can also be improved by removing defects at points of stress concentration from which fatigue cracks may grow to cause failure.

Post-weld treatments fall into three categories:

1. shape changing methods, for example weld profile grinding,
2. mechanical methods, for example peening or prior overloading, and
3. thermal methods such as stress relieving.

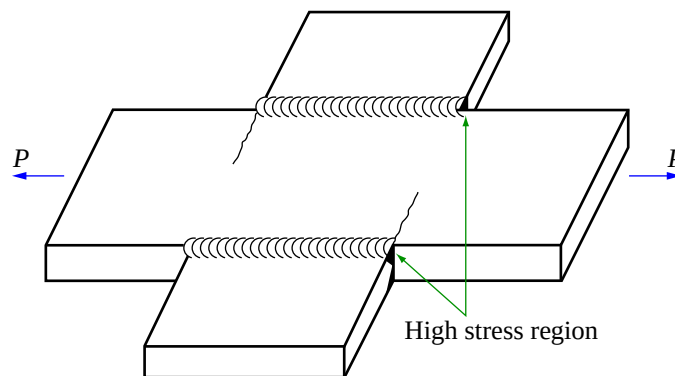
The following sections deal with the above three categories in turn. Treatments for which insufficient data are available or in which application methods are ill-defined are dealt with separately in Section 7. Summaries of these processes and their effects are given in Table 9.1. Improvement in fatigue strength may not always be the main reason for applying these processes.

Combinations of processes can be used as long as care is taken to apply them in the correct order. Shape changing processes are always beneficial as they reduce K and hence the local stress range. The effects of processes that alter the state of residual stress are not always so. This is because applied stresses can be such that even after treatment the yield limited condition applies or because subsequent treatment can remove material containing a beneficial stress system.

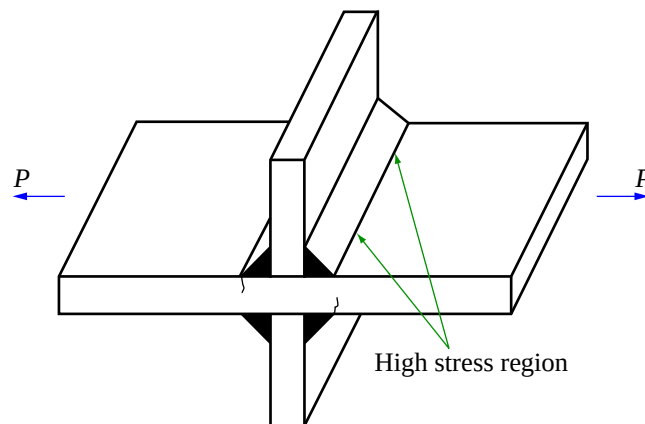


(a) Longitudinal stiffener type fillet welded attachment

(b) Longitudinal flange type fillet welded attachment



(c) Wing-butt welded attachment



(d) Transverse fillet welded attachment

Sketch 3.1 Attachments covered by this Item