FATIGUE STRENGTH OF LOAD CARRYING FILLET WELDED JOINTS

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The main objective of this work was to assess the influence of weld size and penetration, both on the location of the crack propagation plane and on the fatigue strength. The joints studied were load carrying T and cruciform loaded in bending. For the T joints several relationships between the ratio of the attachment plate thickness and main plate thickness T/B were analysed (0.5; 1; 2). Several weld penetration cases were considered (from full penetration to zero penetration). Fatigue life was evaluated by integration of a Paris type law assuming a semi-elliptical crack shape. A more detailed analysis is given refering the probability of fatigue crack growth at the three assumed locations, i.e. weld root and through the weld metal at 45^{0} angle, or at the weld toes either in the main plate or in the attachment plate.

INTRODUCTION

Lack of penetration at the weld root occurs frequently in welded joints either as a result of welding deficiencies or as a result of a design decision.

In previous work carried out by Ferreira and Branco (1,2) the fatigue behaviour of cruciform and non load carrying joints was analysed in detail. Fatigue life was computed with a LEFM model and the main geometric variables of the weldment were studied.

In this paper results are presented refering the fatigue behaviour of load carrying fillet welds with lack of penetration at the weld root. Fatigue life prediction results are shown including geometry effects such as attachment plate thickness T, weld leg length, LG and main plate thickness, B.

RESULTS AND DISCUSSION

The welded joint is shown in Figure 1 and the loading modes are also identified. One loading mode is for T joint and gives tension in the attachment inducing bending in the main plate who is simply supported at both ends. The other loading mode is tension in the main plate giving secondary bending in the attachment.

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The joint nomenclature is also refered in the same figure.

The analysis is to make a fatigue life prediction and flaw assessment using a LEFM model with Paris law.

In the T joint three fracture planes were assumed; sections 1 (S_1) and 3 (S_3) both from the weld toe and section 2 (S_2) with θ=45^0 and from the weld root. The lack of penetration was studied for ratios p/B=1/6, 1/3, full penetration and no penetration all for the relations T/B=0.5, 1 and 2. In all cases A=10B and LG=0.25B.

In the cruciform joints the fracture planes were S_1 passing at the weld toe and S_2 from the weld root (θ=75^0). The values of p/B were 0; 1/6 and 1/3 for ℓ/B=1.3, 1.8, 2.6 and 4.6.

Mode I crack propagation was assumed for sections 1 and 3. Hence only K_I was used. For section 2 a mixed mode crack propagation was considered with an equivalent K proposed by Usami (3) and based on K_I and K_{II}.

A 2D eight node isoparametric FE program with special crack tip elements was used to calculate K_I and K_{II}. The element is described in Parker (4).

In the T joint with the attachment loaded in tension the most likely fracture plane is S_3. Fatigue strength for cracks growing from the weld toe was found independent of root penetration and ratio T/B.

The results shown in Figures 2 and 5 were obtained assuming a through crack with an initial flaw size of 0.15mm, B=12mm and m=3.0; C=1.83x10^{-13} (Nmm$^{-3/2}$). In Figure 2 the fatigue strength for N_r=2x10^6 cycles is plotted against the ratio T/B for the attachment loaded in bending and for the values of p/B refered above. Fatigue strength is considerably reduced when the lack of penetration increases (p/B=1/6) in comparison with the joints with full penetration. The most likely fracture planes are S_1 for T/B $\leqslant$ 1 and S_3 for T/B=2.

In Figure 3 the results indicate the influence of both thickness B and penetration on the fatigue strength for N_r=2x10^6 cycles and for the T joint with T/B=1. The most likely fracture planes are S_1 for the attachment in bending and S_3 for the attachment in tension. The nominal stress is the stress at weld toe in section 3.

For the results in Figure 3 and Figure 4 Paris law was integrated assuming initial semi-circular flaws with 0.15mm depth. K was obtained with the Raju equation (5) for semi-elliptical surface cracks multiplied by a computed magnifying factor M_K.

The values of m and C in Paris law were m=3.0 and C=1.83x10^{-13} in the crack depth direction and m=3.0 and C=1.33x10^{-13} in the crack length direction ("C" direction).

For cruciform joints in bending Figure 4 shows the influence of penetration and ℓ/B on the fatigue strength at 2x10^6 cycles and for B=12mm. It is seen that there is no influence of ℓ/B and a fatigue strength reduction of about 10% is observed for the joints with p/B=1/6 in comparison with the full penetration joints.

Figure 5 shows the fatigue strength results ($\Delta\sigma$ at $2x10^6$ cycles against ℓ/B) for the cruciform joints in tension and for the different values of p/B. The weld penetration has a great influence on the fatigue strength. For $\ell/B \leqslant 1.8$ fatigue strength has the lower value for cracks initiated at section 2 (weld root) while for $\ell/B \geqslant 2.6$ the fatigue strength is lower when the cracks initiate at weld toe.

CONCLUSIONS

1 - In T joints and with the attachment loaded in tension fatigue strength is not affected by the weld penetration and by the ratio T/B. However when the attachment is loaded in bending these parameters change the fatigue strength and the cracking plane.

2 - Cruciform joints loaded in bending have fatigue failure from the weld toe and a fatigue strength reduction of 10% is observed in the joints with lack of penetration. For tensile loading the cracking plane changes with the leg length and attachment thickness and a fatigue strength reduction occurs as the lack of penetration increases.

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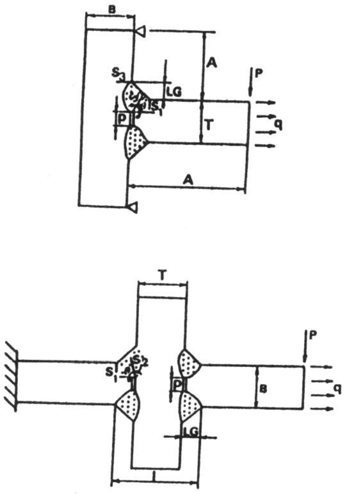

Figure 1 – Nomenclature of the welded joint.

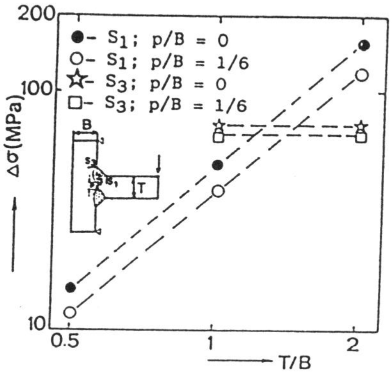

Figure 2 – Δσ against T/B as a function of p/B. $N_r=2x10^6$ cycles. Bending. B=12mm.

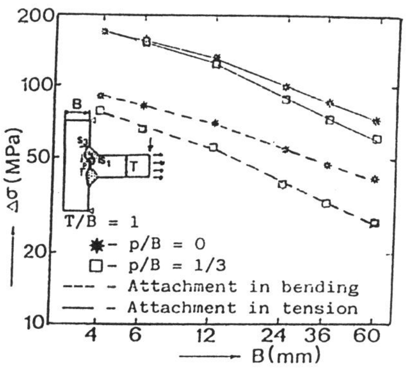

Figure 3 – Δσ against main plate thickness B. N_r=2x10^6 cycles. Bending and tension.

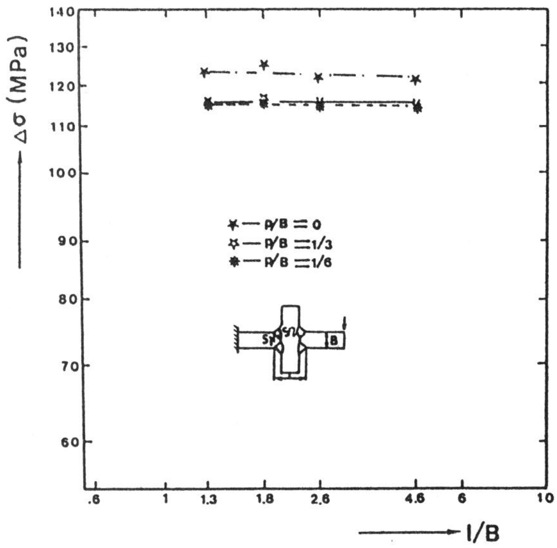

Figure 4 – $\Delta\sigma$ in section 1 against ℓ/B for 3 values of p/B. $N_r=2x10^6$ cycles.B=12mm

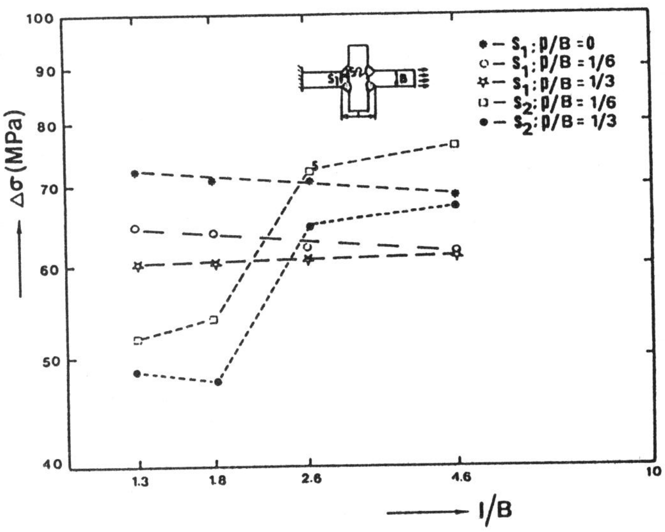

Figure 5 – $\Delta\sigma$ in section 1 against ℓ/B and function of p/B. $N_r=2x10^6$ cycles.B=12mm