# FATIGUE ANALYSIS OF LONGITUDINAL FILLET WELDED JOINTS

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The paper presents results of a fatigue life study carried out in single and double lap longitudinal fillet weld joints loaded in tension in the main plate only. Using weight function methods the $M_K$ factors of the welded joint were computed for different values of geometrical parameters of the joint. A fatigue life analysis, both for crack initiation and crack propagation is also given. The life for crack initiation was predicted using the local stress-strain approach. Agreement of theoretical predictions of fatigue life with experimental data is presented.

## INTRODUCTION

Fatigue behaviour of welded joints is influenced by many parameters including the geometry of the weldment, plate and attachment. Recently, two text books by Maddox (1) and Radaj (2) have reviewed the subject in detail.

The fatigue life of a welded joint is more accurately assessed by the sum of a crack initiation period plus a crack propagation life. The crack initiation phase can be described by the local strain method which application to welded joints was described recently by Skorupa (3). The strain intensity factor approach, developed by Topper et al (4), can be applied for cracks growing in highly stress concentration areas. Recently, the authors have verified the validity of this approach both for butt joints (5) and fillet welded joints (6).

In this paper an analysis is presented concerning the fatigue behaviour of lap joints (longitudinal fillet). Both crack initiation and crack propagation predictions were obtained.

## RESULTS AND DISCUSSION

Figs.1 a) and b) show the welded joints analysed. The loading condition analysed was tensile stresses in the main plate (Fig.1). The values of the geometrical parameters studied are given in the table 1 .

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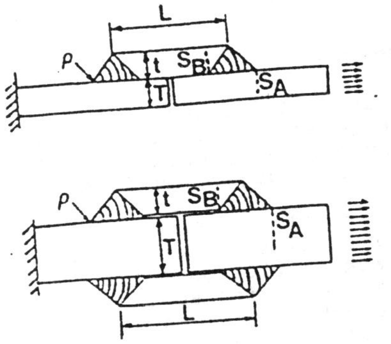
Table 1 Geometrical parameters

| | | | |
|---|---|---|---|
| ρ /T | 0 | 1 | 1 |
| L/T | 3 | 10 | |
| t/T | 0.3 | 0.5 | 1 |

## Stress intensity factor determination

K was computed using the Bueckner weight function (7) for cracks in the weld toe and for $\rho/t=1$ only (quarter circular contour). The same weight function was used for the cracks in the weld root. For cracks at the weld toe in the case of $\rho\to0$ the Glinka weight functions were used (8).



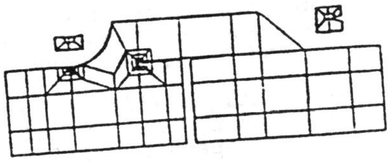


Fig.2 - Typical 2DFE mesh

Fig.1 - Weld geometry.
a) Single lap joint.
b) double lap joint.

$M_k$ was obtained by the equation, $M_K=K/K_r$ where $K_r$ is a reference stress intensity factor solution for a plate with a side crack. In this work 2D isoparametric finite elements were used and the typical mesh proportions are shown in Fig.2.

$M_k$ is plotted in Fig.3 against a/t and for the three assumed values of t/T.

For double lap joints and cracking at the weld toe through the main plate the plot $M_k$ obtained by the Glinka weight function method, against a/T is shown in Fig.4 for a straight face joint ( $\rho \to 0$) and for the ratio L/T=3. Although $M_K$ increases when the ratio t/T is decreased the variation is smaller compared with Fig.3 (single lap joint).

## FATIGUE LIFE RESULTS

The number of cycles for crack initiation in the weld joints, $N_i$, was obtained by the solution of the Morrow (9) equation.

The equation of the cyclic stress-strain curve was used to obtain the local stresses and strains $\Delta\sigma$ and $\Delta\varepsilon$. The Glinka (10) equivalent strain energy concept was used to relate the local stress and strains in the crack area.

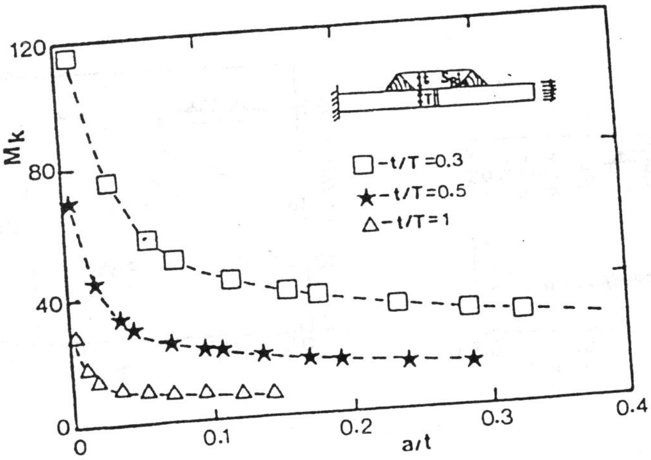


Fig.3 - $M_K$ against a/t. Single lap joint. Crack in the weld root.

Crack propagation life was obtained by integration of Paris Law assuming $K=M_k \times K'$ where $K'$ is the Raju (11) stress intensity factor solution for semielliptical cracks in a plate loaded in tension. The initial crack size in the analysis was taken as $a_i$=0.15mm and the final crack size, $a_f$=0.5T or 0.5t.

Results obtained for the single lap joint are shown in Fig.5. In this figure the local, $\Delta\sigma$, and the nominal fatigue strength, $\Delta S$, are plotted against t/T for a fatigue life in crack propagation of $10^5$ cycles and for a joint with $\rho/t=1$ and L/T=3. The local stress (Fig.5) is considerably above the nominal stress.

Similar results as in Fig.5 are plotted in Fig.6 for the double lap joint and assuming crack growth from the weld toe and weld root. For cracks growing from the weld toe the fatigue strength shows only a slight increase with the ratio t/T. However when cracking occurs in the weld root there is a great increase of fatigue strength with t/T. For t/T=0.3 and L/T=3 fatigue failure will occur from the weld root. In all the remaining cases fatigue failure initiated from the weld toe and through the main plate.

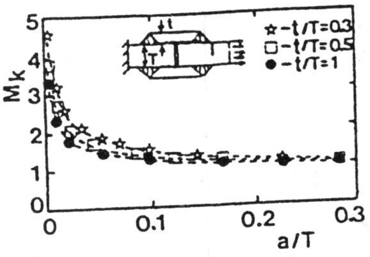


Fig.4 - $M_K$ against a/T. Crack in weld root.

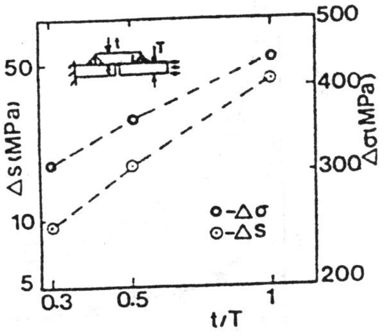


Fig.5 - $\Delta\sigma$ and $\Delta S$ vs. t/T. Single lap joint.

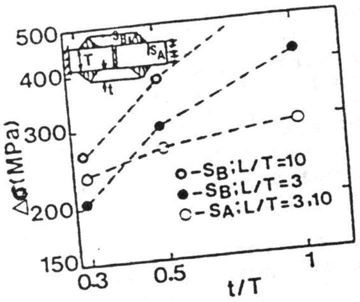


Fig.6 - $\Delta\sigma$ against t/T for a double lap joint.

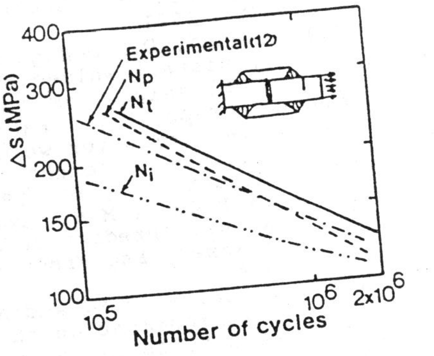


Fig.7 - S-N curves for $N_i$ and $N_p$. Exp. data also. $a_i$=0.15mm.

Results of crack initiation and propagation are plotted in Fig.7 for a double lap joint failing from the weld toe and with t/T=1; L/T=3 and $\rho/t=0$. The resulting curve $N_t = N_i + N_p$ gives a good agreement with experimental results obtained by Gurney (12). Note that the number of cycles for crack propagation is considerably larger than the number of cycles for crack initiation due to the sharp weld toe radius created ($\rho \to 0$). For $\rho/t=1$ (circular contour at the weld toe) good agreement was also found with experimental results but in this case $N_i$ was considerably larger than $N_p$

CONCLUSIONS

1 . Higher values of K occur usually for cracks at the weld root. For the double lap joint $M_K$ decreases when $\rho/t$ increases.

2 . Total fatigue life results (crack initiation + crack propagation) have shown that for double lap joints with improved profile, crack initiation

life is greater than crack propagation. Good agreement was found between the experimental results and the theoretical predictions.

## REFERENCES

(1) - Maddox, S.J., "Fatigue strength of welded structures", Ed.Abington Publishing, Cambridge, UK, 1991.

(2) - Radaj, D.,"Design and analysis of fatigue resistant welded structures", Ed. Abington Publishing, Cambridge, UK, 1991

(3) - Skorupa, M., " Fatigue crack initiation life prediction for welded joints by low cycle fatigue approach", Fat. Fract. Eng. Mat. Struct., 13, 6, 1990, pp.597-614

(4) - El Haddad, M.H., Topper, T.H. and Smith, K. N., "Prediction of non-propagating cracks", Eng.Fract.Mech., 11, 1979, pp. 573-584

(5) - Ferreira, J.M. and Branco, C.M.,"Influence of misalignement on the fatigue strength of butt welds", Int.J.Fat., 13, 5, 1991, pp.405-409

(6) - Branco, C.M., Ferreira, J.M.,Radon, J.C., " Assessment of non-propagating cracks in welded joints using the strain intensity approach" Proc. 10th Congress on Materials Testing, Budapest, Hungary, Vol II, 1991, pp.454-460

(7) - Bueckner, M.F., "A novel principle for the computation of stress intensity factors", Z. Angew. Math. Mech.,50,1970.p.529

(8) - Glinka, G., Niu, X., "The weld profile effects on stress intensity factors in weldments ", Int. J. Fract., 35, 1987, pp.28-30

(9) - Morrow, J., "Fatigue properties of metals", SAE Fatigue Design Handbook, 1968, pp. 21-30

(10) - Glinka, G., "Energy density approach to calculation of inelastic strain-stress near notches and cracks", Eng. Fract Mech., 22, 3, 1985, pp.485-508

(11) - Raju, I.S., Newman, J.C., "Stress intensity factor equations for cracks in three dimensional finite bodies subjected to tension and bending loading", NASA TM 85793, Langley Research Center, Virginia, USA, 1984

(12) - Gurney, T.R., Maddox, S.J., "A reanalyis of fatigue data for welded joints in steel",Weld. Inst. Rep. E 44/72, The Welding Institute, UK, 1972