EFFECT OF WELD TOE ANGLE AND OTHER GEOMETRICAL PARAMETERS ON STRESS CONCENTRATION IN LONGITUDINAL ATTACHMENTS

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By finite element modelling, stress concentration at weld toes of fillet welded longitudinal attachments is investigated. The stress concentration correction factor f_c has been computed for joints with different geometries, and is pointed out how it is influenced by the main geometrical parameters. An equation is presented, allowing rapid computation of f_c.

INTRODUCTION

In a former experimental research carried out on longitudinal fillet welded attachments specimens, Gurney (1) identified trends in fatigue resistance of these joints, due to geometrical parameters. However it is not possible to examine all practical geometrical combinations by means of fatigue testing: when calibrated on a few test data, fracture mechanics models and finite element analysis can provide a quick and economical alternative.

A numerical study by Smith and Gurney (2) focused on the determination of the stress intensity correction factor f_c at potential crack sites, generally located at weld toe zones, at the ends of the welded attachments. Although this work confirmed some trends observed in the experimental research (1), its results, when used within a fracture mechanics analysis, led to underestimating fatigue test results of specimens and full scale welded joints.

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Extensive experimental work was recently performed at EPFL-ICOM by Smith and Bremen (3), Dubois and Bremen (4), Bremen (5) and Bremen et al. (6), focusing on the effect of residual-stress improvement methods on fatigue crack propagation in large specimens with longitudinal welded attachments.

The fatigue resistance of such joints is among the lowest, and is usually considered to depend mainly on the attachment length, as a result of very high stress concentrations at the weld toes. The geometries of the specimens considered in the study are shown in fig. 1. By reanalyzing these experimental results, differences of one order of magnitude on crack growth rate were observed at the very early stages of crack growth between specimens subject to different improvement methods and having attachments of different lengths. Although making reference to an effective value of the stress intensity factor range, which among other parameters accounts for residual stresses, these differences could not be fully explained by means of fracture mechanics considerations.

In order to verify if the observed dicrepancies upon crack growth rates were to be explained by some other phenomena, and to make sure that no additional errors were brought into the calculation of the effective stress intensity factor range, a finite element analysis was recently performed by Castiglioni and Bremen (7). The main objective of the numerical study (7) was to analyze the influence of attachment length, and thickness, as well as of the weld toe angle on the local stress field around the weld toe, the other parameters having been sufficiently covered by the study by Smith and Gurney (2).

In the study by Castiglioni and Bremen (7), 1/8 of the joint was modelled by means of isoparametric quadratic brick elements. In order to avoid numerical problems connected with the distortion of the element shape, effort was made to keep all the faces of the elements rectangular. The mesh adopted (fig. 2) was very refined at the weld toe, while when increasing the distance from it, the dimensions of the elements were increased, roughly in proportion to the distance. In the same paper (7), a comparison between numerical and experimental results was presented and extensively discussed together with some preliminary results showing the influence of the geometric parameters on f_c.

In this paper, based on results of an extensive finite element simulation study, a simplified formulation is presented for an easy computation of f_c.

STRESS CONCENTRATION CORRECTION FACTORS

The correction factor f_c for stress concentration in the stress intensity factor was calculated using a procedure proposed by Albrecht and Yamada (8), based on a superposition principle. Values of the correction factor were computed for depths at which stresses from the finite element modelling were known, using linear interpolation between the numerical results.

The geometries considered in this study are summarized in TABLE 1.

Previous work on longitudinal attachments (2) has shown that the relation between values of the correction factor and relative depth z/T (where T is the main plate thickness) tend to be very close to a straight line in a log-log plot. With reference to the axis orientation shown in fig. 2, the relation can therefore be expressed as:

$$f_c = \frac{P}{(\frac{1}{2}\text{-}z/T)^Q} \qquad \text{.........(1)}$$

Once coefficients P and Q of equation (1) are known in function of the joint geometry, the stress concentration corretion factor f_c can be easily computed.

By means of a regression analysis, P and Q were determined in the present study by fitting equation (1) through the f_c values computed on the basis of the finite element results. Figures 3a and 3b show the variation of P and Q with the attachment length (L), for different values of the weld toe angle α, while figures 4a and 4b show the variation of P and Q with α, for different attachment lengths.

By examining figs. 3 and 4 it can be noticed that:

- P is decreasing when increasing α; the contrary holds for Q.
- While Q is practically unaffected by variations of the attachment length (L), the influence of a variation of L on P is relevant, but only for $L \leq 200$ mm. For $L > 200$ mm, P remains nearly constant.
- Variations of the weld toe angle α have a relevant influence on both P and Q, that decreases when increasing α.

SIMPLIFIED COMPUTATION OF P AND Q

Based on the previous considerations and by means of least squares fitting technique, the following equations were obtained, allowing the computation of P and Q in function of the weld toe angle α and of the attachment length L:

$P(\alpha,L) = 2.509642\ \alpha^{-.4210038} + .1521008\ \alpha^{-.159617}\ \ln(L)$................. (2)
$P(\alpha,L) = 2.509642\ \alpha^{-.4210038} + .8058783\ \alpha^{-.1557}$................................(3)
$Q(\alpha) = -.4450376 + .1892823\ \ln(\alpha)$...(4)

where equation (2) holds for L<200 mm, equation (3) for L>200 mm, and units for L are mm and for α degrees.

CONCLUSION

A parametric study was performed by finite element modelling fillet welded longitudinal attachments, in order to investigate the effect of the main geometrical parameters on the stress concentrations at the weld toes in these joints. As most parameters were already studied in a previous work by Smith and Gurney (1), in this paper attention was focused on the weld toe angle.

It has been noticed that:

a) the variation of the weld toe angle only affects the slope of the exponential relation giving the value of the correction factor f_c in terms of the relative depth z/T. In terms of fatigue life, the effect of the weld toe angle is at least of the same order of magnitude of the one of practical initial crack depths;
b) f_c can be considered independent on the attachment length, for attachment above 200 mm long;
c) the relative attachment thickness with respect to the one of the main plate only slightly influences f_c.

In this paper simple equations are presented, allowing an easy and quick computation of f_c as a function of the joint geometry.

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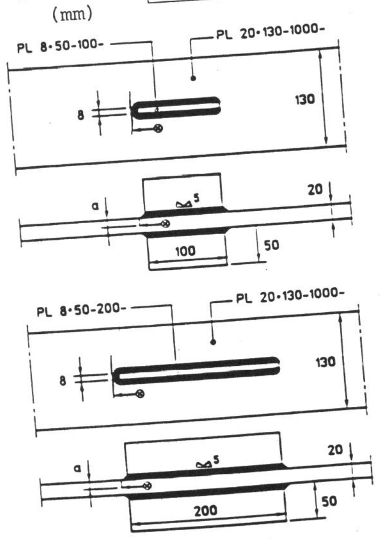
ATTACHMENT LENGTH (mm)

		50	100	150	200	400	800
WELD TOE ANGLE (degrees)	30	•	•		•	•	
	37				•		
	45	•	•	•	•	•	•
	52				•		
	60	•	•		•	•	
ATTACHMENT THICKNESS (mm)	8	•	•	•	•	•	•
	20				•		

TABLE 1



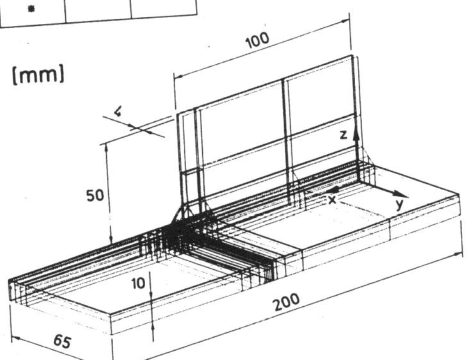


Fig. 2 Finite element mesh for overall geometry of 1/8 of the welded joint

Fig. 1 Welded joint geometries considered in the experimental study at EPFL-ICOM. Dimensions in mm.

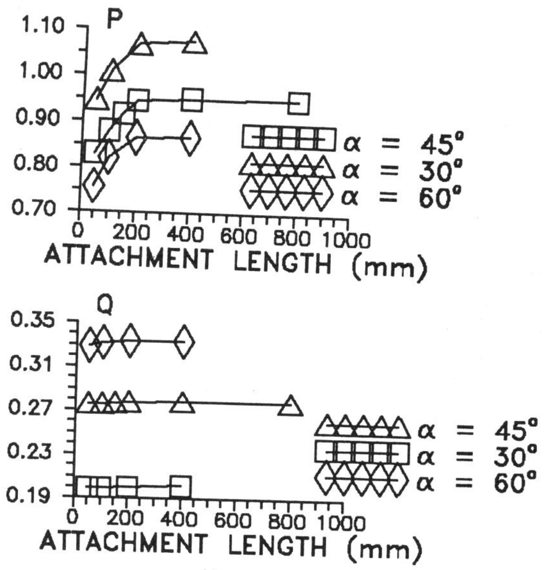


Fig. 3 Variation of coefficients P and Q with the attachment length

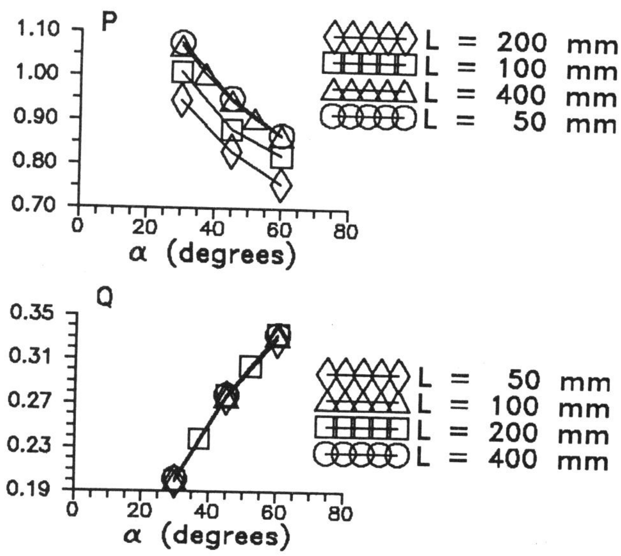


Fig. 4 Variation of coefficients P and Q with the weld toe angle