第 I 部門

Parametric study on stress concentration factors of load-carrying cruciform welded joints based on the real weld profile

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1. Introduction

Load-carrying cruciform welded joints are widely used in engineering structures, in which high stress concentrations occur at the weld toe and the weld root. Therefore, fatigue cracks may initiate from these critical areas and lead to fatigue failure. To evaluate the fatigue performance of these joints, the stress concentration factors (SCFs) at these locations are quite valuable, especially for various local stress-life approaches. However, in most of the previous studies (i.e. [1] and [2]), an idealized weld profile was usually assumed when calculating the SCFs, and some actual geometric detail information was neglected with almost no discussion.

Hence, in order to improve the calculation accuracy of the SCF, this paper carried out a more real weld geometry model which characterized by several parameters (see Fig.1), together with a comprehensive parametric study under tension loading condition by means of two-dimensional (2D) finite element analysis (FEA). The influences of the geometric parameters on the SCFs at the weld toe and the weld root of load carrying cruciform welded joints were discussed respectively.

2. The real weld geometry model

The idealized fillet weld contour which characterized by the weld toe radii and 45° flank angle were usually adopted in most studies when evaluating the SCF by numerical calculations. While the effects of the neglected geometric parameters on the SCFs are not clear. To consider this aspect, referring to Fricke and Kahl's work [3], a more real weld geometry model was proposed to describe the weld profile quantitatively (see Fig.1).

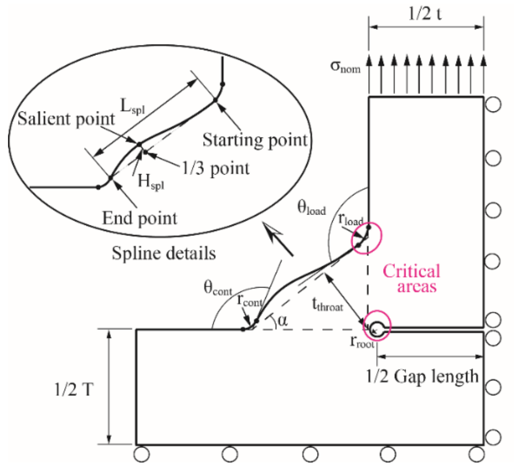

Fig.1. The real weld geometry model

This unsymmetrical geometry model of fillet weld based on the assumption that the weld position is consistent with that shown in Fig.1. In this way, due to gravity, there is a tendency that the weld pool floats downwards before solidification which leads to a gentle curve between the weld toe arcs. Moreover, a larger weld toe radius (r_{laod}) can be produced in the direction where the load is transferred, and it is beneficial to the load-carrying cases [4]. As it can be noticed, plenty of parameters were employed to describe the profile quantitatively.

3. Parametric study on SCFs

A comprehensive parametric study was carried out subsequently based on the aforementioned geometry model. The angle parameters and the ratios of various length dimensions to the loaded plate thickness t were chosen as independent variables. Then, numerous 2D finite element analyses were executed to investigate the effects of these parameters on the SCFs at both the weld toe and the weld root.

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A quarter 2D plane strain FE model with very fine mesh was adopted in the current study. Isotropic linear elastic material with elastic modulus $Es=210GPa$ and Poisson's ratio $\mu=0.3$ was used. Eight-noded quadratic fully integration plane strain elements were employed. Uniform tensile stress of $1MPa$ was submitted to the loading end as nominal stress σ_{nom}, and the first principal stress was taken for the local stress σ_{local}. As a result, the SCF can be defined as $K_t=\sigma_{local}/\sigma_{nom}$.

Besides, when studying a certain parameter effect on the SCFs, the others were assigned to the average values (see table 1) which originating from a practical fatigue test project measured by 3D digital microscope. It has to be mentioned that the average values of the weld root radius and the gap length were assumed to $1.0mm$ and $t\text{-}2{\cdot}r_{root}$ respectively.

Table 1 The average values of various parameters

Parameter	t/mm	T/mm	r_{load}/mm	r_{cont}/mm
AVE.	16.0	16.0	1.79	0.69
Parameter	α / deg.	θ_{load}/deg.	θ_{cont}/deg.	t_{throat}/mm
AVE.	39.8	123.4	120.2	6.60

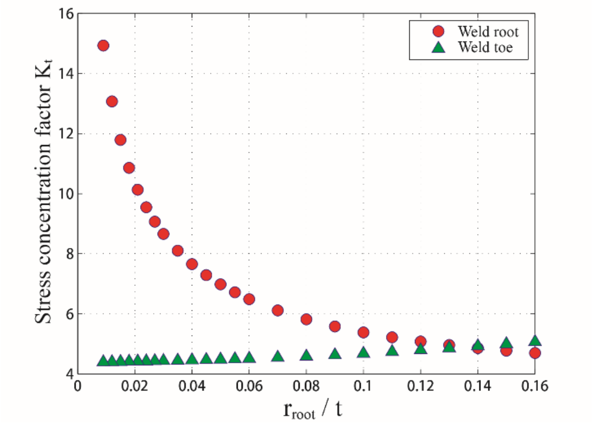
4. Results and discussion

Undoubtedly, the radii of the weld toe and the weld root contribute the greatest impact on the SCFs at the weld toe and root respectively. Fig.2 shows some representative results from the parametric study. As can be seen, the SCF at the weld root increases sharply with the decrease of the weld root radius. And both of SCFs at the weld toe and root increase with the increase of the incomplete fusion length (gap length).

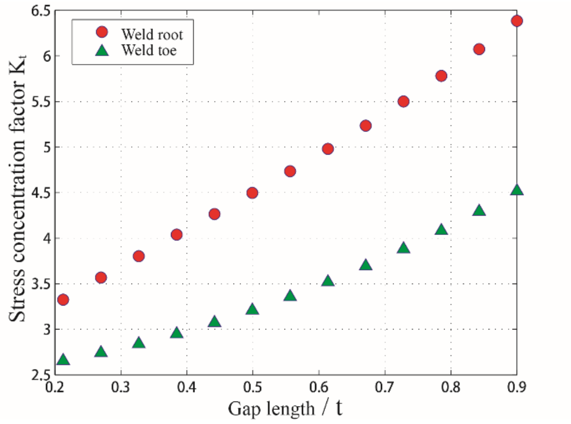
Besides, both of SCFs at the weld toe and root decrease with the increase of the weld throat thickness t_{throat} and the flank angle α. Also, the continuous plate thickness T and the local angle of the load transferred weld toe θ_{load} have non-ignorable effects on SCFs.

5. Conclusions

A comprehensive parametric study on SCF of load-carrying cruciform welded joints was carried out based on the real weld profile, the results revealed the effects of various parameters on the SCFs at both the weld toe and the weld root areas.



(a) The weld root radius effect on the SCFs



(b) The gap length effect on the SCFs

Fig.2. Presentative results of the parametric study

References

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