Parametric Formula for Stress Concentration Factor of Fillet Weld Joints with Spline Bead Shape

Osaka University, Joining and Welding Research Institute, Student Member, ○WANG Yixun
Osaka University, Joining and Welding Research Institute, Member, TSUTSUMI Seiichiro

1. Introduction

The welded joints have been widely used in the steel structures such as the bridges, towers, pressure vessels and ships, while fatigue cracks are prone to initiate at the local position with serious stress concentration caused by geometric discontinuities and notches [1]. The stress concentration effects can be expressed by the stress concentration factor (SCF), and plenty of parametric formulae have been proposed to predict the SCF [2]. The existing formulae usually neglect the streamline shape of the real weld [3], which probably results in reduced accuracy of the SCF.

This paper aims to propose the parametric formulae for the fillet weld based on the FEM and regression analysis. The accuracy of the line model widely used in the existing parametric formulae was discussed. The geometric model with a spline curve was proposed to consider the real shape of weld. The parameters of the cruciform joint specimen were also measured, and the severity of stress concentration was assessed by the probability analysis.

2. Comparison of the spline and line model of fillet weld

The geometric shape of the spline model was proposed for the fillet weld as shown in Fig. 1. The additional parameters compared to the line model were proposed including the central angle (θ) of weld toe, salient point position ($1/n$) and the aspect ratio (R). The spline was started at the end of the bottom arc, turning and converging from the salient point and stopped at the end of top arc, which resembled the real shape of fillet weld more accurately than the line model.

The FE model for the cruciform joint under the tensile stress was built as an example to discuss the necessity in consideration of the streamline weld shape. The essential parameters to build the fillet weld were measured by the 3D scanner from a specimen. The grid size of 0.05mm was used for the weld toe in FE analysis to ensure the accurate results of the parametric study. Taking ±10% deviation as the limit error, the results of SCF for the spline model and line model were shown in Fig. 2. It was indicated that only 40% of the results by the line model could meet the requirement of accuracy. Besides, the SCF calculated by the line model was always smaller than that by the spline model. Therefore, it was comparatively dangerous to assess the SCF of fillet weld based on the line model.

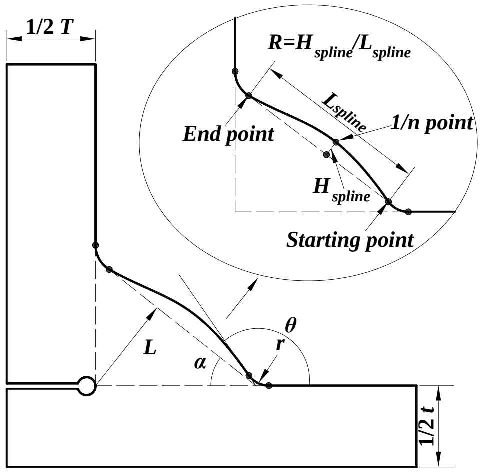

Fig. 1 The spline model for fillet weld

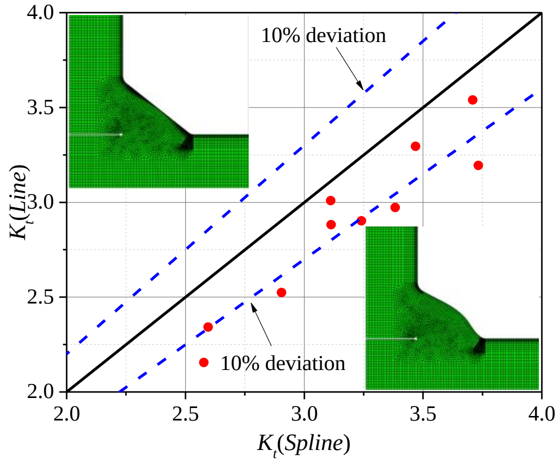

Fig. 2 Comparison of the spline and line model

Key words: parametric formulae; stress concentration factor; fillet weld; weld model; probability analysis

Contact information: Seiichiro TSUTSUMI, Joining and Welding Research Institute, Osaka University, 11-1, Mihogaoka, Ibaraki, Osaka, 567-0047. (TEL 06-6879-4887)

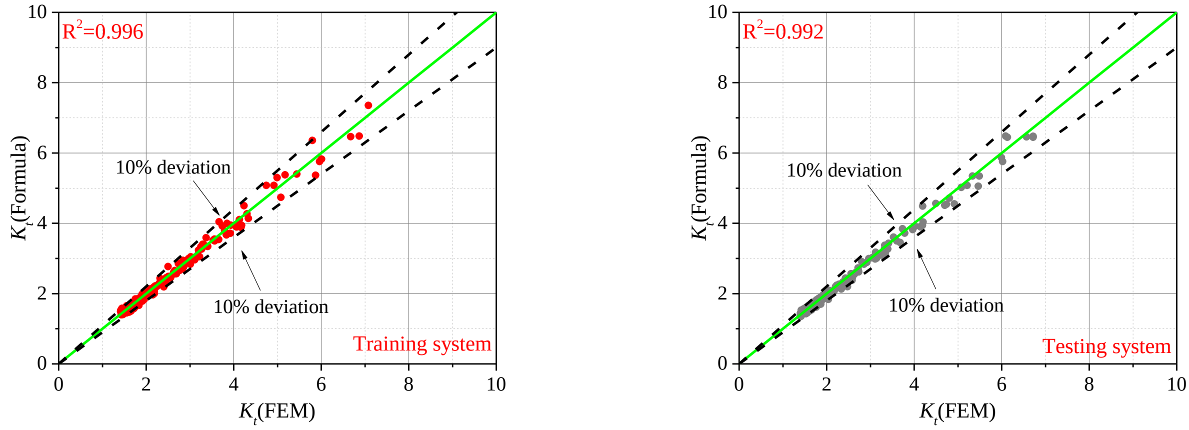

Fig. 3 SCF of T-shape joint under tensile stress

3. The proposed parametric formula for fillet weld

The parametric formulae for fillet weld of T-shape joints and cruciform joints under the tensile stress and bending stress were proposed respectively in this research. 400 cases for each type of joints and loading conditions were built as the training data system and another 200 cases were built as the testing data system based on the spline model. The accuracy of existing parametric formulae was first examined and proved to have shortcomings for the narrow ranges and insufficient precisions. The trend of SCF changing with characteristic parameters was discussed, based on which the form of parametric formulae was decided. The results indicated that parameters defining the shape of weld toe (r/t, θ) always had the most significant influence on the SCF under four conditions. The notch stress at the weld toe was obtained from the FE model for SCF calculation, and parametric formulae were fitted by the regression analysis. The deviation between the results by the proposed parametric formulae and FE analysis was smaller than 10% under the four conditions studied in this research, indicating more accurate results in the broader ranges than existing formulae. An example of regression results for the T-shape joint under tensile stress was shown in Fig. 3.

4. Probability analysis of fillet weld based on the parametric formulae

The geometric data of the cruciform joint specimen were measured for the probability analysis of SCF of the fillet weld. The SCF of four conditions studied in this research was calculated by the proposed parametric formulae, and a total of 200 cases were fitted by the lognormal density function. Considering a survival probability of 95%, the confidence intervals for four conditions were also calculated. The overlapping range of confidence interval was great for T-shape joint under the tensile stress and cruciform joint under the bending stress, indicating similar severity of stress concentration. The SCF of the cruciform joint under the tensile stress was the greatest if assessed by both the mean value and the confidence interval considering the welding condition in this research.

5. Conclusion

The spline model considering the streamline shape of fillet weld was proposed in this research. The existing parametric formulae were examined to have shortcomings for the narrow ranges and insufficient precisions. The deviation rate of SCF by the proposed parametric formulae compared to the FE analysis was proved to be less than 10%. The stress concentration of cruciform joints under the tensile stress was the most serious if assessed by both the mean value and the confidence interval of 95% survival probability considering the welding condition in this research.

References

1) Luo, Y., Ma, R., Tsutsumi, S. (2020). Parametric Formulae for Elastic Stress Concentration Factor at the Weld Toe of Distorted Butt-Welded Joints. Materials, 13(1): 169.

2) Brennan, F., Peleties, P., Hellier, A. (2000). Predicting weld toe stress concentration factors for T and skewed T-joint plate connections. International Journal of Fatigue, 22(7): 573-584.

3) Tsuji, I. (1990). Estimation of stress concentration factor at weld toe of non-load carrying fillet welded joints. West Japan Society of Naval Architecture, 80: 241–251. (In Japanese).