INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : SAJITH S

Roll Number : 11610333

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Thesis Title: Experimental and numerical investigation of equivalent stress intensity factor models for fatigue life predictions

Name of Thesis Supervisor(s) : Prof. K.S.R.K. Murthy and Prof. P.S. Robi

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SHORT ABSTRACT

Fracture of engineering components due to the fatigue is an important research area of fracture mechanics. Prediction of crack length versus number of loading cycles (fatigue life) or crack growth curves of vital engineering components is paramount importance in the damage tolerance design and structural integrity analyses. Due to the complex geometry, boundary conditions and loading, such predictions are to be made using the numerical methods such as finite element method etc. The Paris law is a popular and an established fatigue crack growth law for the mode I loading conditions. This law and its variants are extensively used for the prediction of the mode I fatigue life of engineering components. However, due to the same reasons such as the complex geometry, boundary conditions and loading, often, the cracks are subjected to the mixed mode loading conditions. An important issue that made understanding of the mixed mode fatigue phenomena is due to the non-self-similar crack growth i.e., crack grows in a curvilinear manner than in the direction of its axis. In 1974, Tanaka extended the mode I Paris law to the mixed mode (I/II) loading conditions and is termed as the modified Paris law. This law relates the mixed mode fatigue crack growth rate to the equivalent stress intensity factor (ΔK_{eq}) which is a function of the mode I and mode II stress intensity factors. Subsequently, due to the widespread use of the modified Paris law, a large number of various ΔK_{eq} models are appeared in the literature for the last 40 decades. Using these models, a large number of mixed mode (I/II) fatigue experiments are conducted to correlate the crack growth rate with the selected ΔK_{eq} model. Furthermore, numerous studies appeared on the numerical prediction of the mixed mode fatigue life of engineering components using the selected ΔK_{eq} models. To the knowledge of the author, no serious attempt till date is available for an exhaustive study on comparison of their performances while using with the modified Paris law for the prediction of the mixed mode fatigue life. Clearly, the analyst will be perplexed in assessing which of these models provide numerical predictions of the mixed mode fatigue lives close to the experimental data or on the conservative side. The works which provide a meaningful and substantiated answer to the above question are very scare. In view of the importance of fatigue fractures of engineering components, and frequent occurrence of the mixed mode (I/II) fatigue loading, in the present investigation an extensive study has been made to understand the nature of predictability of various ΔK_{eq} models in numerical estimation of the mixed mode (I/II) fatigue life of the engineering components while using the modified Paris law.

In the present work, predictability of the equivalent stress intensity factor models is assessed with the help of experimental and finite element simulation data. For this purpose, mixed mode fatigue crack growth experiments are carried out using the widely used Compact Tension Shear specimen using Al 6061-T6 alloy and SS 316 for three different loading angles and fatigue crack growth life are obtained. The fatigue crack growth data contains significant scattering and comparison of the crack growth lives obtained from numerical simulation is difficult. In order to overcome this, a three parameter double exponential model for fitting the fatigue life data is proposed in this work. During the numerical estimation of the fatigue life, the fatigue crack path needs to be estimated at each step. The available displacement based techniques for the stress intensity factor determination was unable to estimate the sign of the mode II stress intensity factor and thus unable to estimate the fatigue crack path. A novel displacement based technique based on the crack flank opening and sliding displacements is also proposed in this work.

Numerical fatigue crack growth simulations are performed and mixed mode fatigue life are estimated using the specimen geometry and loading conditions used in the experiment. The predictability of the equivalent stress intensity factor models are assessed by comparing the estimated fatigue life with the experimental fatigue life and important conclusions are made. For definitive conclusions, three different error estimates are formulated in this work. The numerical simulation is also repeated using the experimental results published in the literature to further verify the predictability of the selected models. The results of the present work show that, the models proposed by Irwin is identified to be providing accurate estimates of the mixed mode (I/II) fatigue life. One of the models proposed by Tanaka is found to be providing accurate fatigue life prediction for lower mode mixity angles and the model introduced by Demir is accurate at higher mode mixity angles. The models proposed by Richard and Yan are offering conservative estimates of the mixed mode fatigue life.

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