A Model Based on Finite Fracture Mechanics to Predict the Fatigue Lifetime of Notched Components

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This study presents a model based on Finite Fracture Mechanics (FFM) [1,2] to predict the fatigue lifetime of notched structures under uniaxial loading. The investigation focuses on the medium/high-cycle fatigue regime and assumes that stage II is dominant during the fatigue process, so that a linear elastic mechanics approach can be employed under mode I loading conditions.

The coupled FFM approach is based on a discrete crack extension and on the simultaneous fulfilment of two conditions: a stress requirement and an energy balance. Originally proposed in the static framework [1,2], the criterion was later extended to the fatigue limit regime [3,4]. To describe the brittle failure behavior of notched components, FFM implements two material properties: the ultimate tensile stress and the fracture toughness for static loadings; the high-cycle fatigue strength as well as the threshold value of the stress intensity factor (SIF) range for cyclical loadings.

To develop FFM for estimating finite fatigue life, a new couple of material properties called critical cyclic stress and SIF at failure are introduced. Moreover, it is supposed that they follow a power law relation with respect to the number of cycles (Basquin's equation).

To determine the variation of critical cyclic stress, a best-fitting interpolation procedure is applied to experimental data obtained from plain samples. On the other hand, to estimate SIF at failure, an inverse calibration of Basquin's equation is performed on experimental data related to notched samples. FFM reverts to a system of two equations in two unknowns: the number of cycles to failure and the critical crack advance.

Finally, the FFM model is validated using experimental results of samples weakened by V-notches, U-notches or circular holes made of EN3B steel [5]. Tests were performed under tension-compression or tension-tension loading and different loading ratios. The number of cycles to failure was determined by 50% decrease in initial stiffness. The results from the tension-compression loading case show that the FFM predictions for different samples are satisfactory, falling within the scatter band 1/3 and 3. For the tension-tension loading, , the finite life predictions agree with the experimental data, but are more conservative for bending samples. The present approach thus reveals promising for lifetime estimations of notched components and allows to overcome the drawbacks related to approaches based on critical distance which reveals a material property.

References

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