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Crack Growth-based Fatigue Reliability Evaluation Using Spline Fictitious Boundary Element Method

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Fatigue reliability evaluation is of great importance to the design and maintenance of structural components. A crack growth-based approach is proposed in this study for fatigue reliability evaluation using spline fictitious boundary element method. The proposed methodology is based on the Paris equation for fatigue crack growth rate in accordance with the amplitude of the stress intensity factor (SIF) as a crack grows. The SIF is then determined by the fracture spline fictitious boundary element method (SFBEM) based on the Erdogan fundamental solutions for plane cracked problems. The fusion of SFBEM and the Erdogan fundamental solutions is computationally efficient and provides a powerful tool for crack growth-based fatigue life prediction. On this basis, fatigue life for structures experiencing variable loading during their life can be obtained in conjunction with the Miner rule for accumulative fatigue damage. To account for the inherent uncertainties in crack geometry, material properties and external loadings of structural components, a response surface approach based on the above approach is further adopted to predict the mean value and standard deviation of the fatigue life for a given component. The fatigue failure probability within the design period of the component can be finally evaluated using the random characteristics of the fatigue life. Numerical examples based on the mode-I and mixed-mode crack problems are presented to validate the present method. An engineering application to the fatigue reliability evaluation of a long-span cable-stayed bridge under vehicle loadings is also given in the present study showing the effectiveness of the proposed method.

Keywords: Fatigue crack growth, Life prediction, Reliability, Fracture mechanics, Spline fictitious boundary element method