The safety analysis concept of welded components under cyclic loads using fracture mechanics method

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Fracture Mechanics process of Welded Joint is a very vast research area and has many possibilities for solution and prediction. Although the fatigue strength (FAT) and stress intensity factor (SIF) solutions are reported in several handbooks and recommendations, these values are available only for a small number of specimens, components, loading and welding geometries. The available solutions are not always adequate for particular engineering applications. Moreover, the reliable solutions of SIF are still difficult to find in spite of several SIF handbooks have been published regarding the nominal applied SIF. The effect of residual stresses is still the most challenge in fatigue life estimation. The reason is that the stress distributions and SIF modified by the residual stresses have to be estimated. The stress distribution is governed by many parameters such as the materials type, joint geometry and welding processes. In this work, the linear elastic fracture mechanics (LEFM), which used crack tip SIFs for cases involving the effect of weld geometry, is used to calculate the crack growth life for some different notch cases. The variety of crack configurations and the complexity of stress fields occurring in engineering components require more versatile tools for calculating SIFs than available in handbook's solutions that were obtained for a range of specific geometries and load combinations. Therefore, the finite element method (FEM) has been used to calculate SIFs of cracks subjected to stress fields. LEFM is encoded in the FEM software, FRANC, which stands for fracture analysis code. The SIFs due to residual stress are calculated in this work using the weight function method. The fatigue strength (FAT) of load-carrying and non-load carrying welded joints with lack of penetration (LOP) and toe crack, respectively, are determined using the LEFM. In some studied cases, the geometry, material properties and loading conditions of the joints are identical to those of specimens for which experimental results of fatigue life and SIF were available in literature so that the FEM model could be validated. For a given welded material and set of test conditions, the crack growth behavior is described by the relationship between cyclic crack growth rate, da/dN, and range of the stress intensity factor (K) , i.e., by Paris' law. Numerical integration of the Paris' equation is carried out by a FORTRAN computer routine. The obtained results can be used for calculating FAT values. The computed SIFs along with the Paris' law are used to predict the crack propagation. The typical crack lengths for each joint geometry are determined using the built language program by backward calculations. To incorporate the effect of residual stresses, the fatigue crack growth equations which are sensitive to stress ratio R are recommended to be used. The Forman, Newman and de Konig (FNK) solution is considered to be the most suitable one for the present purpose. In spite of the recent considerable progress in fracture mechanics theories and applications, there seems to be no, at least to the author's knowledge, systematic study of the effect of welding geometries and residual stresses upon fatigue crack propagation based completely on an analytical approach where the SIF due to external applied load (Kapp) is calculated using FEM. In contrast, the SIF due to residual stresses (Kres) is calculated using the analytical weight function method and residual stress distribution. To assess the influence of the residual stresses on the failure of a weldment, their distribution must be known. Although residual stresses in welded structures and components have long been known to have an effect on the components fatigue performance, access to reliable, spatially accurate residual stress field data are limited. This work constitutes a systematic research program regarding the concept for the safety analysis of welded components with fracture mechanics methods, to clarify the effect of welding residual stresses upon fatigue crack propagation.