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Fatigue crack growth in cruciform welded joints: influence of residual stresses and of the weld toe geometry

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Abstract

The aim of the present investigation is to calculate the fatigue life of cruciform welded joints by taking into account both the effect of residual stresses and the influence of the weld toe geometry. Two and three dimensional finite element models, with cracks as initial defects, will be constructed for this purpose. Fatigue crack growth analyses are performed by using the node release technique, together with the finite element program ABAQUS. The welding residual stresses, as well as the plasticity induced crack closure effects, are considered. The effective cyclic J-integral (ΔJ_{eff}) is used as crack tip parameter in a relation similar to the Paris equation for the calculation of the fatigue life. For this purpose, a specific code was written for the determination of ΔJ_{eff} at each crack length configuration. The impact of residual stresses on ΔJ_{eff} as well as on the fatigue life during short crack growth is investigated. Results reveal that the influence of residual stresses can be neglected only for large load amplitudes. The calculated fatigue lives are compared with experimental data and a good accordance between both results is achieved. The influences of the weld toe radius and of the weld flank angle are also investigated.

Keywords: Effective cyclic J-integral; fatigue crack growth; residual stress field; welded joint; weld toe radius/flank angle.

1. Introduction

Welding is one of the most important joining methods in the technology, particularly for metallic structures. Thus, improving the design of welded structure is of high technical use. Welded structures are in general exposed to fatigue failure: under cyclic external loading, an immense part of the crack growth takes place in the weld notch area. As a result of the notch effect, the local behaviour of the weld in this area is elastic-plastic. Thereby, the material is subject to transient processes like the cyclic hardening/softening, the cyclic relaxation and ratcheting.

During the welding process, residual stresses can arise in the joint because of the different heating and cooling cycles during this process. In case of an external cyclic loading, these stresses can have an influence on the fatigue life of the welded structure: a tensile residual stress field for example reduces the fatigue life, while a compressive residual stress field extends it [1-5]. Actually, the initial residual stress field, induced during welding, may not remain stable: it can relax or redistribute due to cyclic loading or to crack extension [6-10]. Furthermore, the build-up of the residual stress field in the plastic zone in front of the crack takes place simultaneously with the gradual build-up of crack closure effects as well as with the evolution of the cyclic hardening/softening, the cyclic relaxation and ratcheting.

Crack closure means “contact between crack faces” and the main closure mechanisms are: the plasticity-induced crack closure, the oxide-induced crack closure and the roughness-induced crack closure [11-20].