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Fatigue Crack Front Behavior near the Free Surface

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Abstract: The development of the fatigue crack front shape in the engineering materials is still not fully understood problem. The fatigue crack front shape is influenced by many factors, e.g., crack closure, geometry of the structure, microstructure of the material, free surface effect, etc. The aim of this contribution is to provide experimental and numerical results that could help to quantify the influence of the main effects. The fatigue test results on aluminum is provided with emphasize on the geometry of the crack front. Experimentally obtained fatigue crack front shapes are compared with numerically estimated crack front shapes and discussed in the contribution.

Introduction

Phenomenon of fatigue of materials has already been studied for many years and there still exist many unknowns. One of them concerns the crack front curvature. By inspecting the fatigue fracture surface the initially straight crack front develops into the curved crack front [1].

Experimental observations demonstrated that as soon as the crack front shape is changed into the saturated (final) curved crack front the further crack propagation does not influence the crack front shape [2]. This implies that if the crack front reaches its saturated state the crack growth rate is constant along the crack front.

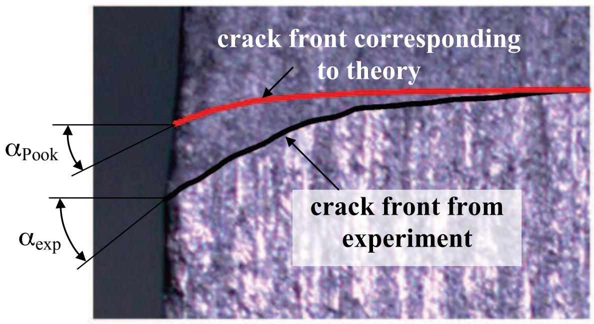

Fig. 1: Development of the fatigue crack front from the initially straight crack front

The intersection of the crack front and free surface is called vertex point. It has been shown that the stress singularity in the vertex point is different than in the centre of the body [4] and this affect the intersection angle between the crack front and the free surface in the vertex point, see Fig. 1. Pook [6] pointed out that the intersection angle depends on the Poisson's ratio, however, this is valid only for the brittle materials. Comparing theoretical crack front shapes and the experimental data obtained on the aluminum it is possible to see discrepancy between crack intersection angles, see Fig. 1. Whereas Pook [6] predicts the intersection angle around 12° the experimental measurement show more than 60°. This discrepancy is not well clarified in the literature. One of the possible explanations could be that the plasticity induced crack closure becomes important and together with the vertex singularity leads to much higher crack front curvature than predicted based on the theory of Pook. Therefore, for the prediction of the crack front shape the assumption of the constant crack closure along the crack front can be used [7].

The aim of this paper is to provide new numerical results obtained by the finite element method, see Fig. 2 where the numerical model is shown. The boundary layer method is used here as it

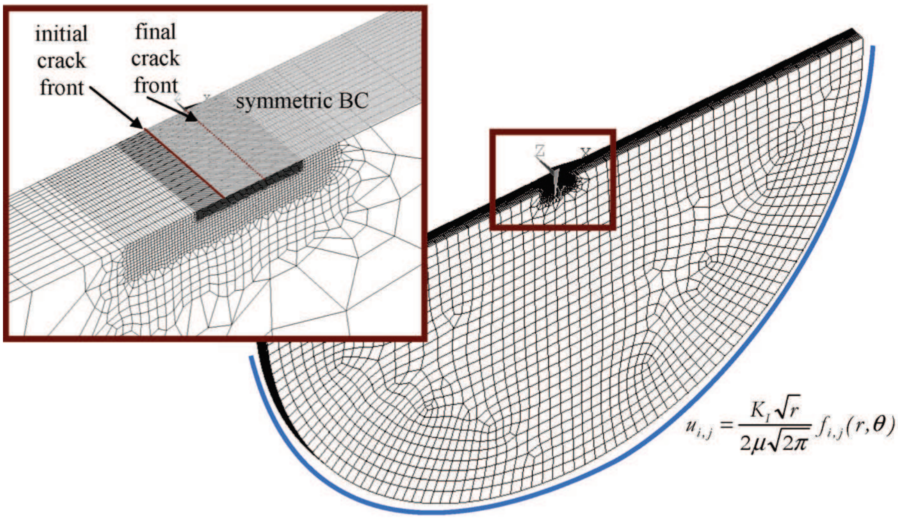

Fig. 2: Preview of the finite element model of the boundary layer method for modeling of the crack closure phenomenon

provides possibility for generalization of the obtained results [8]. The comparison of the straight and curved crack front shape is provided here from the perspective of the plasticity induced crack closure. This contribution contains also an overview of numerical modeling techniques of the plasticity-induced crack closure in the three-dimensional body. The numerically obtained results are compared with the experimentally obtained fatigue crack front shapes found on the aluminum.

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