Investigation of the in-depth growth of micro cracks in ferritic-martensitic dual-phase steel

P. Pitz*, L. Zellmer, A. Brueckner-Foit

Institute for Materials Engineering, University of Kassel, Moenchebergstrasse 3, D-34109 Kassel, Germany

*p.pitz@uni-kassel.de

Keywords: crack depth, fatigue crack growth, CTOD, finite element analysis, focused ion beam

Well-known techniques for three-dimensional crack observations are either destructive (e.g. focused ion beam tomography) or require a lot of effort, for example X-ray tomography using synchrotron radiation. Consequently, only selected cracks can be analyzed with respect to their spatial extension.

This paper deals with a newly developed non-destructive approximation procedure which is used to obtain an estimate of the in-depth extension of small fatigue cracks based on the crack face displacement on the surface and its relation to fracture mechanics loading parameters. The procedure can be briefly summarized as follows: Smooth specimens containing fatigue cracks are mounted in a micro-tensile loading stage which can be placed in the SEM. The specimen is then loaded and the ensuing crack face displacement is measured. An example of such a crack with and without loading is given in Fig. 1. A three-dimensional surface crack with the same trace on the surface is then defined by a suitable FE mesh (see Fig. 2). The in-depth geometry of the model crack is simplified, and its depth is adjusted until similar values of the crack face opening are obtained as those measured in the SEM. In-depth crack extension can be studied by observing the same fatigue crack in dependence of the number of applied load cycles and by adjusting the depth of the model crack at each observation point.

This procedure is applied to a ferritic-martensitic steel as well as to a pure ferritic steel in order to investigate the influence of the hard martensitic phase. Fatigue tests were conducted with small dogbone-shaped specimen under fully reversed axial loading (R = -1) with a constant stress amplitude. By using a long-distance optical microscope, it is possible to interrupt the fatigue test when the surface crack length amounts to a few grains. The real in-depth extension of the cracks is compared to results obtained with the model cracks using FIB destructive analysis.

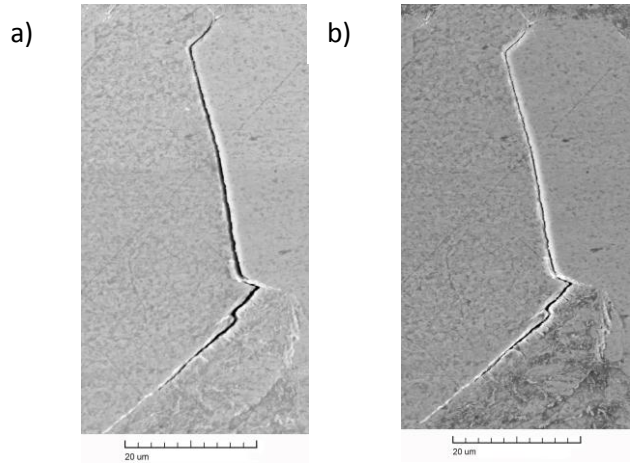

Figure 1: Surface Crack
a) with
b) and without loading

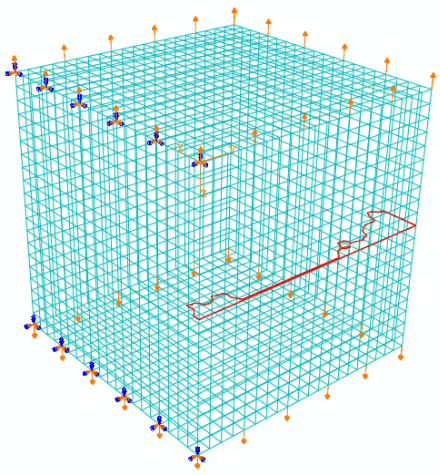

Figure 2: three-dimensional surface crack