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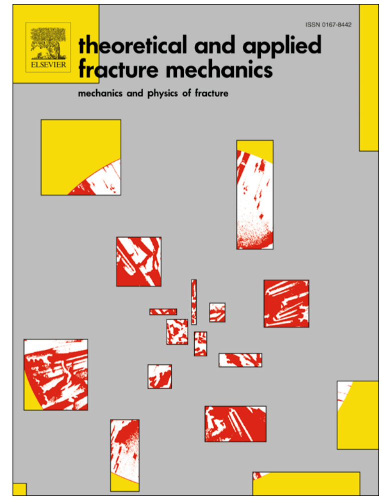

Experimental, analytical and numerical analyses of constant and variable amplitude loadings in the very high cycle fatigue regime

Carsten Stäcker, Manuela Sander

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Experimental, analytical and numerical analyses of constant and variable amplitude loadings in the very high cycle fatigue regime

M. Sc. Carsten Stäcker, Prof. Dr.-Ing. Manuela Sander

Fakultät für Maschinenbau und Schiffstechnik - Lehrstuhl für Strukturmechanik
Albert-Einstein-Str. 2
D-18059 Rostock
Fon: +49 (0) 381 / 498 9345
Corresponding Author: carsten.staecker@uni-rostock.de

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ABSTRACT

Mechanical components often exceed a very high number of cycles in their fatigue life. Within the very high cycle fatigue (VHCF) regime, different damage mechanisms occur and the conventional fatigue limit is not valid any more, which has to be considered in a safety-relevant design. Especially in reference to operation loads or variable amplitude loading insufficient knowledge exists. Therefore, within the scope of this paper, the cumulative frequency distributions Felix/28 and WISPER are applied by blocks on a high strength steel by means of an ultrasonic fatigue testing system. The results are compared to those of constant amplitude loading at different stress ratios. Due to the variable amplitude loadings arrest marks are produced within the fish-eye surrounding the inclusion. The sizes and the area, where arrest marks are observable, as well as the spacings between the arrest marks are influenced by the different load sequences. By counting and measuring the arrest marks an average crack growth rate for the crack propagation within the fish eye can be calculated. For further studies a three-dimensional finite element model is created to work out the stress distribution surrounding internal inclusions or cavities and to compare the obtained stress intensity factors of a circumferential crack initiating at the imperfection with analytical solutions. Because VHCF failure is highly dependent on the type of the imperfection and also on the interaction to the surrounding matrix, the stiffness of the inclusion as well as the contact formulation between the matrix and the inclusion in the finite element model are modified. Finally, three-dimensional crack propagation simulations are performed to investigate the influence of crack closure behaviour and the mean stresses.

NOMENCLATURE

a	Crack length
a_0	Intrinsic crack length
A_5	Elongation at fracture
Δa	Crack growth increment
CA	Constant amplitude
CPS	Crack propagation simulations
ctn	Crack tip node
E	Young's modulus
eek	Extrapolation first node technique
fn	First node behind the crack tip
H_0	Maximum number of cycles of load sequence
HV	Vickers hardness
IST	Incremental step test
k	Slope of S-N curve
K	Stress intensity factor
ΔK_{defect}	Cyclic stress intensity factor range for defect sizes
K_{max}	Maximum stress intensity factor
K_{op}	Crack opening stress intensity factor