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Multiple crack initiation and propagation in weldments under fatigue loading

M. Madia[a,]*, B. Schork[b], J. Bernhard[c], M. Kaffenberger[b]

[a]*Bundesanstalt für Materialforschung und -prüfung (BAM), Division 9.1, Unter den Eichen 87, D-12205 Berlin, Germany*
[b]*Center for Engineering Materials – State Materials Testing Institute Darmstadt (MPA) Institute for Materials Technology (IfW), Technical University Darmstadt, Grafenstraße 2, D-64283 Darmstadt, Germany*
[c]*Fraunhofer Institute for Structural Durability and System Reliability LBF, Bartningstraße 47, D-64289 Darmstadt, Germany*

Abstract

The work aims at addressing the modelling and implementation of criteria for multiple crack propagation, including interaction and coalescence, for a more reliable fracture mechanics-based prediction of stress-life curves for weldments.
A large experimental work is presented in which micro-cracks have been made visible by heat-tinting at successive stages of fatigue life of the welded specimens. Here the correlation between the number of initiation sites and the applied stress level has been also investigated.
The criteria have been implemented in in-house software, which allows multiple fatigue crack propagation, and validated against selected experimental tests. The results have shown that the modelling of multiple crack propagation and interaction is crucial for the prediction of the fatigue strength of weldments, both in finite and infinite life regime.

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Keywords: Weldments; fatigue strength; multiple crack propagation; short cracks

* Corresponding author. Tel.: +49 (0) 30 8104 4166.
E-mail address: mauro.madia@bam.de

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Nomenclature

a	crack depth
a_i	initial crack depth
c	crack semi-length
h	excess weld metal
k	depth of the secondary notches
k_t	stress concentration factor
K_{LC}	stress intensity factor for long cracks
K_{SC}	stress intensity factor for short cracks
ℓ	width of each stripe in the modelling of the weld toe geometry
L	weld width
s	distance of the surface tips of two neighbouring cracks
T	thickness of the base plate
α	flank angle
ΔJ	cyclic J-integral
σ	stress
ρ	weld toe radius

1. Introduction

The investigation of multiple crack initiation and propagation is crucial for the structural integrity assessment of many engineering components subject to fatigue loading. Diverse metallic materials for technical applications are characterized by populations of defects which are dispersed in the metal matrix, like shrinkage cavities and gas pores in ductile cast iron [1] or micro-pores and un-melted powder in components obtained by additive manufacturing [2].

Micro-cracks initiate very often from these defects in the early stage of fatigue life, they propagate individually and simultaneously until they eventually coalescence with neighbouring cracks. Multiple crack initiation can be also triggered by irregularities of structural features, like weld ripples in weldments [3]. Here the initiation sites of micro-cracks are highly stressed regions at local stress raisers.

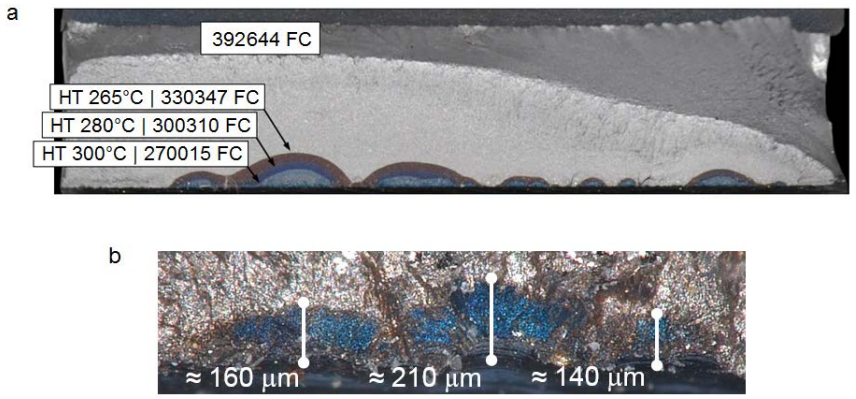

Fig. 1. Post-mortem analysis of the fracture surfaces in case of a cruciform joint made of medium strength steel (S355NL): (a) heat-tinting (HT) has been used to make the cracks visible for different fatigue cycles (FC); (b) small cracks marked by means of heat-tinting at about 40% of the total life of the joint.