Engineering Fracture Mechanics 174 (2017) 21–29

Contents lists available at ScienceDirect

Engineering Fracture Mechanics

journal homepage: www.elsevier.com/locate/engfracmech

Facet formation at the crack front under combined crack opening and anti-plane shear loading

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ARTICLE INFO

Article history:
Received 8 September 2016
Received in revised form 25 November 2016
Accepted 9 December 2016
Available online 18 December 2016

Keywords:
3D-mixed-mode
Facets
Fatigue
Fracture
CTSR-specimen

ABSTRACT

This article addresses the topic of crack initiation and crack growth behaviour under combined cyclic mode I- and cyclic mode III-loading. Such loading combinations especially lead to a crack, which unscrews out of its initial orientation and segments into many single cracks respectively facets. This characteristic of facet formation depicts the crucial difference to crack propagation under pure mode I-loading, pure in-plane shearing (mode II) as well as 2D-mixed-mode-loadings. Since investigations about these stepped fractured surfaces are scarce till today, their characterisation remains to be researched deeper. Consequently, a facet quantification is performed by some characteristic dimensions, which will be presented and discussed within this paper. After the description of experiments for facet creation, a quantification of each facet will be analysed concerning characteristic dimensions by the crack profile near the initial position. Finally, the findings will be illustrated and discussed in this contribution.

1. Introduction

Event till today, an unsolved and long existing research matter in fracture mechanics is the characterisation of crack initiation and growth behaviour under combined mode I- and mode III-loading. This loading combination specially leads the initial crack to twist out of its previous direction and separate into multiple daughter cracks, in other words facets. Afterwards these facets form a stepped fractured surface in the crack propagation process. Moreover, Pons and Karma [1] observed an increase in space between the facets during the crack growth event, which finally leads to a coarsening and enlargement of each facet. Furthermore, Knauss [2] and Sommer [3] concluded from their experimental researches, that the facet formation directly happens perpendicular to the axle of the maximum principal stress with a twisting angle ψ_0 of around 45° with respect to the initial crack. The definition of the crack twisting angle ψ_0 is illustrated in Fig. 1.

Building on from the researches and findings of Knauss [2], Sommer [3] as well as from the findings of Pons and Karma [1], a quantification of facets will be presented and discussed within this article. The purpose is to get new insights and facts about facet creation and initiation behaviour under combined mode I- and mode III-loading. Finally, an analysis of a possible application of the hypothesis developed by Lin et al. on the experimental results is carried out. This hypothesis is able to describe the crack initiation under combined mode I-mode III-loadings.

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http://dx.doi.org/10.1016/j.engfracmech.2016.12.004
0013-7944/

Nomenclature

AFM	All Fracture Mode
CTSR	Compact Tension Shear Rotation
f_{as}	ascending facets
f_{fa}	falling facets
A	elongation at break
B	bridging region
E	Young's modulus
F	force
ΔF	cyclic load range
K_{IC}	fracture toughness for mode I-loading
ΔK_I, ΔK_{III}	cyclic stress intensity factor for mode I- and mode III-loading
ΔK_{IC}	critical cyclic stress intensity factor
$\Delta K_{I,th}$	threshold value for mode I-loading
ΔK_V	cyclic comparative stress intensity factor
N	cycles
R	stress ratio
R_m	ultimate strength
$R_{p0,2}$	0.2%-yield strength
a	crack length
a_0	initial crack length
c	facet distance
d	projected facet length
e	width of the bridging regions B
da/dN	crack growth rate
l	specimen length
t	specimen thickness
w	specimen width
α	loading angle
β	loading angle
ν	Poisson's ratio
τ_z	shear stress in z-direction
ψ_0	crack twisting angle
ψ_F	facet angle

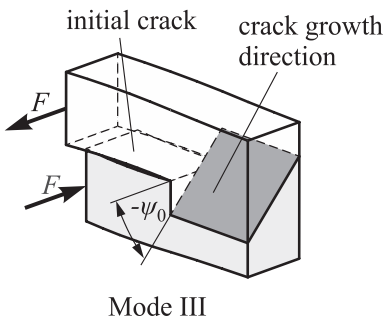

Fig. 1. Definition of the crack twisting angle ψ_0.

2. Crack growth experiments under combined cyclic mode I- and cyclic mode III-loading

In order to create facets, experiments under mixed-mode I + III-loading were performed using the CTSR-specimen and the appropriate loading device [4,5]. The next section gives a detailed explanation of the material that is investigated, the CTSR-specimen and the experimental procedure of the mixed-mode tests performed.