CRACK DEFLECTION AT CURVED INTERFACES. A FINITE FRACTURE MECHANICS ANALYSIS

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Abstract

Curved weak interfaces present promising advantages to be implemented as crack arrestors in structures designed under the tolerant-design principles. Among other advantages, they neither add extra weight nor affect significantly to the global stiffness of the structural element, in contrast with other crack arrestors. To be employed as crack arrestor, it is key that the interface can deviate the crack. If the crack penetrates across the interface, the effect of the weak interface as crack arrestor is canceled. In view of this, this work studies how to set the interface parameters to promote the crack deviation along the interface. In particular, following the dimensional analysis of the problem, the effect of three significant dimensionless parameters is studied: interface to bulk fracture toughness, interface to bulk tensile strength and the interface curvature radius normalized with the material characteristic length. The study is carried out using the Coupled Criterion of the Finite Fracture Mechanics,

1. Introduction

The demanding interest for the achievement of optimized performance of layered materials and structural systems has stimulated the conception of multiple material arrangements at different scales. These arrangements have been extensively exploited in different applications with special interest on fracture resistance capabilities. This trend ranges from the conception of multilayered systems at the macroscale to engineering the design of microstructures, mimicking many concepts and designs found in nature. Specifically, several investigations aimed at providing a profound mechanical insight of the underlying cracking mechanisms in bio-inspired interface designs, pinpointing their potential for next generation of engineering products.

Within this context, one of the most relevant aspects that inherently determines the effective fracture toughness of such systems is characterized by stability of the composing interfaces in conjunction with their ability to engineering the potential crack paths. Representative applications of these events can be found in thermal and environmental barrier coatings, delamination events in layered ceramics and laminated composite materials, micromechanics cracking phenomena in composite materials, among many other applications. The importance of these phenomena can be also encountered in the designs of crack arrestors in many engineering applications, whereby the presence of interfaces plays a major role.

The comprehensive understanding of potential fracture phenomena in heterogeneous materials has been a research topic that has attracted a significant scientific attention over the last decades. The competition propagation vs deflection of a crack impinging on an interface has been extensively investigated by different authors.

However, many systems are characterized by the presence of interfaces non-planar profiles, including textured definitions or wavy patterns which can be accordingly engineered to achieve outstanding fracture response. Despite this potential, at present, the vast majority of previous studies have concerned with scenarios in which a crack with an arbitrary orientation impinges at a flat interface. Notwithstanding, structured- and wavy interfaces might lead to crack trapping or retardant phenomena, whose efficiency strongly depend upon the geometric definition in conjunction with the materials (in terms of stiffness, strength and fracture toughness) characteristics of the interface and the adjoining bodies. Stemming from the scarcity of previous studies on the matter, in this investigation, the problem of the competition between penetration and deflection of a crack impinging at a curved interface is analyzed. The analysis is carried out using the coupled criterion of the finite fracture mechanics.

2. Results

The results show that:

a) The ratio of interface to bulk fracture toughness is the most relevant dimensionless parameter to switch from crack penetration to deflection.
b) The dimensionless radius of the curved interface affects also significantly the failure mechanism governing the deflection/penetration competition.
c) The other dimensionless parameters extracted from the dimensional analysis affects much less the competition.

3. Conclusions

The coupled criterion of the finite fracture mechanics is able to predict successfully the competition between crack deflection and competition at curved weak interfaces. In particular it predicts a strong influence of the ratio of bulk to interface fracture toughness and dimensionless radius of the interface. These results is in agreement with some preliminary experiments.

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