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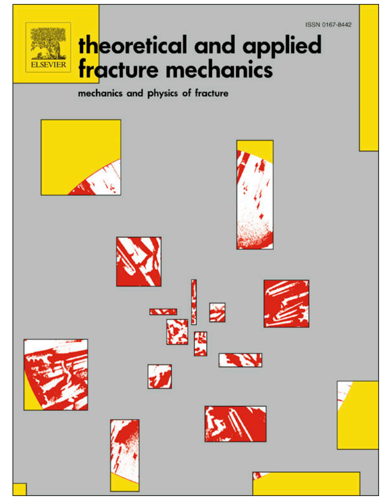

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Crack arrest through branching at curved weak interfaces: an experimental and numerical study

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Abstract

The phenomenon of arrest of an unstably-growing crack due to a curved weak interface is investigated. The weak interface can produce the deviation of the crack path, trapping the crack at the interface, leading to stable crack growth for certain interface geometries. This idea could be used as a technical solution for a new type of crack arrester, with a negligible impact on the global stiffness, strength and weight of the structure. In order to exploit this concept, an experimental campaign based on photo-elasticity and digital image correlation (DIC) is carried out, showing the capability of curved weak interfaces to arrest cracks. The experiment is repeated for several geometrical configurations through the modification of the interface curvature radii. The phenomenon of crack deviation and subsequent arrest at the interface is also investigated with the assistance of a computational model based on the finite element method. The computational predictions provide the rationale for the interpretation of the experimental observations, and distinguish between the different behaviour of concave and convex interfaces. Consequently, as is shown in the present study, the curved interface concept fosters new routes for the attainment of structures with enhanced fracture resistance capacities, which are of paramount importance for materials and components used in extreme conditions.

Keywords: Curved interface, Crack arrest, Fracture mechanics, Experimental mechanics, Crack-interface interaction, Crack branching

1. Introduction

The damage-tolerant approach has become a recurrent standard for the design of structures in aerospace and ship-building industries, among others, see e.g. Braga et al. (2014). The objective of this methodology is the specific design of structures tolerant to the presence of flaws, i.e. where the presence of cracks does not imply necessarily the catastrophic failure of the structure upon their propagation. Following this idea, many attempts have been made in materials science in order to identify optimal material microstructures to arrest cracks, also inspired by nature, see e.g. Gao (2006); Gao et al. (2003, 2004); Paggi and Wriggers (2012). However, the application of this approach generally requires: (*i*) advanced inspection techniques in order to detect damage events prior they reach the corresponding critical sizes, and (*ii*) the design of structural elements that enable either preventing or slowing-down the progress of crack evolution and the related structural softening. Within this context, the so-called crack arresters can be understood as structural elements that are designed for this purpose. In the last years, such a concept has been prolifically employed in different practical applications in engineering, see e.g. (Lena et al., 2008; Somerville, 1982). In materials science, the role of structural arresters can be played by material interfaces, suitably arranged across the scales in order to prevent the catastrophic propagation of flaws. For instance, Paggi and Wriggers (2012) have shown that a two-scale arrangement of material interfaces can be profitable to stop the propagation of cracks from the microscale to the mesoscale in polycrystalline materials used for extreme structural applications such as drilling.

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