Materials and Design 32 (2011) 2490–2495

Contents lists available at ScienceDirect

Materials and Design

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

Technical Report

Linear analysis of mechanics of single and multiple cracks at fiber/matrix interface using axisymmetric model

A.S. Bouchikhi *, A. Megueni, A. Lousdad, K. Reffessi

Department of Mechanics Engineering, BP 89, Cité Ben M'hidi-Sidi Bel Abbes (22000), Djillali Liabès University of Sidi Bel-Abbès, Algeria

ARTICLE INFO

Article history:
Received 5 July 2010
Accepted 27 October 2010
Available online 11 November 2010

ABSTRACT

It is well known that the life of material composite depends on the hardness of the interface between the fiber and the matrix. Herein, the aim of this work is the calculation by finite element method interaction effect between a crack and an interface by energy release rate approach. The first part of this work is devoted to the crack normal to the interface and the second one deals with the crack terminated at the interface. In this study, two cases are considered using a copper matrix with different fibers. An axisymmetric model has been used to evaluate the conditions for the crack deflection/penetration by the interface as well as the effects of the volume percent of fibers and the effects of the distance between the crack tip and the interface were highlighted as well as the effects of the elastic properties of two bonded materials.

1. Introduction

Knowledge of damage mechanisms at micromechanical level in composite materials is essential for the elaboration of physically based failure criteria to be applied in the design of composite structures [1].

There are a number of studies which analyzes details of crack penetration and/or deflection at an interface with specifically focusing on the competition between the two modes of cracking.

Han et al. [2] have treated interaction among interface, multiple cracks and dislocations. The interaction effect of any number of collinear interface cracks is then numerically analyzed with the hyper-singular integral equations Sun et al. [3].

The mechanism of failure associated to transverse loads is commonly known as inter-fiber failure (also known as matrix failure). In previous works by Parts and co-workers [4–7], it was demonstrated that, under the particular case of tension loads, this mechanism of failure is characterized by the appearance of small debonds (interface cracks) at the fiber–matrix interfaces that grow along the interfaces. After these interface cracks have grown to a certain length at the interfaces, they change their direction of propagation, kinking into the matrix and propagating unstably through it, thus leading to the macro failure of the ply. The conclusions of these works lead the interface crack growth to be considered as an essential step in the whole damage process, its role being even more emphasised in the case of cyclic loads [8].

Other investigators, e.g. Voyiadjis and Deliktas [9], Zhu and Sun [10], Espinosa et al. [11], Williams and Vaziri [12], Tang et al. [13], Maa and Cheng [14], have employed numerical and analytical methods to predict damage initiation and propagation in composite structures. It is common to assume that damage initiates at a point when the state of deformation and/or stress there lies on a damage envelope defined in terms of the equivalent stress, or the equivalent strain, or their combination. The moduli are assumed to degrade with the development of damage till they become zero, and the material point then is taken to have failed completely. Other criteria for predicting damage include a fracture mechanics approach based on the energy release rate, or a distributed damage mechanics approach involving an evolution equation for damage that must be integrated together with equations of motion.

1.1. Energy release rate criterion

The failure strain of the matrix in uniaxial tension is generally smaller than that of fibers, and this provides the reasonable assumption that the first crack in a composite is developed from the largest intrinsic flaw in the matrix. Under increasing tensile loading in the fiber direction, this microcrack grows until it reaches the fiber/matrix interface; then it may either deflect along the interface or penetrate into the fiber. If the interface is weak enough for the matrix crack to be deflected along the interface, the fibers remain intact and the composite can be tough. If the interface is too strong, the matrix crack penetrates into the fibers and the composite becomes brittle like a monolithic ceramic. Therefore, the crack propagation behavior at the interface is critical to toughening in composites. The prerequisite conditions to obtain an interfacial debond crack from a main matrix crack has recently been analyzed in terms of energy release rates by a number of researchers [15–18]. The deflection of a matrix crack at the fiber/matrix interface

* Corresponding author. Tel.: +213 48 56 54 44; fax: +213 48 54 43 44.
E-mail address: asbouchikhi@yahoo.fr (A.S. Bouchikhi).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.10.029