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ANALYSIS OF DYNAMIC INTERFACIAL CRACK GROWTH IN FIBER-REINFOCED COMPOSITE STRUCTURES

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ABSTRACT

Composite materials in the form of laminates structures are widely utilized for strategic applications in both mechanical and aerospace engineering fields. However, substantial experimental evidences have shown that delamination phenomena dramatically affect composite structures by means of catastrophic failure modes [1-2].

During the last decades many efforts have been spent, mainly, to analyze static fracture behavior, giving rise to several studies devoted to predict crack growth phenomena. Most research efforts were confined to static or low velocity crack propagation, whereas dynamic characteristics of delamination phenomena in the frameworks of composite structures are not completely investigated.

In the present paper, the dynamic behavior of fiber reinforced composite structures is investigated. The model is developed in the framework of a steady state crack growth, in which the delamination phenomena are assumed to be time invariant with respect to a reference system fixed at crack tip and moving at constant speed. This assumption is motivated by several experimental observations, which show that the crack moves at a constant speed even thought the crack-tip motion may not be considered as a steady-state motion [3].

Typically, the composite structures are formed by weak interfaces in which the interfacial finite length defects are able to growth As a consequence, the delamination modeling is based on the interface methodology and the plate/beam formulation. In this study an investigation on delamination models based on plate theories and interface technique for analyzing general delamination problems in composite structures is presented. The proposed method considers the laminated structures as composed by first-order shear deformable plate elements interconnected by interface elements, whose constitutive relationships are based on fracture and contact mechanics [4].

Delamination phenomena are discussed in the framework of dynamic analyses, investigating the influence of both crack growth speed and inertial effects on the energy release rate. In particular, under steady state crack growth assumptions, closed form solutions are obtained for specific loading conditions and geometric configurations.

Expressions related to the multilayered composite are provided emphasizing the

influence of new standard terms related to kinematic assumptions and inertial effects of the composite structures. A parametric study of the energy release rate in terms of crack tip speed, shear deformability and crack growth conditions are provided. Finally, comparisons with numerical solutions obtained by a finite element approach guarantee about the reliability of the closed form expressions for simple case referred to mode I and mode II loading conditions to predict the dynamic energy release rate and the "crack arrest phenomenon".

In order to show the influence of the crack advance from the dynamic structural behavior, a simple example regarding a double cantilever beams with two opening forces involving pure mode I loading condition is reported in Fig.1. In particular, the relationship between dimensionless Energy Release Rate and speed of the crack tip front normalized over the shear wave speed of the laminate (c_{sh}) for different geometric ratios of the composite structure is investigated. As far as the speed increases large contact zones existing behind the crack tip front are observed and consequently the normalized vertical displacements close to the crack tip, even before the Rayleigh speed, became negative exactly when the ERR approaches to zero, leading to interfacial "crack arrest phenomena".

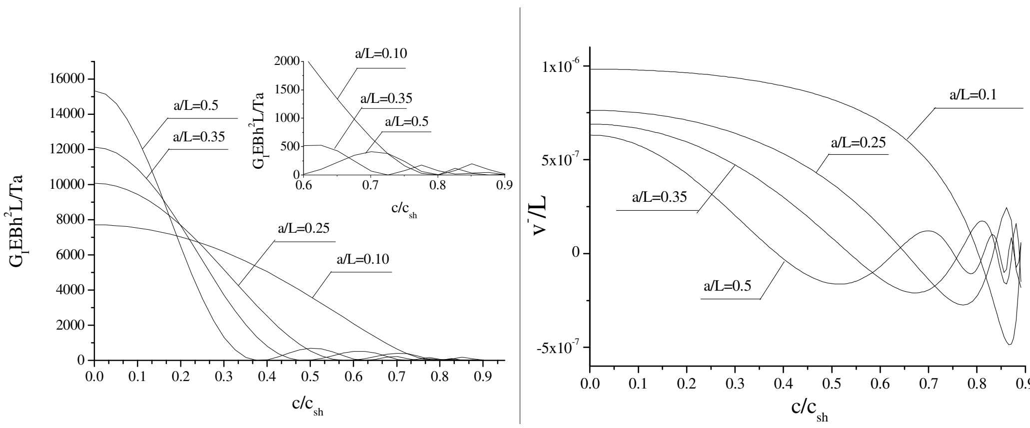

Fig.1 a) Dimensionless ERR for different speed of the crack front and initial delaminated length.

b) Dimensionless relative displacements close to the crack tip front.

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