MICROMECHANICS-BASED EVALUATION OF INTERFACES: THE CONCEPT OF DEVIATION POTENTIAL

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Keywords: *composites, multilayers, interface, debonding, failure*

1 General Introduction

Interfaces are a key element in ceramic matrix composites (CMCs), but also in several material assemblies, such as, for instance, multilayers. This is not only because they can cause crack deflection and make materials damage tolerant, but also because they can be tailored with regard to material performances.

An appropriate approach to crack deflection at interfaces or within interphases is based on the basis of the Cook and Gordon's mechanism: a crack is nucleated along an interface, first, ahead of a propagating crack; deflection of this crack, then, results from coalescence with the interface crack.
The stress state induced by a crack was computed in a cell of bimaterial using the finite element method. The cell represents a matrix and a fiber, or an interphase and a fiber or two layers in a multilayer. A master curve was established. It represents the debonding condition based on strengths and elastic moduli of constituents. Then a deviation potential was defined. Deviation potentials were calculated for various fibre/matrix or layer combinations.

2 Stress based approach to crack deflection

The Cook and Gordon's mechanism based approach is an alternative to those models that consider a stationary crack lying at the interface. It is based on the tri axial stress-state induced by the crack and it is supported by various experimental observations. The stress field at the tip of a crack placed in a homogeneous material subjected to uni-axial tension is multi-axial. It involves a stress component parallel to the crack plane that reaches a maximum at a critical distance from crack tip. Thus, when an interface is placed perpendicular to crack growth direction, the stress component parallel to crack plane may cause interface failure (opening mode).

3 Model

The stress state was computed in a cell of dissimilar materials, subjected to a uniform stress, and containing a crack (figure 1). The finite element method was used.

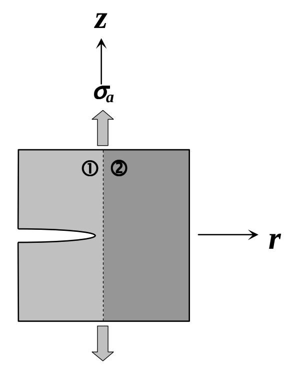

Fig.1. Cell of dissimilar materials subjected to a uniform tensile stress

A debonding condition was derived from the comparison of stresses in the interface and in the uncracked material (referred to as material 2 in figure 1), with the resistances of the interface and of the uncracked material:

$$\frac{\sigma_2^c}{\sigma_2^c} \leq \frac{\sigma_{rr}(r=l)}{\sigma_{zz}(r \geq l, z)} \qquad (1)$$

where σ_{rr} (r = l) is the opening stress component, parallel to crack plane, acting on the interface, σ_{zz} (r ≥ l, z) is the tensile stress operating on the uncracked material. σ_i^c is the interface strength and σ_2^c is the strength of uncracked material.

When σ_2^c is not available, the following condition can be derived from (1):

$$\frac{\sigma_i^c}{\sigma_2^c} \leq \frac{\sigma_{rr}^{\max}}{\sigma_{zz}^{\max}(r \geq l)} \qquad (2)$$

where $\sigma_{zz}^{\max}$ is the maximum of σ_{zz} , and $\sigma_{rr}^{\max}$ is the maximum of σ_{rr} .

4 Concept of deviation potential

Ratio of maximum stresses was computed for various combinations of constituent elastic properties. Figure 2 provides an upper bound of the interface strength, that is denoted σ_i^{c+} :

$$\sigma_i^{c+} = \sigma_2^c \frac{\sigma_{rr}^{\max}}{\sigma_{zz}^{\max}} = \sigma_2^c f\left(\frac{E_2}{E_1}, \upsilon_2, \upsilon_1\right) \qquad (3)$$

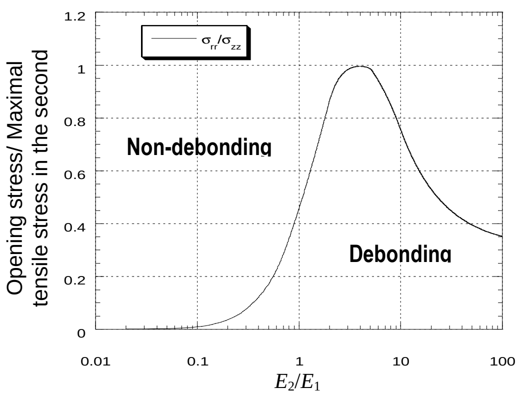

Figure 2 : Criterion of debonding ahead of a matrix crack with respect to constituent properties

Equation (3) shows that debonding depends on two sets of data :

- on one hand, properties of materials : σ_2^c, E_1, E_2, υ_1 , υ_2
- on the other hand, the interface opening strength σ_i^{c+} .

Thus, σ_i^{c+} represents the initial potential to debonding for a couple of materials.

When is σ_i^{c+} large, the probability to get debonding is high. When σ_i^{c+} is small, the probability to get debonding is small. Crack deviation requires that the interface opening strength is small.

Deviation potentials were determined for various combinations of materials, from properties available in the literature. Results are discussed with respect to available experimental data.