DYNAMIC FRACTURE OF ADVANCED FIBER COMPOSITES

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Materials Division of the
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by

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ABSTRACT

Efforts to investigate some of the theoretical bases for the dynamic fracture of graphite fiber reinforced composites are described. In particular, the initiation of unstable fracture in unidirectional cracked composites, dynamic crack propagation as modeled by orthotropic double cantilever beams, and interlaminar stresses for laminates having arbitrary stacking sequences are summarized.

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INTRODUCTION

Graphite fiber composites generally display a quasi-brittle fracture behavior. Thus, it is important to understand the essential features of the fracture of these materials in order to develop rational concepts for improving their damage tolerance. The purpose of this program was to investigate the theoretical bases for describing the dynamic fracture of fiber reinforced composites in general, and graphite fiber reinforced composites in particular, in order to proceed toward rational crack arrestment concepts.

In formulating an overall framework for the program, three major categories of the problem were defined. These are

1. Intralaminar - interfiber fracture,
2. Interlaminar fracture, and
3. Intralaminar - transfiber fracture.

For each of these categories, it is necessary to establish critical stress/strain criteria for the onset of rapid fracture. The specific considerations given to the various aspects of the problem are summarized in the sections which follow.

INITIATION OF UNSTABLE FRACTURE

As indicated in the previous section, it is important to establish the criteria for the onset of rapid fracture. The importance of establishing such criteria lies in the fact that the stored strain energy at the onset of rapid fracture represents an important part of the dynamic energy release rate which "drives" the crack during subsequent fracture. It is this dynamic energy release rate which must be either reduced (e.g., by stiffeners) or overcome (e.g., by increased material toughness) in order to achieve fracture arrest.

A heterogeneous anisotropic model* for notched fiber composites which was developed earlier was extended to derive relationships between the critical stress intensity factors of unidirectional composites having the same constituents but different fiber reinforcement angles. A maximum principal stress-brittle fracture criterion was used in the analysis although other fracture criteria could be employed to obtain similar results for composites which display the same general type of matrix fracture. This analysis is presented in publication No. 1 of the cumulated bibliography of this report.

Experimental verification of these results is continuing.

*P.N. Kousiounelos and J.H. Williams, Jr., "Heterogeneous Anisotropic Model for Notched Fibre Composites", To appear in Fibre Science and Technology.

DYNAMIC CRACK PROPAGATION

An orthotropic double cantilever beam model was used to analyze the dynamic propagation behavior for some intralaminar - interfiber composite fractures. The analytical model consisted of the upper half of the specimen which was modeled as a Timoshenko beam on a generalized foundation which is present only along the uncracked length of the specimen. The composite material was modeled as being homogeneous orthotropic. The equations of motion were derived via variational principles.

The elastic foundation parameters were derived and the dynamic energy release rate was expressed in terms of these foundation parameters and the generalized coordinates of the beam. A finite-difference solution scheme for solving the equations of motion was presented. Publication No. 2 of the cumulated bibliography contains all of the above analyses.

INTERLAMINAR STRESSES

In an earlier report*, we developed a theoretical formulation of the interlaminar stresses in a laminate having an arbitrary stacking sequence and subjected to uniform axial extension. A closed-form solution was obtained in terms of the number of laminae, the laminae fiber directions, the laminae thicknesses, and the fiber and matrix constitutive properties. The solution, although closed-form, is somewhat laborious in terms of performing calculations for specific problems, and therefore would almost certainly be used only in conjunction with an electronic digital computer.

Using the essential features of that analysis*, we have reformulated the basic equations in order to cast them in a form which is suitable for solution using generally available computer subroutines. By doing this, we have reduced the length of the required analytical formulation and we have obtained some numerical results. This reformulated problem and the accompanying results are given in publication No. 3 of the cumulated bibliography.

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*Z. Bin Ahmad and J.H. Williams, Jr., "Theoretical Formulation of Interlaminar Stresses in Arbitrarily Laminated Composites", Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, December 1976.

CUMULATED BIBLIOGRAPHY OF ISSUED PUBLICATIONS

The documents listed below were issued during the conduct of this research program and were supported by funds from the subject grant.

1. P.N. Kousiounelos and J.H. Williams, Jr., "Relationships Between Critical Stress Intensity Factors For Unidirectional Composites Having Different Reinforcement Angles", Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, October 1977.

2. P.N. Kousiounelos and J.H. Williams, Jr., "Governing Equations for Dynamic Crack Propagation in DCB Unidirectional Composite Specimens", Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, November 1977.

3. Z. Bin Ahmad and J.H. Williams, Jr., "Interlaminar Stresses in Arbitrarily Laminated Composites", Composite Materials and Nondestructive Evaluation Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, December 1977. (Submitted for refereed publication.)