A FINITE ELEMENT MODEL TO CHARACTERIZE THE RESPONSE
OF COMPOSITE CYLINDERS TO LOW-VELOCITY IMPACT

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ABSTRACT

A three-dimensional dynamic finite element structural analysis code, DYNA3D, was employed to simulate the behavior of multi-directional composite laminates subjected to low velocity impact. The objectives of the work performed herein was to develop a finite element model which could ultimately be used to predict the delamination in graphite/epoxy composite cylinders. The computer computations were made with the assistance of a Digital Equipment Corporation VAX 11/780 mainframe and a VAX II/GPX mini-computer. Four computer codes, MESH, DYNA3D, and TAURUS, were processed on one or both of these computers. A pre-processor (MESH) was developed to generate the finite element mesh read by the main computing program, DYNA3D. The post-processor, TAURUS read the binary plot files generated by DYNA3D and plotted time histories and deformed shapes.

A finite element model of a three laminae [0/90/0] lay-up graphite/epoxy plate was constructed and analyzed for stresses near the impact zone. The plate was impacted with a spherical indenter traveling at an initial velocity of 16 m/s. The results were compared to experimental data and finite element analysis of a similar plate. The two models yielded similar results. By using the same modeling criteria used for the plate, a cylinder mesh was constructed and loaded under the exact same conditions.

Numerical results demonstrate that the proposed finite element analysis is effective in predicting the stress-strain-displacement near the impact area. The behavior of composites cylinders to dynamic loading is highly dependent on the boundary conditions. Stresses near the impact zone for a cylinder and plate are higher near the point of impact and decrease away from the impact. Boundary effects were explained in terms of the theory of stress waves in solids.

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CHAPTER 1

1. Introduction

1.1. Definition of Problem

The importance of composite materials is their high strength-to-weight ratio. These newly developed materials are by no means excluded from damage of external bodies impacting the composite material. In some cases of normal use, the composite may appear to be sound when struck by some foreign object, but interior structural damage may result from the separation between laminae. The delamination would not be immediately known and could later spread in use.

Delamination has caused significant concern in the design and analysis of composite materials and structures. The failure mechanism is complicated because it involves not only geometric and material discontinuities (i.e. interlaminar cracks and variation of ply properties in the transverse direction), but also the coupled mode I, mode II and mode III fracture in a layered anisotropic material system. Interlaminar delamination may occur as a result of a nonperforating low-velocity impact of foreign object against a continuous-fiber composite laminate [1].

Figure 1 shows the three types of relative movements of two crack surfaces. The opening mode, Mode I, is characterized by local displacements that are symmetric with respect to the x-y and x-z planes. The sliding or shear mode, Mode II, is symmetric with respect to the x-y

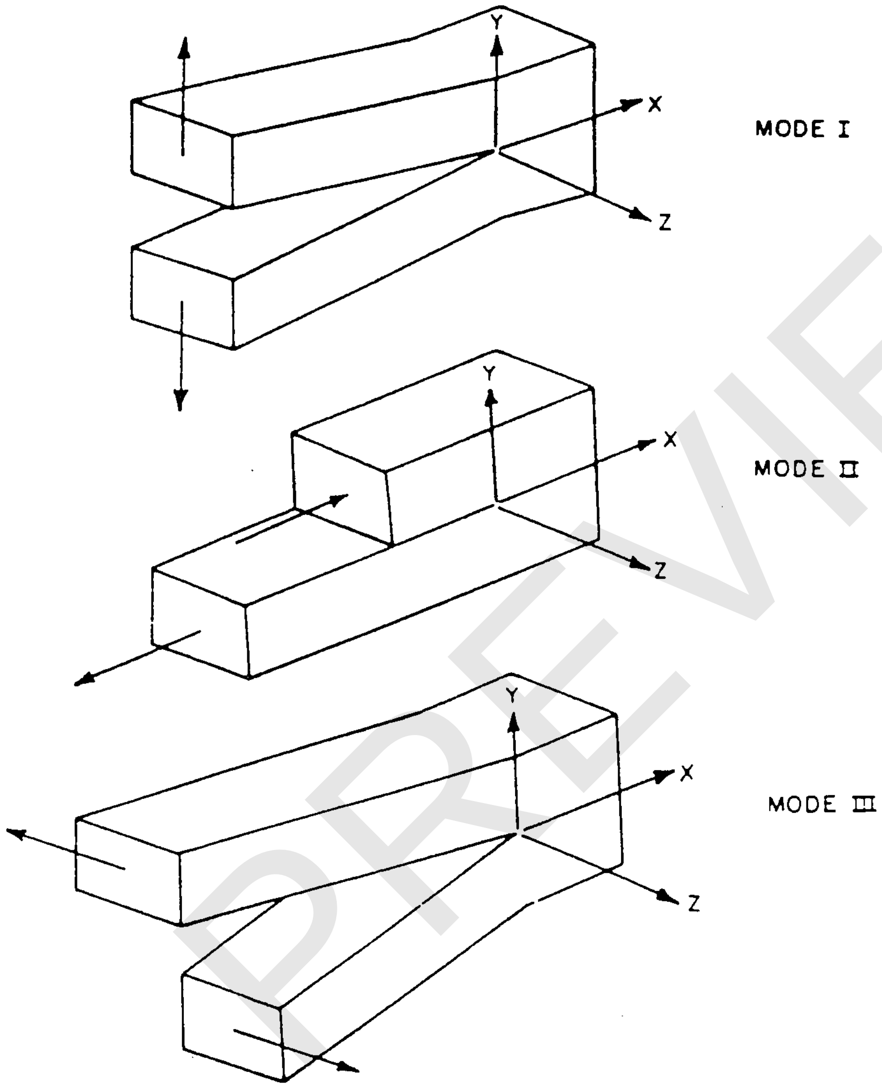

Figure 1. The Three Basic Modes of Crack Surface Displacements: Mode I, Mode II, and Mode III (Ref. 14).

plane and distorted with respect to the x-z plane. The tearing mode, Mode III, is associated with local displacements that are distorted with respect to both x-y and x-z planes. Released energy associated with these fracture surfaces is an integrated effect of the energy-adsorbing micromechanics mechanisms. Mode I, II, and III type of mechanisms are gross energy release mechanisms and, as such, do not represent fundamental material characteristics [2].

A target-impactor test and including some finite element models have been developed to study the effects of composite materials under different dynamic loading conditions. From results of these tests, important data on the stress-strain-delamination relationship can be used to make further studies on the behavior of multi-directional composites to low-velocity impact. The finite element method for determining the stress-strain-fracture relationships is a powerful tool for optimizing the composite in terms of its ply geometry, number of laminae, dimensions, and material properties. With an efficient finite element model, the stress-strain-displacement conditions for dynamically loaded bodies can be predicted, and the composite can be assessed for fiber failure, matrix failure, and delamination. Thus, optimization of the composite design to withstand dynamic loads becomes more efficient and easier.

The purpose of the work described herein, is to model the impact of a composite cylinder, because experimental results on the response of composite cylinders to dynamic loading is lacking. In addition, experimental results do not provide the stresses generated along laminate interfaces and within the laminates themselves. Thus,