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NASA TECH BRIEF

Study Made of Mechanics of Deformation and Fracture of Fibrous Composites

The existence of many very high strength and stiffness filaments has motivated considerable interest in the selection of appropriate matrix materials to obtain fibrous composites which can utilize these outstanding properties. Studies have been made of the influence of both fiber and matrix characteristics upon the mechanics of deformation and fracture of fibrous composites. A report summarizing the findings of these studies has been prepared presenting the information needed to select appropriate constituents for given applications. These studies consider the response of a matrix reinforced by uniaxially oriented fibers. The strength of such a material is treated for the cases where the failure criteria are maximum tensile and compressive loads carried by the composite in a direction parallel to the fiber orientation.

When the response of a composite is to be measured in terms of average stress and average strain, the material can be represented by an effective homogeneous but anisotropic material having the same average response. For the case of a matrix containing uniaxially oriented fibers, the effective material is transversely isotropic and is therefore characterized by five elastic constants. Various analytical approaches to the evaluation of these constants as functions of the constituent properties have been made and the relationship between constituent properties and elastic moduli is reasonably well understood.

However, when a fracture criterion is desired, an understanding of the average stress-strain response is no longer sufficient, and consideration must be given to internal irregularities in the state of stress. The report treats these problems for both ultimate compressive and tensile strengths.

The failure of a fibrous composite under a uniaxial compressive load is considered first. A possible failure mechanism for this case is the hypothesis that the individual fibers buckle in a short wavelength pattern in a fashion analogous to the buckling of a column or plate on an elastic foundation. An approximate evaluation of the influence of fiber geometry and fiber and matrix moduli upon the composite compressive strength can then be made. These results are compared to the results of an experimental program which utilized hollow and solid glass fibers in several matrix materials. The test specimens were short columns designed to achieve a compressive strength failure.

The major portion of the report is devoted to a study of the mechanics of tensile failure of a fibrous composite. The study is based upon consideration of the phenomena which occur subsequent to an initial internal fracture. The strength of the brittle fibers are considered to be defined by a statistical distribution function. Thus, the initial fracture is likely to occur in a fiber. The resulting perturbation of the local stress field is treated. An approximate solution indicates the nature of the interface stress distribution as well as stress concentrations in nearby fibers. This stress field could result in adjacent fiber fracture, that is, a crack propagation effect, or in separation along the interface. A third possibility is that the stresses in the vicinity of an initial fiber fracture do not produce further fracture and that increasing load produces a distribution of fiber fractures corresponding to the initial distribution of weak points in the fibers. The continued accumulation of these fractures would produce a weak cross section at which the remaining un-

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broken fibers could no longer transmit the applied load. Instantaneous tensile failure would then occur.

A statistical tensile failure model of a fibrous composite is established on this basis, and the mechanical characteristics of fiber and matrix are utilized to obtain a statistical failure definition. An experimental program to investigate the validity of the model is described, and an attempt is made to correlate the tensile properties of constituents and composites.

Note:

Additional details of this study are contained in: *Mechanics of Composite Strengthening*, by B. Walter Rosen, General Electric Co. Copies of this report are available from:

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Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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