STRESS BASED YIELD/FAILURE CRITERIA FOR FIBER COMPOSITES

R. M. Christensen

Lawrence Livermore National Laboratory, P.O. Box 808, L-355, Livermore, CA 94550, USA
and
Stanford University, Stanford, CA 94305, USA

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SUMMARY

In the present work a new theory of yielding and failure is derived for fiber composite materials. The importance of this general area is underscored by the high degree of activity that has been expended over the past 30 years or so in searching for the elusive "best" formulation. The difficulty of the search is evident from the multitude of empirical approaches that have been offered. The approach given here stresses the need to derive the governing forms from some basic physical postulations. In performing this derivation, a balance is sought between achieving the maximum generality and minimizing the number of materials parameters that must be experimentally evaluated for applications to any particular material system.

There are two key steps that guide the following derivation. In the first one, micro-mechanics is used to distinguish or discriminate different modes of failure. In particular, these are fiber dominated and matrix dominated modes. However, these two terms, fiber dominated and matrix dominated, are just convenient labels used to distinguish the two different modes of yield or failure that can occur in far different regions of stress space, different by as much as an order of magnitude or more. Of course, for both modes, both phases (fiber and matrix) play vital and strongly interactive roles.

The second key physical requirement is that of independence of hydrostatic compressive stress states, when imposed as a state by itself. That is, yield or failure is taken not to occur under independent states of hydrostatic compressive stress, within the range of the present second degree terms.

This does not mean that yield and failure cannot occur beyond this range or under hydrostatic tensile stress states or under hydrostatic, meaning equi-normal, strain states. In the latter cases, the ensuing theory will indeed predict yield or failure.

The resulting forms for the fiber dominated and matrix dominated modes of yield/failure are quadratic in the components of the average stress tensor with five materials parameters. The intended application is to aligned fiber composites at the lamina level with a polymeric matrix phase under high fiber concentration conditions.

The matrix dominated mode of failure is given by the three parameter form

$$\alpha_1 k_1(\sigma_{22} + \sigma_{33}) + (1 + 2\alpha_1)\left[\frac{1}{4}(\sigma_{22} - \sigma_{33})^2 + \sigma_{23}^2\right] + \beta_1(\sigma_{12}^2 + \sigma_{31}^2) = k_1^2$$

where

$$k_1 = \frac{\left|\sigma_{22}^C\right|}{2}$$

$$\alpha_1 = \frac{1}{2}\left(\frac{\left|\sigma_{22}^C\right|}{\sigma_{22}^T} - 1\right)$$

$$\beta_1 = \left(\frac{\sigma_{22}^C}{2\sigma_{12}^Y}\right)^2$$

and where axis 1 is in the fiber direction.

The corresponding fiber dominated criterion is given by the two parameter form

$$-\alpha_2 k_2 \sigma_{11} - \frac{1}{4}(1 + 2\alpha_2)\sigma_{11}^2 - \frac{(1+\alpha_2)^2}{2}\left(\frac{\sigma_{22} + \sigma_{33}}{2}\right) = k_2^2$$

Where

$$k_2 = \frac{\sigma_{11}^T}{2}$$

$$\alpha_2 = \frac{1}{2}\left(\frac{\sigma_{11}^T}{\left|\sigma_{11}^C\right|} - 1 \right)$$

The five failure parameters are obtained from the five experimental data characteristics of fiber direction tensile and compressive failure, transverse direction tensile and compressive failure, and longitudinal shear failure.

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