MICROMECHANICAL MODELING OF ENERGY TO FAILURE FOR RANDOMLY ORIENTED SHORT FIBER COMPOSITES

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From a macroscopic perspective, random fiber composites exhibit a very simple structure that can be described with a few parameters. However, the inadequacy of such a parametric representation becomes apparent when one attempts to derive a material's mechanical properties from its constituents under the usual assumptions of isotropy and homogeneity. In particular, calculations of the impact, strength, and fracture properties yield inaccurate results. As part of an effort to refine these calculations, a computer program was developed for modeling the fiber deposition for a discontinuous fiber manufacturing process and for characterizing the structure and properties of the resulting fiber networks. It was found that the most important of these was a multi-scale disorder of the seemingly simple fibrous microstructure, a disorder which arises primarily as a result of the material manufacturing processes. It has been computationally established and experimentally verified that, of many possible fracture and energy dissipation-related parameters, the length of the fiber segments (where segment is defined as the distance along one fiber between two contacts with other fibers) that break and the number of broken bonds (fibers or their segments) are of the utmost importance since they determine the nature of a fracture and the amount of energy that is dissipated in producing it. The fracture zone size is related to the effective breaking length of fibers, which becomes the internal scale of the material, its cohesion length. The cohesion length forms a link between the conventional tensile strength and toughness and can be used to deal formally with damage localization and failure using the cohesion band approach. The damage evolution in random fiber composites can be divided into three main phases. The first phase, or Percolation Phase, consists of random failures of lattice links that are driven mainly by the distribution of disorder and depletion of weak links in the material. The damage growth then been shown to accelerate (Localization and Failure Phase) in the one-dimensional uncorrelated zone of finite width, which makes it possible to use a cohesive model framework for modeling of material failure. The estimates of the work to fracture based on the developed cohesion parameters show a very good agreement with the measured values from the variable ligament Double Edge Notch Tension (DENT) fracture test for random carbon fiber composite.

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