The Department of Mechanical Engineering / College of Engineering and Applied Sciences
Stony Brook University

Mechanical Engineering Seminar
Faculty Candidate

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Failure in Quasibrittle Fiber Composites: Size Effect Testing and the Microplane Triad Model

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Abstract

Fiber composites are attractive for various engineering applications owing to their superior mechanical properties. One such example is their application to automotive and aerospace crashworthiness, given their superior energy dissipation capability compared to other light-weight materials. However successful commercialization of such applications requires an insightful understanding of the fracturing behavior. Traditionally, the material failure criteria based on stresses or strains do not account for the quasi-brittle failure behavior of these composites. All quasi-brittle materials fail by localization of softening damage and, in contrast to plasticity, exhibit a material characteristic length, which is related to the size of the fracture process zone that forms during failure. This zone is not negligible compared to structural dimensions and leads to a peculiar, non-self-similar structural size effect in the failure behavior. This must be accounted for in any realistic constitutive description of failure of the material. In the first part of this talk, a novel experimental protocol, called size effect testing, is presented, which involves fracture tests on geometrically scaled carbon-epoxy woven composite specimen of different sizes. These tests serve two purposes. First, they provide a strong evidence of quasi-brittle behavior of the composite. Secondly they provide a means to indirectly measure the fracture energy of the composite, direct measurement of which is elusive due to the snap-back behavior typical of composites. The second part demonstrates the effective incorporation of these aspects in constitutive modeling, using the so-called microplane triad model. In this multi-scale model, the mechanical behavior of the undulating weave yarns within a representative cell is described by a finite number of microplane triads of various orientations, the microplanes being imagined planes within the material microstructure. Within each triad, the constitutive behavior is defined in terms of stress and strain vectors, rather than tensors, which facilitates intuitive description of various damaging mechanisms such as fiber breaking and matrix cracking. The quasi-brittleness is captured by relating the sub-scale damage evolution to the macro-scale fracture energy measured from the aforementioned size effect tests. The material characteristic length is introduced through the framework of the crack band theory. It is shown found that the model built on these principles can accurately predict all the orthotropic elastic constants of the composite, as well as its fracturing behavior under impact, including the correct energy dissipation, and failure pattern. The approach is promising and extensible to many modern composite materials, including braided, hybrid and multi-functional, which are of much current interest.

Biography

Dr. Kedar Kirane is a Senior Research Engineer at the ExxonMobil Upstream Research Company. He received his doctorate from Northwestern University, M.S. from the Ohio State University and B.S. from the University of Pune, India, all in mechanical engineering. Prior to his doctorate at Northwestern, he worked for over three years at the Goodyear tire and rubber company as a development engineer. He has a diverse experience in the field of solid mechanics and his contributions comprise of computational, theoretical as well as experimental studies. His research interest lies primarily in mechanics of materials and structures, with emphasis on fracture, fatigue, damage and scaling, and with applications to various heterogeneous composite materials.

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