MECHANICAL & MATERIAL COLLOQUIUM

Augmented Finite Element Method for Non-linear Fracture Analysis and Virtual Testing of Composite Materials

by Qingda Yang (University of Miami)

With rapid expansion of carbon fiber-reinforced polymer (CFRP) composites as primary load-bearing components in many applications such as the fuselages and wings of Boeing 787, the safety and long-term durability of these highly heterogeneous materials become an issue of paramount importance. These materials typically exhibit complex multiscale, progressive damage evolution until final failure. Predicting and quantification of such complex damage processes remain an open research topic despite decades of extensive research.

In this presentation I will start with a review of recent advances in high-fidelity simulation methods that attempt to capture the arbitrary small-scale cracks and their coupled progression until final failure. In particular, I shall introduce a relatively new numerical approach named augmented finite element method (A-FEM), developed by my research group in recent years and has been demonstrated with orders-of-magnitude improvement in numerical efficiency, accuracy, and robustness. Extension of the A-FEM to include nonlinear effects due to large deformation and matrix nonlinearity of PMCs will also be presented.

After the introduction of the A-FEM, I shall demonstrate its virtual testing capability through two recent examples. The first is its application in multidirectional PMC laminates. This case will show that through a multiscale hierarchal analysis with explicit consideration of all major damage modes in each scale, the ultimate laminate strength can be adequately predicted from the intrinsic properties of matrix, fiber, and their interfaces. The second example is a recent application of the A-FEM on an envisioned short fiber reinforced composite. With this example we show that we can predict the material properties including the progressive damage and failure based on intrinsic properties of constituent materials only (i.e. no empirical parameters from actual testing of physical material). This represents a major step forward to achieve virtual designing of materials and structures.

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Dr. Qingda Yang is a professor and the Chair of the Department of Mechanical and Aerospace Engineering (MAE) at the University of Miami (UM). Dr. Yang's recent research has focused on developing multi-scale methodologies that can lead to realistic virtual testing and designing of complex heterogeneous materials and structures under general and/or extreme thermal-mechanical loading environments. He is an author/coauthor of 100+ journal publications, 4 book chapters, and more than 30 refereed conference proceedings. He was a past Chair of the Composite and Heterogeneous Materials Committee in ASME (2010-2012), and is currently serving an editorial board member for three professional journals.

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