Homogenization-Based Design of Textile Reinforced Composites

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The development of durable material systems with excellent mechanical performance characteristics for both civil infrastructure and aerospace structural applications is a compelling mechanics and materials issue. Fiber reinforced polymer matrix composites (FRPs) represent a potentially attractive materials system due to their lightness, viscoelastic damping characteristics, and strong resistance to many forms of chemical and environmental attack. A real problem with most existing classes of FRPs is that their fibrous reinforcing geometries, which provide the composite's real stiffness and strength, are only continuous in one or perhaps two-dimensions. This can lead to potentially serious mechanical performance deficiencies. As a first example, pultruded FRPs feature primarily one-dimensional aligned-fiber geometries and have effective material behaviors which are stiff and strong in only one direction. The low stiffnesses and strengths in transverse directions can give rise to documented modes of including splitting, transverse bearing failures, buckling of pultruded structural elements, web-flange tearing in structural elements, etc. As a second example, laminated composites feature continuous two-dimensional fiber reinforcing geometries but lack reinforcing in the third stacking direction. Such composites have problems with splitting and delamination, and the layup process for laminated composites may not be appropriate for many structural members with irregular cross-section characteristics. The basic premise of the research program is that integrated analysis, design and production methods are needed to develop new generations of composites with continuous, three-dimensional fiber reinforcing geometries. Continuous three-dimensional reinforcing geometries (textiles) hold the **possibility** of providing new generations of FRPs with dramatically enhanced mechanical performance characteristics.

To investigate whether such composites can actually be realized, and whether their mechanical performance characteristics can be accurately predicted, an integrated analytical / experimental research program is being conducted. The program's objective is to develop systematic analysis and optimization techniques by which the fibrous textile reinforcing structure of polymer matrix composites can be engineered to optimize their three-dimensional stiffness and strength performance characteristics. To accomplish this objective, research is being performed along the following lines:

a. development of constitutive models for textile composites using homogenization methods;

b. topological optimization of the textile reinforcing layout in composites;

c. prototyping of novel textile reinforced polymer matrix specimens; and

d. mechanical testing of these specimens to verify their performance characteristics.

The analysis and design method features usage of structural topology optimization methods to design the layout of the textiles in composites. The research program also features interactive collaboration with a leading industrial manufacturer of textile reinforced FRPs