Modeling of Slender Structural Members: An Asymptotic Approach to the Modeling of Composite Beams, Plates, and Shells

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An asymptotic approach to the modeling of composite beams, plates and shells is presented. The method is based on rigorous dimensional reduction from geometrically nonlinear three-dimensional (3-D) elasticity theory using the Variational Asymptotic Method (VAM). The presentation will outline the basics of the methodology and illustrate it for composite beams and plates, starting with a 3-D intrinsic formulation of the kinematics for beams. The resulting composite beam models based on VAM are presented, along with features and capabilities of a 2-D finite element code (VABS) built around VAM. Numerical examples are presented that show the accuracy of recovered stresses to be comparable to that of 3-D finite element modeling, but at a significantly lower computational cost. The beam modeling is illustrated and applied in a variety of ways, including aeroelastic analysis of HALE aircraft, optimization of rotor blade cross-sections, and elastic stability of arches. Future work involving the dynamics of beams is outlined.

A 3-D intrinsic formulation for plates is then presented, and composite plate modeling by the VAM is described. The transformation of the theory to a Reissner-like model enables one to use this theory in standard plate finite element codes. Moreover, the method provides closed-form recovering relations for through-the-thickness distributions of stress and strain that are very close to the 3-D elasticity solutions for moderately thick, laminated plates, as demonstrated by numerical examples. Extension to shells is accomplished in a similar manner. Future work involving the dynamics of shells is outlined.