Evaluation of Thermoelastic Properties and the Residual Thermal Stresses of Fibrous Composites with Fiber Waviness

G. Karami
Department of Mechanical Engineering and Applied Mechanics
North Dakota State University
Fargo, ND 58105-5285

M. Garnich
Department of Mechanical Engineering
University of Wyoming
Laramie, WY 82071-3295

Abstract

A finite element-based micromechanical modeling for fibrous materials is introduced for determination of thermoelastic properties of continuous fiber composites with fiber waviness. The fibrous composite is assumed to be of periodic type and is composed of circular fibers distributed within the matrix. The periodic unit cell based on hexagonal fiber packing is assumed as a representative volume element. Implementation of periodic constraints on a wavy unit cell is to assume wavy fibers all through the structure. Following the thermoelastic finite element analysis of the unit cell for each of the six common load cases and under a temperature change, the stress and strain components are volume averaged to obtain the continuum components of the stress and strain at a typical material point represented by the unit cell. The stiffness and the coefficient of thermal expansion parameters of the fibrous material are the measure using the constitutive relations. To measure the coefficients of thermal expansion (CTE), it is sufficient to evaluate the strain distribution within the unit cell under an arbitrary temperature change. In the numerical examples, the fiber is assumed transversely isotropic and the matrix is taken as an isotropic material. The composite is therefore, transversely isotropic with straight fibers, but becomes orthotropic for the case of wavy fibers. The thermal residual stresses generated per unit temperature change are studied in detail by volume averaging over slices (to be called sub-volumes) of the representative volume element (RVE) along the length of the fiber, and also, within the fiber and the matrix individually. The sub-volume averaging scheme shows the variation of the internal stresses and strains within the RVE. It is shown that fiber waviness does not have a big impact on the coefficients of thermal expansion, but the associated thermal stresses can play a significant role on the composite failure.