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HOMOGENIZATION ESTIMATES FOR THE MACROSCOPIC BEHAVIOR AND FIELD STATISTICS IN TWO-PHASE VISCOELASTIC COMPOSITES WITH TEMPERATURE-DEPENDENT PROPERTIES

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Abstract. Upon consolidation, reinforced polymer composites develop internal stresses due to the pronounced mismatch between the thermomechanical properties of the matrix and the reinforcement. These so-called thermal stresses can significantly reduce the mechanical strength and fatigue endurance of the composite material, and can induce undesired dimensional changes of the structural element. This has motivated numerous attempts to correlate the magnitude of thermal stresses with material and process parameters such as matrix rheology, reinforcement shape and distribution, and cooling rate. In the absence of chemical changes, as in, for instance, reinforced amorphous polymers, the problem reduces to that of estimating the macroscopic behavior and micromechanical field statistics of a two-phase viscoelastic composite in terms of its microstructural morphology and the thermomechanical properties of its constituents. Thus, homogenization methods constitute an attractive approach. However, given that most consolidation processes vary the temperature of the sample across the glass transition temperature of the polymeric matrix, the method of choice should simultaneously account for i) the strong coupling between deformation processes of energetic and dissipative nature, and ii) the strong variation of matrix rheology with temperature. To that end, homogenization estimates are derived within the framework of generalized standard materials by means of time-incremental variational principles together with approximate variational schemes that identify macroscopic internal variables with low-order statistics of the microscopic internal variables. Unlike classical estimates for viscoelastic composites based on the correspondence principle, the new estimates can account for the expected variations of mechanical properties with temperature. Specific estimates for a class of fiber-reinforced model composites cooling down at various rates are reported and confronted to full-field numerical simulations obtained by means of a Fast-Fourier Transform algorithm. Good agreement is found.