A NUMERICAL HOMOGENIZATION SCHEME FOR PARTICULATE REINFORCED COMPOSITES

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Composite material systems can be precisely tailored to meet a desired performance for various structural applications by varying reinforcement types and in-situ material properties. Polymers that are commonly used in composite materials are often brittle with poor resistance to fracture. Thus, nano and/or micro particles are added to the polymers to increase crack resistance in composites. The present study introduces a simplified micromechanical model for composite systems with solid spherical particles. The solid spherical particle reinforced polymers are represented by uniformly distributed cubic particle over an infinite medium. This geometry representation is similar to the one proposed by Aboudi and co-authors [1] to study functionally graded materials with non-uniform fiber spacing. One eighth unit-cell model with particle and polymer subcells is generated. Perfect bond is assumed at the particle/matrix interphase/interface. The solid spherical particle is modeled as linear elastic materials while the polymer will be modeled with elastic and inelastic material responses. A homogenization scheme is developed by satisfying traction continuity and displacement compatibility at an interface between subcells in an average sense, which follows homogenization approaches of Haj-Ali and Muliana [2, 3] for fiber reinforced composites. A new incremental formulation for the micromechanical model of spherical reinforced composites will be developed in term of the average strains and stresses. The incremental formulation will be generalized to include an explicit time-scale and to allow modeling time-dependent behavior. The homogenization schemes also include stress correction algorithm to enhance computational efficiency and accuracy. The micromechanical model provides three-dimensional (3D) effective properties of homogeneous material responses, while recognizing important micro-structural aspects and parameters of the heterogeneous medium. In addition, the simplified micromechanical model can be easily coupled with different constitutive material models, which is suitable for integration within a multi-scale material framework. The micromechanical model will be implemented as a material model (Gaussian integration points) in the finite element (FE) structural analyses. Numerical applications of composite structural analyses will be performed using the proposed multi-scale framework.

References:

[1] Aboudi, J., Pindera, M. J., and Arnold, S. M., (1999), “Higher-order Theory of Functionally Graded Materials," Composites Part B, 30, pp. 777-832.
[2] Haj-Ali, R. and Muliana, A., "Micromechanical Models for the Nonlinear Viscoelastic Behavior of Pultruded Composite Materials," Int. J. Solids and Structures, 40, pp. 1037, 2003.
[3] Muliana, A. and Haj-Ali, R., "Nested Nonlinear Viscoelastic and Micromechanical Models for the Analysis of Pultruded Composite Structures," Mechanics of Materials (MOM), 36, pp. 1087, 2004.