World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:9, No:06, 2015

Coupled Space and Time Homogenization of Viscoelastic-Viscoplastic Composites

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Abstract : In this work, a multiscale computational strategy is proposed for the analysis of structures, which are described at a refined level both in space and in time. The proposal is applied to two-phase viscoelastic-viscoplastic (VE-VP) reinforced thermoplastics subjected to large numbers of cycles. The main aim is to predict the effective long time response while reducing the computational cost considerably. The proposed computational framework is a combination of the mean-field space homogenization based on the generalized incrementally affine formulation for VE-VP composites, and the asymptotic time homogenization approach for coupled isotropic VE-VP homogeneous solids under large numbers of cycles. The time homogenization method is based on the definition of micro and macro-chronological time scales, and on asymptotic expansions of the unknown variables. First, the original anisotropic VE-VP initial-boundary value problem of the composite material is decomposed into coupled micro-chronological (fast time scale) and macro-chronological (slow time-scale) problems. The former is purely VE, and solved once for each macro time step, whereas the latter problem is nonlinear and solved iteratively using fully implicit time integration. Second, mean-field space homogenization is used for both micro and macro-chronological problems to determine the micro and macro-chronological effective behavior of the composite material. The response of the matrix material is VE-VP with J2 flow theory assuming small strains. The formulation exploits the return-mapping algorithm for the J2 model, with its two steps: viscoelastic predictor and plastic corrections. The proposal is implemented for an extended Mori-Tanaka scheme, and verified against finite element simulations of representative volume elements, for a number of polymer composite materials subjected to large numbers of cycles.

Keywords : asymptotic expansions, cyclic loadings, inclusion-reinforced thermoplastics, mean-field homogenization, time homogenization
Conference Title : ICACM 2015 : International Conference on Advanced Composite Materials
Conference Location : New York, United States
Conference Dates : June 04-05, 2015