Micromechanical modeling of the nonlinear deformation of porous and composite thermoplastic polymers

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For polymer composites with viscoelastic-viscoplastic (VE- VP) constituents, two mean-field homogenization (MFH) models based on completely dissimilar theoretical approaches are extended from elasto-viscoplasticity (EVP) to VE-VP and assessed. The first approach is the incremental-secant method. It relies on a fictitious unloading of the composite at the beginning of each time step. The second approach is the integral affine method. It starts by linearizing the rates of viscoplastic strain and internal variables. The linearized constitutive equations are then recast in a hereditary integral format to which the Laplace-Carson (L-C) transform is applied.

For porous materials, MFH models are usually unable to predict any plasticity under hydrostatic loadings or other high stress triaxiality cases. A predictive micromechanical approach is proposed. It is based on an alternative microstructure made of inelastic inhomogeneities embedded in a homogenized porous matrix phase, and the volume fractions are determined from a maximum packing argument. The effective properties of single coated cavities are computed either with Gurson's solution in the rigid-perfectly plastic case or with an energy-based approach coupled with full-field finite element (FE) analyses in the elasto-plastic hardening regime. Next, the alternative microstructures are homogenized with mean-field (MF) models.

In all cases, the accuracy of the proposed micromechanical approaches was assessed against full-field finite element (FE) results for different microstructures and loadings.