

Thermodynamic Constitutive Modeling of State-Dependent Materials

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ABSTRACT

The mechanical response of engineering materials is governed by their deformation and the evolution of internal states under mechanical loading, thermal exposure, and processing. Accurately capturing these history-dependent effects requires thermodynamically consistent constitutive frameworks that connect material evolution with measurable behavior. This work evaluates such frameworks through their application to asphalt materials and additively manufactured polymers. For asphalt binders and mixtures, including reclaimed asphalt pavement (RAP), nonlinear viscoelastic models based on evolving natural configurations are employed to capture multiple relaxation mechanisms. When combined with creep-recovery experiments, these models enable characterization of constituent contributions and assessment of rutting parameters across both linear and nonlinear regimes. In the context of additive manufacturing, material response is further affected by the interplay among thermal history, relaxation, and phase transitions. A coupled thermo-mechanical framework for material-extrusion processing of amorphous polymers incorporates melt relaxation, thermal contraction, melt-to-glass transition, and temperature-dependent properties to predict residual stresses, shrinkage, and warpage. Model predictions are validated through experimental measurements of printed polycarbonate specimens. Collectively, these studies illustrate how constitutive modeling, computational analysis, and experimental validation elucidate the influence of evolving material states on engineering performance under diverse mechanical loading and manufacturing conditions.

ABOUT THE SPEAKER

Dr. Bhaskar Vajipeyajula is an Instructional Assistant Professor at Texas A&M University, USA, and an alumnus of GITAM University, India, with a Ph.D. and M.Eng. in Mechanical Engineering from Texas A&M University. His research focuses on nonlinear mechanics, continuum mechanics, thermodynamically consistent constitutive modeling, and additive manufacturing. He integrates theoretical, computational, and experimental approaches to investigate the influence of material behavior, loading history, and manufacturing processes on the performance of engineering materials. His work encompasses nonlinear viscoelastic modeling of asphalt materials, thermo-mechanical modeling of additively manufactured polymers, mechanical characterization of metal additive manufacturing processes, and fatigue behavior of engineering materials. His broader research interests include process-structure-property relationships, mechanics of viscoelastic fluids, and predictive modeling of advanced materials. He also has extensive teaching experience in mechanics, thermodynamics, manufacturing, and fluid power, emphasizing active learning and the application of fundamental engineering principles to practical problems.



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