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Homogenization and Applications to Nonlinear Rheological Models: Active Composite Materials, Fluid Suspensions and Sea Ice

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ABSTRACT:

Many naturally occurring and artificial materials exhibit significant heterogeneities in their properties at length scales that are well above atomic scales (e.g., the grains in an ice polycrystal, or the fibers in a rubber composite). For this reason, it is of interest to be able to generate constitutive relations for the average or macroscopic response of these heterogeneous materials. This is a challenging task, especially when the microstructures are random and multi-scale, and the properties of the elementary constituents are nonlinear (e.g., plasticity, or finite-strain elasticity). In this presentation, I will discuss a general "homogenization" approach that is based on appropriately designed variational principles for the properties of "linear comparison composites." Such "variational linear comparison" methods provide optimal linearization schemes incorporating information on the local field statistics and allowing the direct conversion of robust homogenization estimates for linear composites into corresponding estimates for nonlinear composites. We will consider three illustrative examples: fiber-reinforced magneto-active elastomers, soft-particles fluid suspensions and sea ice. The objective will be to show how these methods can be used to generate constitutive models for the macroscopic response incorporating suitably defined "internal variables" characterizing the microstructure and its evolution in time with the deformation. The resulting models can be used to not only accurately predict the macroscopic response and microstructure evolution, but also the corresponding field statistics, as well as the possible development of material instabilities. On the other hand, they are simple enough for numerical implementation in standard finite element codes as constitutive subroutines.

BIOGRAPHY:

Pedro Ponte Castañeda is currently Raymond S. Markowitz Faculty Fellow and Professor in the Departments of Mechanical Engineering and Applied Mechanics and Mathematics (secondary), and Member of the Graduate Group in Applied Mathematics and Computational Science at the University of Pennsylvania. He earned a B.S. in Mechanical Engineering and a B.A. in Mathematics from Lehigh University in 1982, and an S.M. in Engineering Sciences and a Ph.D. in Applied Mathematics from Harvard University in 1983 and 1986, respectively. Prior to joining Penn, he was a postdoctoral fellow in the School of Mathematical Sciences at the University of Bath (1986-1987) and Assistant Professor of Mechanical Engineering at the Johns Hopkins University (1987-90). He was also Professor of Mechanics at the École Polytechnique (2004-06, full time; 2006-08, part time). He currently serves as Associate Editor of the Journal of the Mechanics and Physics of Solids and the Journal of Elasticity. He is an ASME Fellow and his honors include the ASME Thomas J.R. Hughes Young Investigator Award (2000), the George H. Heilmeier Faculty Award for Excellence in Research from Penn's School of Engineering and Applied Science (2007), the Humboldt Senior Research Prize (2013) and the ASME Warner T. Koiter Medal (2016).