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Chemo-Mechanical Coupling and Material Evolution in Finitely Deforming Solids Permeated with Reactive Fluids

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ABSTRACT:

This talk presents a new class of numerical methods for coupled chemo-mechanical problems involving chemically reacting fluids permeating through deformable elastic solids. The fluid-infused solid model is presented within the context of mixture theory which provides a framework for modeling material systems that are comprised of multiple constituents. The constitutive relations for the constituents are derived assuming maximization of the rate of entropy production. An interactive force field in the momentum balance equations couples the constituents implicitly at the level of the governing system of equations. Since the inter-constituent interactive effects are mathematically accounted for at the local continuum level, the resulting system serves as physics-based reduced-order model for the microstructure evolution. Evolving nonlinearities and coupled chemo-mechanical effects give rise to spatially localized phenomena which can exhibit boundary and/or internal layers. Presence of shear bands, boundary layers, and steep gradients that appear at the reaction fronts requires numerical schemes that possess enhanced stability and accuracy properties. A class of stabilized finite element methods is presented for the analysis of mixed-field nonlinear problems that appear in process modeling of materials, as well as in the growth of soft biological tissues. Mathematical attributes of the method are investigated, and enhanced stabilization features and higher spatial accuracy of the models and the methods are highlighted.

BIOGRAPHY:

Arif Masud is John and Eileen Blumenschein Professor of Mechanics and Computations in the Department of Civil and Environmental Engineering, and the Department of Aerospace Engineering, at the University of Illinois at Urbana-Champaign. He also holds joint appointment as Professor of Biomedical and Translational Sciences in the Carle-Illinois College of Medicine. Dr. Masud has made fundamental and pioneering contributions to the development of Variational Multiscale (VMS) Methods for fluid and solid mechanics. VMS methods possess enhanced stability and higher accuracy for mathematically non-smooth problems which makes them ideally suited for the modeling of coupled multiphysics phenomena in science and engineering.

Prof Masud has been elected as President-elect of the Society of Engineering Science (SES) for 2023, and is currently serving as the Vice-President of the Engineering Mechanics Institute (EMI) of ASCE. He has served as an Associate Editor (AE) of the ASCE Journal of Engineering Mechanics, and AE of the ASME Journal of Applied Mechanics. He was Chair of the Computational Mechanics Committee of ASCE, and Chair of the Fluid Mechanics Committee of ASME. Dr. Masud was the General Conference Chair for McMAT- 2011, Co-Chair for FEF 2019, Co-Chair for the 2020 Virtual Conference of SES, and General Conference Chair for the US National Congress on Computational Mechanics (USNCCM 2021). He is an Associate Fellow of AIAA, and Fellow of USACM, IACM, AAM, ASME, EMI, and SES. Prof Masud was awarded the 2019 G.I. Taylor Medal by SES, and the 2022 Ted Belytschko Applied Mechanics Award by AMD-ASME for fundamental contributions to the Theory of Stabilized and Variational Multiscale Methods in Computational Mechanics.