ARMA Future Leader Webinar Series

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Continuum damage modeling of fluid-driven fracturing: Towards energy budget quantification

Dr. Mostafa Mobasher, New York University Abu Dhabi (NYUAD)

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https://westernuniversity.zoom.us/j/99355457319

Abstract

Fracture in porous materials is a complex process in which several non-linear and multiphysical processes contribute to the microcrack network nucleation and growth to the formation of macroscale damage. In this research, several challenges are sought to be tackled: a) the need to model sub-scale long-range mechanical and fluid-flow interactions, b) the need to understand the energy budget and quantify the energy stored versus the energy dissipated in solid fracture and fluid flow, and c) the need to address the extremely elevated computational cost of the non-linear Multiphysics models.

To address these challenges, we present a non-local damage and transport model that can represent long-range sub-scale crack networks and long-range capillary fluid networks. The model is originated from a thermodynamically consistent framework and implemented within a mixed finite element setup. The model is successfully used to represent various loading conditions including 1d and 2d consolidation, slope stability, and fluid driven fracturing; the latter is also extended to analyze the interactions with pre-existing fractures. The thermodynamic basis allows for the derivation of the pertinent expressions of energy storage and dissipation, which are also calculated numerically using the finite element setup. In hydraulic fracturing, the calculation of energy quantities provides valuable insights about the ratio of the applied work that gets utilized to increase the stimulated reservoir volume versus that spent in fluid-viscous flow. This framework can be extended to serve as a basis for hydraulic fracturing optimization based on the energy budget. To address the elevated computational cost of the proposed model, and other expensive models in this research area, we propose a new approach named Integrated Finite Element Neural Network (I-FENN). This approach utilizes the rapidly evolving ML tools within the FEM setup to limit the computational expense of coupled problems; this is achieved through pre-training a network to predict one of the coupled processes and using the network within the FEM setup to predict a map of the coupled variable. The I-FENN setup has been applied to several classes of problems and is showing promising computational gains.

Biography

Mostafa Mobasher is an Assistant Professor of Civil and Urban Engineering at New York University Abu Dhabi (NYUAD). Dr. Mobasher holds Associated Affiliations with the Civil and Urban Engineering and the Mechanical and Aerospace Engineering departments at New York University, Tandon School of Engineering. Dr. Mobasher is also a Co-PI and the leader of the Energy Research Theme for Sand Hazards and Opportunities for Resilience, Energy, and Sustainability (SHORES), one of the NYUAD Research Institute Centers.

Dr. Mobasher's research is focused on modeling fracture and multi-physical response of manmade and natural materials across spatial and temporal scales. The research contributes to the development of a wide-range of numerical models to address the needs for non-linear modeling of materials subjected to mechanical and multi-physical loading scenarios. Dr. Mobasher's research scope was expanded to explore the integration between the Machine Learning (ML) and Artificial Intelligence (AI) approaches along with well-established computational methods such as Finite Element Method (FEM).

Dr. Mobasher received his PhD and MPhil Degrees from Columbia University in Engineering Mechanics in 2017. Prior to joining NYUAD, Dr. Mobasher was an Associate at the Applied Science Practice of the multidisciplinary consultancy firm Thornton Tomasetti based in New York.