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CFD MEETS GRAINS: COUPLED PARTICLE-BASED METHODS FOR GRANULAR FLOWS

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ABSTRACT

Granular materials in geotechnical engineering, like soils, rockfills, and fractured rock, behave strongly coupled with pore fluids, driving phenomena such as slope instability, sediment transport, and internal erosion. Capturing these fluid–grain interactions demands a coupling of computational fluid dynamics (CFD) with particle-based methods such as discrete element method (DEM), material point method (MPM), and particle finite element method (PFEM), which naturally resolve discrete particle-scale processes that continuum models miss. However, robust coupling poses significant challenges: stable momentum exchange at irregular moving interfaces, handling large deformations and solid-fluid phase transitions, bridging length scales from grains to field-scale, and rigorous validation.

This mini-symposium aims to bring together researchers who develop, improve, and apply coupled CFD-particle techniques to geomechanics and geotechnical problems. The objective is to review recent algorithmic advances, share experience from challenging applications, and identify open problems that demand further attention. Topics of interest include, but are not limited to: resolved and unresolved CFD-DEM coupling for debris flows, scour, and suffusion; mesh-free approaches (smoothed particle hydrodynamics (SPH)-DEM, moving particle semi-implicit (MPS)-DEM) for landslide run-out and dam-break flows over erodible beds; continuum-particle hybrids (MPM, PFEM) for large-deformation consolidation and soil-structure interaction with pore-fluid coupling; lattice Boltzmann method (LBM)-DEM for permeability evolution and fines migration at the pore scale; multiscale strategies that bridge grain-resolved simulations to continuum models; high-performance computing and data-driven closure models; and rigorous verification-validation benchmarks. By focusing on the specific complexities of geomechanical media, such wide particle size distributions, irregular shapes, evolving pore pressures, and cohesive/frictional contacts, this mini-symposium will highlight how advanced CFD coupling can bridge fundamental grain-scale physics and engineering-scale predictions. The societal relevance, from natural-hazard mitigation to sustainable infrastructure and offshore geotechnics, underscores the timeliness of this topic and its direct alignment with CFC 2027’s emphasis on multi-phase flows, fluid-structure interaction, and high-performance computing in fluid dynamics.