

Abstract

A generic Volume-Conservative Incompressible Smoothed Particle Hydrodynamics (VC-ISPH) framework has been developed for multifluid flow interaction with deformable porous media. The porous domain may remain rigid or deform based on fluid pressure and relative velocity. An implicit particle shifting algorithm is proposed to minimize numerical compressibility induced by the divergence-free variant of ISPH. The corrective volume-conservative algorithm is validated with two benchmark cases: lid-driven cavity and dam break flow. The correction can be utilized irrespective of closed/open domains with/without porous matrix. The corrective displacement minimizes numerical compressibility while conserving solenoidal velocity criteria. A binary color indicator is introduced based on the miscibility of fluid for multifluid flow simulation. The indicator enables simultaneous simulation of miscible and immiscible fluids. The multifluid framework is validated with three different flow scenarios: single-mode Rayleigh-Taylor Instability and lock-exchange flow (with/without free-surface). Fluid occupies only the pores inside a porous matrix. Thus, representative particle volume is altered using the effective porosity on the current particle coordinate to incorporate solid volume for a continuum approach. The VC-ISPH algorithm is compared with experimental cases of dam break flows in a closed domain with a rectangular porous block placed in the middle. Linear momentum conservative density-weighted pressure gradient operator coupled with hybrid free-surface boundary minimizes spurious velocity fluctuation at the free-surface. Open channel flow simulations with specific inlet/outlet boundary conditions are performed by putting dummy particle across boundary thresholds. The algorithm is validated with different scenarios of laminar/turbulent flows with various topography. Deformable cohesionless granular media is simulated with a rheological approximation of Mohr-Coulomb theory. The granular module is coupled with the Newtonian fluid flow in terms of an interaction force pair comprising of fluid pressure, viscous and drag forces. The coupled framework is validated with scenarios of dam break induced erosion and scour under a marine pipeline. It can capture transition of saturated (wet) to unsaturated (dry) zones of granular media or vice versa due to its separate modular structure. The model results show potential applicability of the developed framework.

Keywords: Divergence-free ISPH, Multifluid Flow, Free-surface Flow through Porous Domain, Deformable Granular Media