Modelling and numerical aspects of fluid-saturated granular materials: application to shear flows

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Introduction: In the first part of this talk, we present an algorithm for the numerical treatment of two-pressure, two velocity continuum models for heterogeneous, immiscible mixtures [1]. This algorithm has been employed in a numerical study of unsteady shear flows of fluid-saturated granular materials, as predicted by the continuum model of [2]. A representative sample of these results are presented and discussed.

Methods: The proposed algorithm constitutes a generalization of projection-type methods to multi-phase flows and employs a predictor-corrector time-marching scheme. Further, it incorporates an interface detection and capturing methodology, based on a local regularization method, for the treatment of the steep volume fraction gradients that are appear across material interfaces.

The efficiency and robustness of the proposed algorithm are assessed via investigating numerically the response of a dense granular bulb, immersed in an interstitial fluid, under shear. Simulations both with and without gravity are performed and are supplemented with parametric and grid-convergence studies.

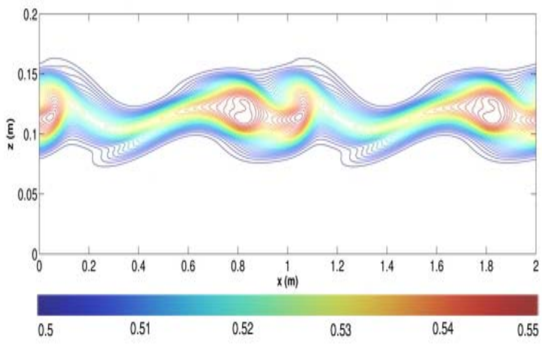

Fig. 1: Shear flow of a fluid-saturated granular material: particle concentration.

Results: Our numerical predictions show that the bulb undergoes Reynold's dilatancy, resulting in the dispersion of particles in the surrounding fluid. In the presence of gravity, due to the onset of the Rayleigh-Taylor instability, the bulb deforms into a filamentary structure which descends and eventually a granular pile is formed. In the absence of gravity, the bulb deforms into a long-wavy granular filament, as shown in Figure 1, due to the onset of the Richtmyer-Meshkov instability. This filament continues to move in an oscillatory manner but the flow remains marginally stable.

Discussion: The main outcome of our study is that suitably generalized projection methods, coupled with interface detection and capturing methodologies, are well adapted for the integration of two-phase flow models for immiscible, heterogeneous methods. Further, our numerical experiments indicate that such methods are able to capture complex flow patterns, emerging from hydrodynamic instabilities and the rheological characteristics of the granular medium.

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References: [1] Varsakelis, Papalexandris (2011), *J. Fluid Mech.* **669**:472-497;
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