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Modelling stick-slip dynamics in frictional fluids

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Dissipative interactions between grains often lead to instabilities and pattern formation in flows involving granular materials. This is especially so in wet granular flows, where viscous and capillary forces add to the complex dynamics. In a recent study we found an extraordinary diversity in the flow behaviour of wet granular material displaced by air in a Hele-Shaw cell [1]. By varying the air injection rate, system compressibility, and granular material filling fraction, several distinct flow morphologies were observed. The study maps these out in phase diagrams.

Here we present a numerical model that focuses on one of the observed pattern transitions; from frictional fingering to stick-slip bubbles. By incorporating surface tension, pressure and frictional forces, we trace the displacement of the interface using a dynamical version of a quasi-static algorithm developed previously [2]. The model reproduces the growth and evolution of the flow dynamics, resulting in patterns that closely resemble those observed in the experiments. The numerical scheme offers a method to study the transition between the pattern formation modes in detail, complementary to the experimental results.

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[2] H. A. Knudsen, B. Sandnes, E. G. Flekkøy and K. J. Måløy. Granular labyrinth structures in confined geometries. Phys. Rev. E 77, 021301 doi: 10.1103/PhysRevE.77.021301 (2008).