Control of a frictional fluid and plug formation in confined geometry

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Multiphase flows involving the transport of granular material in confined geometries are crucial for industrial engineering processes, such as the transport of oil, water and sand in pipelines. They display a rich variety of instabilities leading to the formation of complex patterns stemming from the interplay of different physical processes [1], involving pressure and capillary forces, associated to frictional interactions inside the granular packing. Therefore, a clear understanding aiming at a control of such frictional fluid appears really challenging.
We investigate here, both experimentally and theoretically, a simple model system of a confined, multiphase frictional flow as proposed by [2,3,4]. A mixture of glass beads (few hundred microns size) in a Newtonian liquid is slowly drained out at a constant rate (thanks to a syringe pump) from a capillary tube (2 mm diameter), with one side open to the air. The resulting advancing air-liquid meniscus may push and accumulate particles ahead, in a so-called "bulldozing" process, up to a clogging situation. At this jamming point, the stress against the capillary walls exerted by the granular medium, competes with the pore pressure at which air percolates through the granular assembly. This process repeats periodically leading to the formation of a plug trail along the tube.
We first study the onset of the "bulldozing" process by varying the system's parameters - density, surface tension, amount of particles- and identify the experimental conditions leading to the unstable dynamics and plug formation. Then, we perform experiments with ferromagnetic grains, which acquire a magnetic moment when submitted to a magnetic field, leading to tunable pair interactions. In these conditions, we show that we can trigger the "bulldozing" dynamics. Moreover, we also show that the external magnetic field impacts the final plug pattern along the tube by tuning the Janssen effect inside the granular packing, paving the way towards a tunable frictional fluid.

Références

1. B. Sandnes, E.G. Flekkøy, H.A. Knudsen, K.J. Måløy, and H. See. Patterns and flow in frictional fluid dynamics, *Nature Communications*, **2**, (2011).
2. Benjy Marks, B. Sandnes, Guillaume Dumazer, Jon A. Eriksen, and Knut J. Måløy. Compaction of granular material inside confined geometries, *Frontiers in Physics*, **3**, (2015).
3. Guillaume Dumazer, Bjørnar Sandnes, Monem Ayaz, Knut Jørgen Måløy, and Eirik Grude Flekkøy. Frictional fluid dynamics and plug formation in multiphase millifluidic flow, *Physical Review Letters*, **117**, (2016).
4. Guillaume Dumazer, Bjørnar Sandnes, Knut Jørgen Måløy, and Eirik G. Flekkøy. Capillary bulldozing of sedimented granular material confined in a millifluidic tube, *Physical Review Fluids*, **5**, (2020).