VISCOPLASTIC FINGERS AND FRACTURES IN A HELE-SHAW CELL

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ABSTRACT

Radial displacement flows of viscoplastic fluid in a Hele-Shaw cell can give rise to a range of instabilities. Theoretically, the viscoplastic version of the Saffman-Taylor interfacial instability[1] is predicted to occur when the yield-stress fluid is displaced by a Newtonian one. The interface is expected to remain stable, however, if the yield-stress fluid displaces the Newtonian one[2,3].

Experiments using an aqueous suspension of Carbopol show that the Saffman-Taylor instability is observed when the Carbopol is displaced by either air or an immiscible oil, and no instabilities are observed when the displacement is the other way around. However, when water is used in the displacement experiments, other instabilities appear that take the form of localized fractures of the Carbopol over the sections of the interface that are under tension. The fractures arise in both the stable and unstable Saffman-Taylor configurations, leading to a rich range of patterns within the Hele-Shaw cell.

Supported by these experimental observations, we argue that this pattern formation results from the solid-mechanical-like failure of the Carbopol gel. In particular, the fractures result from a reduction of the effective fracture toughness of the suspension when placed in contact with water, also observed in the spreading of Carbopol gravity currents into a shallow layer of water[5].

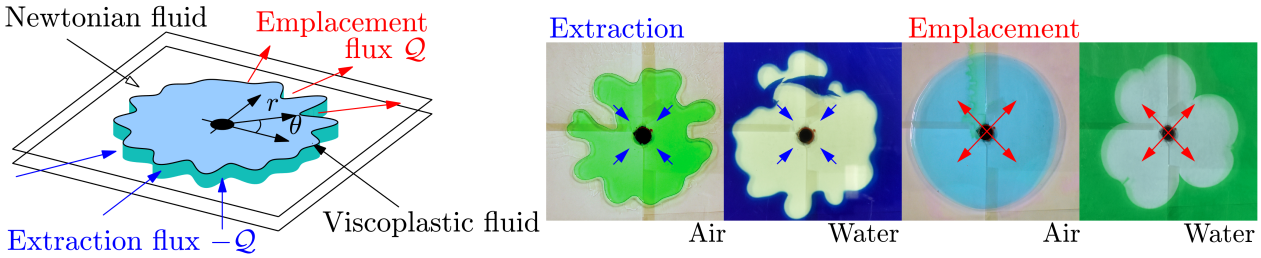

Figure 1: Sketch of the extraction/emplacement of a disk of a viscoplastic fluid with a surrounding Newtonian fluid. Experiments showing the extraction/emplacement of Carbopol when the Newtonian fluid is either air or water. When the Newtonian fluid is water localized fractures appear in both the stable and unstable Saffman-Taylor configurations.

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