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POROUS GRAVITY CURRENTS OF NON-NEWTONIAN POWER-LAW FLUIDS: A REVIEW OF THEORETICAL AND EXPERIMENTAL RESULTS

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The study of gravity currents within porous media is motivated by the need to model environmental and industrial processes in which an intruding fluid propagates inside a porous medium saturated with another fluid [1]. While the body of knowledge accumulated on gravity driven flows in porous media concerns mainly Newtonian fluids [2,3], real flows often involve fluids with complex rheology. Relevant applications include, but are not limited to, environmental contamination and in situ remediation.

The aim of this paper is to present a review of the theoretical and experimental results obtained by our group concerning the modeling of porous gravity currents of power-law fluids of index *n*. The propagation of thin currents over a horizontal, rigid and impermeable bed inside a porous domain saturated with an ambient fluid is considered under the sharp interface schematization. The volume of the advancing current is taken to vary as a monomial function of time with parameter α. First, closed form results were obtained for gravity currents propagating in plane or cylindrical geometry, deriving scalings for current length and thickness as functions of *n* and α [4-6]. Based on these benchmarks, the analytical models were refined introducing additional factors: medium heterogeneity and topographic control.

On one hand, the inherent heterogeneity of natural media was modeled [7-9] considering continuous variations of spatial properties described by simple monomial relationships, in the vertical or horizontal direction. Vertical variations mimick stratifications of natural media, while horizontal variations represent e.g. permeability alterations occurring nearby an injection well and induced by the drilling process. To analyze this configuration, novel results concerning radial spreading in radial geometry were obtained when the medium permeability varies as a monomial function of the distance from the source.

On the other hand, topographic control was modeled considering flows in porous channels of different shapes [10]. Both heterogeneity and topographic control proved relevant for the spreading of gravity currents as they influence the extent and shape of porous domain invaded by the contaminant, or reached by the remediation agent.

Our theoretical results were validated against multiple sets of experiments, conducted with different combinations of spreading scenarios and types of heterogeneity or channelization. Two basic experimental setups were employed, adopting either reconstructed porous media made of glass beads, or Hele-Shaw analogues. To this end, existing Hele-Shaw analogies for porous flow of power-law fluids were extended to heterogeneous media.

All scalings derived for the current front and thickness were confirmed by our experiments, with an agreement between theory and experiments improving with time, due to the limitations of the thin current approximation and boundary effcts near the injection zone. A comparison between the key exponents governing the propagation of the gravity current allows to determine the relative influence of rheology, heterogeneity, domain shape and geometry. The limitations on model parameters imposed by model assumptions are discussed in depth, considering currents with increasing/decreasing velocity, thickness, and aspect ratio, and their sensitivity to model parameters. Multiple critical values of the injection exponent α discriminating between opposite tendencies are thus determined.

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