Demonstration of secondary currents in the pressure-driven flow of a concentrated suspension through a square conduit

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It was shown theoretically by Ramachandran and Leighton [2] that the pressure-driven flow of concentrated suspensions of non-colloidal particles through non-axisymmetric conduits may not be unidirectional, and that the base flow along the axis of the conduits in the flow direction should be accompanied by a secondary flow driven by second normal stress differences. This work confirms the existence of these secondary flows by carrying out pressure-driven suspension flow experiments through a square (non-axisymmetric) duct. By tracking the motion of a thin stream of a contrastingly-dyed suspension introduced into the bulk flow of another, it is demonstrated that the suspension flows out of the sidewalls of the geometry towards the corners of the square cross-section, and then flows towards the center (see figure 1 for numerical calculation). This distortion of the interface was found to be qualitatively consistent with the calculations based on the suspension balance model of Nott and Brady [1] coupled with the constitutive equations of Zarraga and Leighton [3].

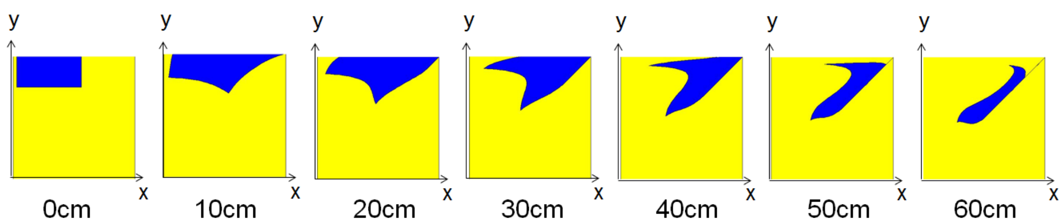

Figure 1: The axial progression of a patch of a non-colloidal suspension (blue) in the bulk flow of another (yellow), as predicted by the suspension balance model of Nott and Brady [1] and the constitutive equations of Zarraga and Leighton [3]. The cross-sectional co-ordinates are x and y, and the flow is into the plane of the paper. The calculation is performed in the first quadrant of the square only (the origin is, therefore, the center of the square).

Secondary currents have been historically neglected in suspension-flow calculations, in spite of the fact that they are predicted to have a stronger and often, counterintuitive influence on concentration distributions as compared to the traditionally-considered effect of shear-induced migration. This paper lends support to the idea that the impact of secondary currents is not negligible, and that such currents may actually be the dominant mechanism that determines particle distribution in suspension flows. This work also has strong implications for co-extrusion of non-colloidal suspensions in non-axisymmetric geometries.

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References

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