Department of Mathematics

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Scientific Computing Seminar

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Particle-laden exchange flows in duct: Mathematical modeling and experiments

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Abstract: Buoyancy-driven lock-exchange flow of a suspension mixture and a pure fluid in ducts is studied theoretically and experimentally. We investigate the interpenetration of the heavy particle-laden fluid and the light pure fluid in Boussinesq limit while considering the effects of the initial volume fraction of particles, ϕ, and inclination angle of pipe, β, on the flow. Applications of such complex flows can be found through the discharge, transport and dispersion of slurries, mine tailings, pastes, pharmaceuticals, paper pulp, drill cuttings, sludge, effluents and sewage, manufacture of cement clinker in inclined kilns, mineral processing in hydrocyclones, and inclined fluidized beds. On the theoretical side, a robust "lubrication" model is developed capturing the interfacial dynamics between heavy and light phases as well as space-time variation of particles volume fraction. The resulting model is in the form of the classical Riemann problem and has been solved numerically using a robust Total Variation Diminishing (TVD) finite difference scheme. In the presence of solid particles, the interface between the heavy and light layers becomes more curved compared to the case of pure fluids. This modification occurs due to the change of heavy mixture viscosity alongside the duct. Novel particle-rich zones are further discovered in the vicinity of the advancing heavy and light fronts. These zones are associated with different transport rates of the fluid and solid particles. On the experimental side, release of non-colloidal glass microspheres mixed with glycerin-water mixture into pure glycerin-water solution within an inclined pipe is considered. Three distinct regimes are identified: I) Sedimentary: at near-horizontal inclinations and for ϕ close to dilute and packed limits, the flow comes to a halt as particles settle out of the mixture. II) Mixing: away from the horizontal angle and for the intermediate volume fraction of particles, flow advances steadily and particles stay mixed within the suspension. III) Transitionary: a novel non-linear and unsteady behavior occurs as flow transitions from sedimentary to mixing regime. Through a scaling analysis, it is revealed that enhanced convection of heavy and light mixtures in inclined pipes (Boycott effect) facilitates the streamwise advancement rate of the particle-laden front.