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# Fluidisation pipe dynamics and associated extrudites: An experimental and numerical approach

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Sand extrusions (also known as sand volcanoes, vents, boils and blows) are widely recognised geomorphological processes occurring across all sedimentary environments. They pose a hazard to flood defence architecture, sea-floor infrastructure and hydrocarbon reservoirs by creating permeable pathways and undermining the structural integrity of the feature. Sand extrusions are ubiquitous and occur at scales spanning several orders of magnitude with examples catalogued from O($10^{-3}$) to O($10^{2}$) metre scales. Here we present laboratory-scale investigations of bi-disperse submerged beds locally fluidised at distinct inlet positions and velocities and compare the resulting qualitative extrudite development with quantitative particle image velocimetry of both the unsteady and steady states of fluidisation. Inlet velocities ranging from laminar (Re $\sim$ 350) to fully turbulent (Re $\sim$ 7000), particle sizes ranging from $d_{50}$ = 51 to 754 $\mu$m and particle size ratios ranging from $d_{50,fine}$/$d_{50,coarse}$ = 0.068 to 0.4 have been explored. Particle segregation had a significant effect on the dynamics of the fluidised system and thus the resulting morphological features. Distinct flow regions were identified, corresponding to a central, sometimes chaotic, turbulent jet, slow moving regions of sinking particles, and transient regions of no flow within the active fluidised zone. Moreover, laminations caused by falling streams of fine particles were observed to interact with the jet, deflecting its pathway. Clearly defined walls formed of fine particles were evident in high permeability cases, but walls were defined by the abrupt difference in bed make-up between the active fluidised zone and the undisturbed bed in low permeability cases. All of the residual morphologies resembled an upward-flaring funnel regardless of bed make-up or inlet velocity. Laboratory-derived results have been explored further through the use of a two-way coupled 3D Eulerian lattice Boltzmann-particle-particle interaction numerical model. The numerical model enables a broader range of bed characteristics to be considered and demonstrates their effect on the overall fluidisation of the bed and the resulting morphology of the extrusion. Insights gleaned from the laboratory and numerical models are summarised by a flow duration-dependent model of the field analogue.