Bubbly flows through granular packed beds: Experiments and Modelling

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Multiphase reactors operated in fixed bed configuration are widely used in petrochemical industry but their hydrodynamic is still not well understood. In order to predict the pressure drop and the mean void fraction for bubbly flows in packed beds, a new one-dimensional model is proposed. The balance equations for both phases are derived from local eulerian two-fluid equations which are spatially averaged at a meso-scale, i.e. at a length scale large compared with the microscale that characterizes the fixed bed. This mechanistic model differs from the earlier proposal of [Attou and Ferschneider 1999]. In particular, the momentum balances as well as the closure laws for the liquid-solid and the gas-liquid interactions have been completely revised in order to better account for the flow dynamics at the pore scale. It is first experimentally demonstrated that, in dilute conditions, the bubble size distribution only depends on the pore size when the later is smaller than the capillary length scale. It is also shown that the mean bubble dynamics is similar to that of a slug, with a relative velocity at meso-scale linearly increasing with the liquid superficial velocity. Besides, that relative velocity monotonically increases with the gas flow rate ratio, a behaviour that is tentatively attributed to the formation of preferential paths for the gas phase. These features allow to predict the mean void fraction with a reasonable accuracy [Bordas et al, 2006] Based on the motion of a bubble train in capillary tubes, the two-phase flow pressure drop \(\psi\) scaled by its single-phase flow counterpart \(\psi_1\) at the same superficial liquid velocity is predicted to linearly increase with the void fraction, with a prefactor \(\lambda\) evolving with the Capillary number: \(\psi=\psi_1\phi+1+\lambda(Ca)^{\alpha}\) Such a behaviour arises from the capillary pressure contribution to the pressure drop. One expect \(\lambda\sim Ca^{(1/3)}\) [Bretherton 1961, Ratulowski 1989]. These closures are validated by available experiments taken from literature as well as experiments performed at LEGI and at IFP, both in upward and in downward situations. From these investigations, a one dimensional model was derived, which account reasonably well for two phases flow in packed bed, even in more industrial configurations (dense regime). To go further, complementary results on the transverse phase distribution will be presented as well as a 2D model, based on the previous 1D model.

References