Liu, W-D, M.E.Sc., "High Density Solids Downflow Gas-Solids Reactors", The University of Western Ontario, April 1999.

Abstract

Experiments were carried out in a specially designed 5 m high, 0.025 m ID high density solids downflow gas-solids fluidized bed to measure the axial pressure gradient profiles along the test column and the actual solids holdup in the fully developed region. FCC particles with a mean particle diameter of 65 μm and a density of 1550 kg/m^3, a Geldart (1973) A powder, was used.

For co-current gas-solids downflow, a particle acceleration region and a fully developed region were identified along the column from the pressure gradient profiles. In the fully developed region, the apparent solids holdup calculated from the pressure gradient agreed well with the actual solids holdup measured by a pair of pinch valves under velocities less than 5.6 m/s, but underestimated it at higher gas velocities due to the increased wall friction loss. Two different flow regimes were observed in the developed region, a constant and high density pseudo-aggregative flow regime under low gas velocities and a reducing density pseudo-particulate flow regime under high gas velocities, with a boundary between U_g = 0.5~ 1.3 m/s, which is the critical gas velocities defined as U_{ap}. U_{ap} can be determined either from the measurement of the solids holdup in the pseudo-aggregative regime or the differential pressure fluctuation. High density downflow operation is defined as operation in the pseudo-aggregative flow regime, where particle velocity remains constant under all solids flux and gas velocity conditions and where the slip velocity is very high, with significant particle agglomeration. A solids holdup as high as 10% has been achieved in this operating regime. In the more dilute pseudo-particulate flow regime, the gas-particle slip velocity remains constant and no particle strands and large particle clusters were observed. The particle velocity was found to increase linearly with the gas velocity given the constant slip velocity. Consequently, the solids holdup decreased with increasing gas velocity in this regime, as reported previously in other riser and downer systems. Comparison of the results obtained here with those from an upflow riser shows inherent similarities between the two gas-solids co-current flow systems.

For gas upward-solids downward counter-current fluidized flow, the flow development and friction are discussed in relation to the pressure gradient profiles. The actual solids holdup measured by a pair of pinch valves and the apparent solids holdup calculated from the pressure gradients are compared for different operating conditions. Based on the changes of the mean particle velocity and the particle slip velocity, the particle agglomeration was studied. Choking is discussed in relation to both riser and counter-current operation. The operable maximum superficial gas velocity and solids flux in this system for FCC were experimentally determined.

The comparison of the high density downflow and the counter-current flow regimes with the upflow flow regime were made by using the differential pressure fluctuations and the particle slip velocity. The flow regimes in the co-current high density downflow and the counter-current flow are expected to exhibit the same types of hydrodynamic behaviour of fast fluidization and pneumatic transport regimes in the upflow system.

Finally, an unified overall flow regime diagram is proposed. This map first gives a general picture of fluidization which includes all types of fluidized beds. A clear "operating window" for FCC particles is proposed. The new unified flow regime diagram extends our current knowledge to wider operating ranges.