Hydrodynamics of Fluidized Bed Gasifiers

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Abstract

The presentation would summarize key contributions of my Ph.D. thesis entitled – Hydrodynamic of fluidized bed gasifiers. As fluidized bed reactors are increasingly being employed in various solid processing and energy industries, one of the principal fields of its deployment relates to its utility as coal gasifiers. Even though industrial coal processing in fluidized bed has been in know-how for nearly a century now, fundamental knowledge concerning flow hydrodynamics has largely impeded its operation and scale up to being mostly empirical. Thus, the primary motivation of this talk is to discuss the investigations that were reported in the thesis to determine the underlying hydrodynamic features affecting fluidized bed coal gasifiers.

The presentation has been broadly structured on three issues. At the outset, I would discuss a detailed analysis of the velocity fields in a binary fluidized bed (0.1 mm ID) of standard bed materials. Non-invasive Radioactive Particle Tracking (RPT) was employed to measure the solids velocity of a bed with a mixture of glass beads of sizes 0.5 and 2 mm. The coarser fraction for the present study was varied from 10-40%. Distinct features of solids flow were observed with varying bed composition. The mean velocity of finer flotsam (0.5 mm particles) fractions were found to achieve higher velocity, which is reduced upon increasing the jetsam fraction (2 mm) due to variation in bed voidage.

Subsequently, the second part of the talk would, for the first time, introduce the determination of velocity fields in a fluidized bed of coal-ash mixtures. Suitable tracers were designed and deployed to determine the solids flow path of a typical particle through RPT. Experiments were conducted in a cylindrical bed of 0.1 m in ID with two inventory compositions, namely, 70% Coal + 30% Bottom Ash (Composition I) and 20% Coal + 80% Bottom Ash (Composition II). Comparative analysis of RPT measurements yielded overall bed behavior, which was quantified in terms of time-averaged mean velocity, solids flux, RMS velocity, and kinetic energy per unit volume of the coal – bottom ash mixture. The mean axial velocity and solids flux profile indicated the influence of strong slugs on the solids flow patterns. Further, a three-dimensional transient CFD model was set up to predict the time-averaged profiles of coal and ash concentrations. Further, the distributions were compared against solids holdup (coal and ash) characteristics measured using γ-ray densitometry, with a single collimated source. Similarly, a comparison of measured solids velocity profiles is also reported between the CFD-predicted and those measured by RPT.

Finally, the last part of the presentation would focus on Residence Time Distribution (RTD) measurements and its analysis. The experiments were conducted by pulse radiotracer (Au-198) injection in a ‘hot’ industrial fluidized bed coal gasifier. The data obtained was treated and analyzed employing a network model based on a cascade of perfectly mixed tanks in series. Based on the non-ideality of flow, three flow Schemes 1, 2, and 3 were proposed whose RTD function was deduced in the Laplace domain. These RTD functions were numerically transformed into the time domain and were compared with that measured using radiotracing. It was noted that Scheme 3, which was based on the backflow of solids in the bed, could satisfactorily predict the actual RTD function. Besides, the parameters of the model provided insights into the actual solids flow pattern in the gasifier. Furthermore, the model demonstrated its adaptability in analyzing RTD of similar studies reported earlier for both single as well as pulse injection of the tracer.