Wu, Bangyou, Ph.D., “Nonlinear flow dynamics in circulating fluidized bed downers and risers”, The University of Western Ontario, December 2004 (co-supervisor: L. Briens from July 2002).

Abstract

Chaos analysis was used to study the nonlinear flow dynamics in circulating fluidized bed downers and risers. Kolmogorov entropy (K), correlation dimension (D), and Hurst exponent (H) were estimated from time series of solids concentration measurements and differential pressure measurements to characterize the nonlinear flow behaviour and flow structures in the downers and the risers.

Differential pressure along the axis and local solids concentration in the fully developed region were measured in a high-density downer (0.025m ID, 5m high). A solids acceleration region within 1-2 m from the top entrance of the downer was identified from the axial profiles of pressure gradient. High-flux flow was identified from profiles of K estimated from solids concentration measurements. Local solids concentration measurements and global differential pressure measurements in the fully developed region were distinguished by estimation of correlation integral. Pressure fluctuations in the fully developed region of the downer showed bi-fractal behaviour. Large-scale behaviour corresponded to a low correlation dimension, and small-scale behaviour corresponded to a high correlation dimension. Local flow dynamics from solids concentration measurements were contributed uniformly by flow behaviour of many different scales, namely dispersed particles and clusters with different size, so that there was only one scaling region in the log-log plot of correlation integral versus distance. Pseudo-particulate, pseudo-turbulent and pseudo-bubbling flow regimes were proposed in the fully developed region of the high-density downer.

Flow development and flow dynamics were systematically investigated using local solids concentration measurements in another larger downer (0.1m ID, 9.3m high) and were compared to a riser of the same diameter (0.1m ID, 15.1m high). Axial distributions of chaos parameters were more complex in the downer than in the riser, especially in the entrance section. In the core region of the downer, K increased and H decreased in the entrance region due to strong gas phase behaviour near the distributor. K decreased along the axis in the wall region of the entrance section in the downer due to intermittent flow of clusters with different size and dispersed particles. A “turbulent flow” was found in the wall region of the dense bottom section of the riser with an S-shaped axial distribution of solids concentration at very high solids flux and not so high superficial gas velocity due to more and large clusters in this region.

Flow in the downer was more uniform with flatter core in all the radial profiles of chaos parameters. The radial profiles of K varied significantly with increasing axial levels due to different clustering behaviour along axis in the wall region of the downer. Too intermittent flow of small clusters and dispersed particles increased the complexity of the local flow behaviour in the wall region of the downer, while moderate clustering behaviour caused the flow to be regular. Low H around 0.45 in the core region and higher H of over 0.5 in the wall region in both the riser and the downer indicated similar anti-persistent flow in the core region and persistent flow behaviour near the wall. D deceased significantly near the wall in the riser due to flow behaviour of large

clusters. Intermittent aggregating behaviour at the wall of the riser caused D to increase; complex flow of small clusters and dispersed particles at the wall of the downer also caused D to increase.

In the core region of the riser and the downer, time-averaged solids concentration (ε_s) was relatively low; flow dynamics were very complex with relatively high K and D and low H due to flow behaviour of dispersed particles and small clusters under dilute flow. In the wall region, flow behaviour were more regular with moderate clustering behaviour at ε_s around 0.01; at $\varepsilon_s > 0.02$, K and D decreased and H increased with increasing ε_s in the riser due to flow behaviour of large clusters, and chaos parameters became almost constant at $\varepsilon_s > 0.04$ due to limited size of clusters; at $\varepsilon_s > 0.02$, K and D increased and H decreased with increasing ε_s in the downer due to intermittent flow of clusters with different size and dispersed particles.