24e The Hydrodynamics of a Rotating Fluidized Bed

Maureen A. Howley and Robert Pfeffer

Fine, ultra fine and nanoparticles have found widespread use in many industrial applications, and the synthesis, dispersion and processing of these particulate systems is a major research focus. The rotating or centrifugal fluidized bed (RFB) has been shown to be particularly important in the processing and handling of very fine, cohesive powders and nanoparticle agglomerates because these particles can be uniformly fluidized in a variable centrifugal force field by simply adjusting the rotational speed of the fluidization chamber. The RFB thus offers a clear advantage over the conventional gravity-driven bed by delaying particle elutriation under conditions of sufficiently high gas velocities, and increasing minimum fluidization velocity (U_{mf}) to prevent onset of the unstable (bubbling) flow regime [1]. Moreover, it has been shown that cohesive micron and sub-micron size powders can be uniformly fluidized within a centrifugal force field sufficient to overcome strong inter-particle (van der Waals) forces, which prohibit fluidization in a gravity-driven column [2,3]. The RFB has been successfully modeled using one-dimensional force balance relationships under steady state conditions to predict maximum pressure drop (ΔP) and the critical fluidization velocity at incipient fluidization (U_{crit}) [4,5]. However these models do not contain time-dependence and therefore cannot be used to study dynamic flow behavior by hydrodynamic stability theory. We have developed a dynamic model of the RFB system based on a continuum approach. Ensemble-averaged equations of continuity and motion are written for the fluid and particle phases in the cylindrical coordinate system to consider the dependence of the centrifugal force and gas velocity on radial position (r). This dependency results in the phenomenon of layered fluidization whereby fluidization occurs *in layers* beginning at the freeboard (inner) surface of the bed where gas velocity is highest and centrifugal force lowest. To provide closure, constitutive relationships are adopted for expressing the particle phase stress contribution in terms of: 1) particle-particle force interactions; 2) the hydrodynamic-based particle bed model approach of Foscolo & Gibilaro [6,7], which has been augmented with an additional force term to consider van der Waals forces of attraction between cohesive powders. Using methods of linear stability analysis, we examine the base state of uniform fluidization in the RFB to predict: 1) the "g" force boundary transition between Geldart A/B behavior based on the criterion that Group B particles become unstable at U□U_{mf} and; 2) the boundary transition between Geldart C/A behavior based on the criterion that Group C particles will fluidize uniformly at $U>U_{mf}$ under "g" force magnitudes sufficient to overcome cohesive forces of attraction. Results will be compared to experimental work demonstrating the transitional boundary shift of the Geldart particle classification (Group C/A and Group A/B) in air-fluidized RFB's containing glass and alumina particles at varying "g" force magnitudes. [3].

[1] Matsuda, S., Hatano, H., Tsuchiya, K. (1998). Proc. of Fluidization IX, 701. [2] Matsuda, S., Hatano. H., Muramato, T., Tsutsumi, A. (2001). Proc. of Fluidization X, 501. [3] Qian, G.H., B¨¢gyi, I., Burdick, I.W., Pfeffer, R., Shaw, H. (2001). AIChE Journal, 47, 1022-1034. [4] Kroger, D.G., Levy, E.K., Chen, J.C. (1979). Powder Technology, 24, 9. [5] Chen, Y. (1987). AIChE Journal, 33, 722. [6] Foscolo, P.U., Gibilaro, L.G. (1984). Chemical Engineering Science, 39, 1667. [7] Foscolo, P.U., Gibilaro, L.G. (1987). Chemical Engineering Science, 42, 1489.