Xu, Chunbao, Ph.D., “Fluidization of ultrafine powders and its applications”, The University of Western Ontario, August 2004.

Abstract

Based on the force balance of the particle bed under vibration, a new correlation for predicting of the minimum fluidization velocity (u_{mf}) for fine particles has been derived by taking both the interparticle forces and the effects of vibration into consideration. A general correlation for the minimum fluidization voidage (ε_{mf}) showing the relationship between ε_{mf} and particle size as well as vibration intensity is also obtained from the experimental data. The newly derived correlation for the prediction of u_{mf} combined with the one for ε_{mf} proves to be superior to the existing correlations for particles of Geldart groups A, B and D, although the application of the present correlations remains unsatisfactory for group C particles.

A novel "online sampling" technique that can prevent the disruption of agglomerates when sampling the agglomerates from a fluidized bed has been developed and has been applied to the investigation of the agglomeration behaviour of cohesive particles during fluidization with and without mechanical vibration. A new model for the prediction of agglomerate size has also been established on the basis of an energy balance. Effects of gas velocity and mechanical vibration on agglomeration for two group C powders in fluidization are examined experimentally and theoretically.

Fundamental studies of the influence of gas type and temperature on the fluidization behaviour of groups C and A particles have been carried out. For all the particles tested, the fluidization quality in different gases generally shows the following priority sequence: Ar > Air > N_2> He > H_2. It is also found that a higher bed temperature usually leads to a larger bed voidage, a higher bed pressure drop as well as a lower u_{mf}. Possible mechanisms governing the operations of gas type and temperature in influencing the fluidization behaviour of fine particles have been discussed with respect to the changes in both gas properties and interparticle forces. It is suggested that the influence of gas type and temperature on fine particle fluidization is mainly through varying the gas properties (especially the gas viscosity). The increased gas viscosity may account for the improved fluidization quality of fine particles, as shown by either using a gas of higher viscosity or elevating the bed temperature.

Comprehensive investigations of the effects of vibration on fluidization of fine particles (4.8-216 μm in average size) show that the fluidization quality of fine particles can be enhanced under mechanical or acoustic vibration, leading to larger bed pressure drops and lower values of u_{mf}. The effectiveness of vibration on improving fluidization is strongly dependent on the properties (Geldart particle type, size or shape) of the primary particles and the vibration parameters (frequency, amplitude or direction). The possible roles of vibration in fine particle fluidization have also been studied. In addition, a novel acoustic method is explored to distinguish the group C particles from the group A particles.

A high-shear mixer has been used for surface coating of cohesive particles with finer particles as flow conditioners (e.g., nanoparticles of Al2O3, SiO2, TiO2 and carbon black). It is observed that

the surface coating can significantly enhance the flowability of all types of the host particles tested. According to the status of the guest particles in relation to the host particles, two different models, i.e., the asperities-contacting model and the sandwich-contacting model, have been proposed and applied to explore the possible mechanisms governing the operation of the flow conditioners.

A new and original technique of fluidized-bed metal-organic chemical vapour deposition (FB-MOCVD) is developed as a one-step method to prepare highly dispersed metal-supported catalysts for carbon nanotubes synthesis. By using ultrafine powder of γ- Al_2O_3 as the support with $Fe(CO)_5$ and $Mo(CO)_6$ as the metal precursors, Fe/Al_2O_3, Mo/Al_2O_3 and $Fe\text{-}Mo/Al_2O_3$ catalysts have been prepared in a FB-MOCVD reactor. The one-step method is advantageous over the conventional methods (such as impregnation, ion-exchange or co-precipitation) since it eliminates the drying and the subsequent calcinations/reduction operations, and hence minimizes the aggregation or growth of crystalline size of the supported metal particles caused by these operations. Bulk quantities of carbon nanotubes are synthesized with the as-prepared catalysts by CVD from acetylene at 650^{o}C or 850^{o}C in a fluidized bed. The as-prepared catalysts and the as-synthesized carbon nanotubes are characterized with various techniques including nitrogen isothermal adsorption, ICP-AES, SEM-EDX, TEM, XRD and TGA. The results render a great potential of applying the fine particle fluidization technology to the production of catalyst, advanced composite materials and carbon nanotubes.