The effect of particle properties on the dynamics of fluidized Beds

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Introduction and motivation

Fluidized beds comprise of a bed of solid particles supported against gravity by the upward flow of a fluid. They are used in a variety of applications in industry because they provide excellent rates of mass and heat transfer. In fluid catalytic cracking, for example, long carbon chains from coal or crude oil may be broken to form shorter chains to make gasoline and other substances.

Fluidized beds are also helpful for the removal of pollutants from flue gas before its release into the atmosphere. In this application, carbon particles react in a fluidized bed and the products are stripped by using steam. Fluidized beds can be used for steam generation and for coating metal objects with plastic. In the latter application, particles adhere on the surface of metal and form a thin layer.

This project focuses on gas fluidized beds. The occurrence of voidage waves such as bubbles, slugs and clusters in gas fluidized beds, has been a subject of considerable interest. The occurrence of such waves can have a significant effect on the economics and safety of operation of a fluidized bed reactor. It is widely recognized that the behavior of any given bed upon fluidization is largely dependent on particle characteristics. Geldart (1973) published a paper classifying powders into four groups based on their size and density. Each of these four groups is associated with a particular type of behavior upon fluidization. One of these is the Group A category which exhibits an interval of uniform expansion before bubbling. Group B powders on the other hand do not exhibit any such interval and start bubbling as soon as bed expansion begins. The reason for this difference in behavior is not well understood and will be the focus of this study.

Objective

In this project, we have measured the fluctuation velocity (during fluidization) of different kinds of powders (glass, ceramic and catalyst) that belong to the Geldart A

and B categories. This has been done in order to investigate the physical mechanisms that lead to the interval of stability in Geldart A particles. This study was conducted by taking advantage of a novel technique based on acoustics, which was used to back out the fluctuation velocity of the particles as a function of the gas flowrate.

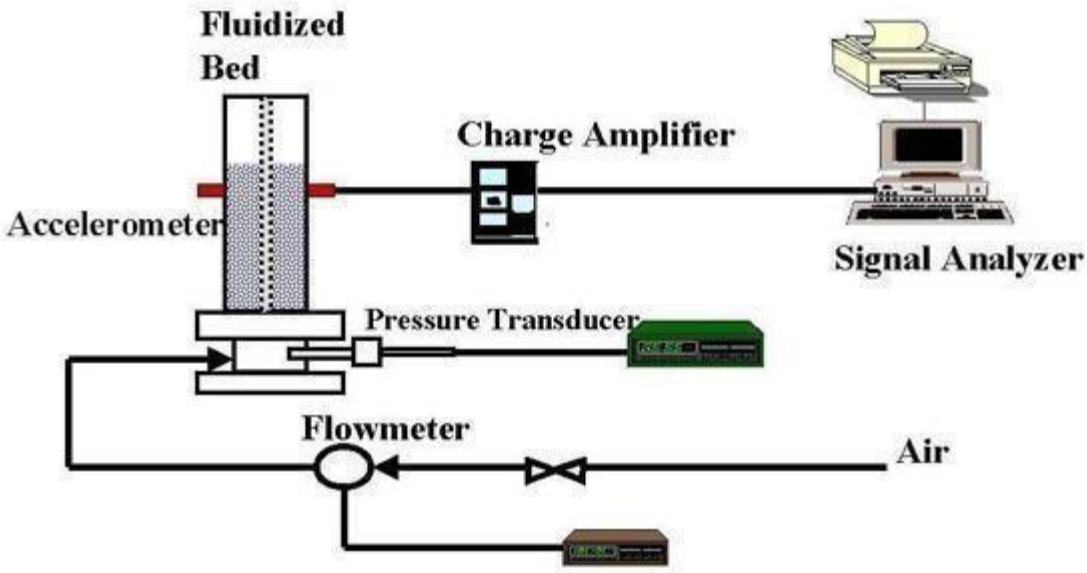
Experimental setup and measurements

Figure 1 shows a schematic of the experimental setup used in this study. The fluidized bed used in this work is a glass vessel, 2.9 inches in diameter. As the gas flows through the fluidized bed, the bed acts as a porous medium at low flow rates. Once the flowrate is high enough for the weight of the beads to be balanced by the drag, the beads become mobile and are termed fluidized. As the beads are fluidized, the beads collide with the wall and cause it to vibrate. The vibration causes a timedependent (charge) signal to be generated in the accelerometers that are attached to the exterior of the fluidized bed vessel. The charge amplifier both converts the charge signal from the accelerometers into a voltage and also amplifies the signal by a fixed factor. The voltage signal is transmitted to the signal analyzer, which converts the time domain signals into the power spectrum. A hundred such power spectra are averaged at any given flow rate to generate a data point that represents the root mean square acceleration. The average root mean square acceleration is converted to the normal fluctuation velocity (Vn) using the following relationship (see Cody et al. 1996):

$$V_n = \left(\frac{1}{D\rho_o^{1/3}\rho_m^{1/3}}\right)\left(\frac{3}{2\pi I^2 A}\right)^{1/3} a^{2/3}$$

where D is the average diameter of the beads is the density of the bead, $_m$ is the overall density in the bed and a is the root mean square acceleration. I^2A is a quantity specific to a given bed. It is related to the transfer function that relates the input (the vibration caused by the beads) at a given location to the output (the signal to the accelerometer). The value of I^2A determined for the fluidized bed in our case by Cody et al. (1996), is $2.23*10^7$ (m^2/kg^2 s).

Figure 1.



During the course of an experiment, a given powder was fluidized at increasingly higher values of the gas flowrate and the fluctuation velocity was recorded at each flowrate.

Fluctuation velocity measurements (Vn)

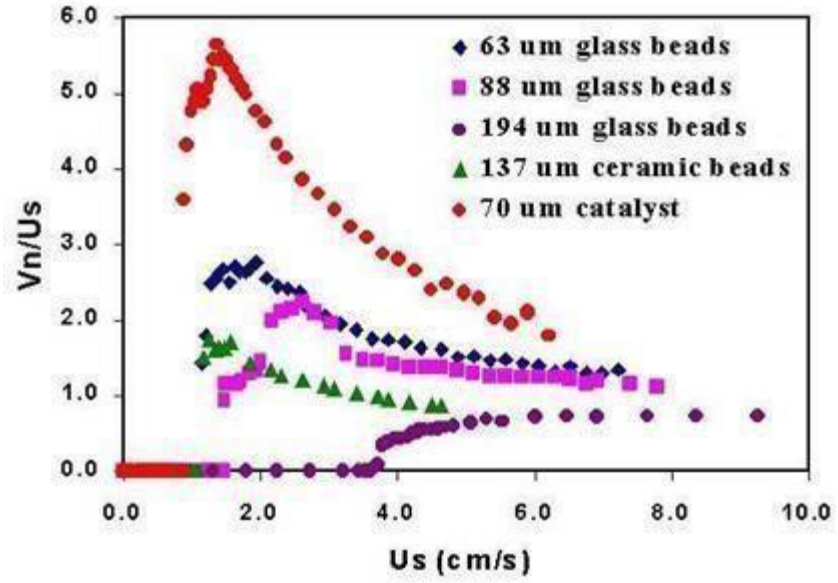
The first part of the project consisted of a survey of suitable powders that were available commercially. Once the appropriate beads were found, they were sieved carefully in order to create batches of purely Geldart A or Geldart B beads (classifications where the particle size is critical). Five different types of powders were selected for the experiments. The five powders considered had mean diameters of:

1. 63 micron glass beads
2. 88 micron glass beads

3. 137 micron ceramic beads
4. 70 micron catalyst beads
5. 194 micron glass beads

The first four powders belong to the Geldart A category and the fifth belongs to the Geldart B category. Figure 2 shows the dependence of Vn/Us (where Us is the gas flowrate) on the flow rate of the gas through the fluidized bed.

Figure 2.



It can be seen from figure 2 that the profiles for the Geldart A powders appear qualitatively different from the profile for the Geldart B powder.

The profiles for the Geldart A beads always increase initially, go through a maximum, and then decrease to a plateau. In contrast, the profile for the Geldart B beads increases and then flattens out. While this difference in behavior has been seen previously in glass beads, this work confirms that the profile seen here is universal for the Geldart A category. More work will be done on the characteristic profile of the Geldart B category in the future.

Conclusion

In this project, we have sought to understand the physical basis for the differences in the way Geldart A and Geldart B powders fluidize. We first identified test

materials belonging to these categories and then studied the variation in the fluctuation velocity as a function of the flowrate for all the materials identified. It was found that there are qualitative differences in the fluctuation velocity profiles of Geldart A and Geldart B materials - Geldart A materials exhibit a peak in the fluctuation velocity that Geldart B materials do not. That this feature is universal was confirmed using a host of Geldart A materials and Geldart B glass beads. Future work will consider a greater variety of materials in both categories (especially in the Geldart B category) to strengthen this finding. We will also consider physical mechanisms that would relate the peak in Geldart A materials to the interval of stability that is exhibited by such materials.

Acknowledgment

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References

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