ACOUSTIC FIELD EFFECTS ON MINIMUM FLUIDIZATION VELOCITY IN A 3D FLUIDIZED BED

David R. Escudero†
Department of Mechanical Engineering, Iowa State University
Ames, Iowa 50011
drescude@iastate.edu

Research Program: Complex Fluids Systems

Abstract

Fluidized beds are used in a variety of process industries because they provide uniform temperature distributions, low pressure drops, and high heat/mass rates. Minimum fluidization velocity is an important factor in understanding the hydrodynamic behavior of fluidized beds, and this characteristic may be modified through high frequency (sound) vibrations. The effects caused by sound wave frequency and sound pressure level on the minimum fluidization velocity in a 3D fluidized bed are investigated in this study. Experiments are carried out in a 10.2 cm ID cold flow fluidized bed filled with glass beads with material density of 2600 kg/m^3, and particles sizes ranging between 212-600 μm. In this study, four different bed height-to-diameter ratios are examined: H/D = 0.5, 1, 1.5, and 2. Moreover, the sound frequency of the loudspeaker used as the acoustic source ranges between 50-200 Hz, with a sound pressure level fixed at 110 dB. Results show that the minimum fluidization velocity is influenced by the frequency change. As the frequency increases, the minimum fluidization velocity decreases until a specific frequency is reached, beyond which the minimum fluidization velocity increases. Thus, acoustic fields provide an improvement in the fluidization quality of these particles.

Introduction

Fluidized bed hydrodynamic behavior is very complex and must be understood to improve fluidized bed operations. One of the most important parameters to characterize fluidized bed conditions is the minimum fluidization velocity (U_{mf}) [1], which is related to the drag force needed to attain solid suspension in the gas phase. The minimum fluidization velocity also constitutes a reference for evaluating fluidization intensity when the bed is operated at higher gas velocities [2]. In general, U_{mf} is a function of particle properties/geometry, fluid properties, and bed geometry.

Sound-assisted fluidized beds have been addressed in this study using different Geldart type particles (Geldart type A-C) to understand the effects produced by the acoustic field on the fluidization behavior and quality. This is an attractive option because it is a non-invasive technique that does not change the internal structure of the bed and there is no limitation to the particle type that can be fluidized.

Results and discussion

Minimum fluidization velocity showed a significant change when frequency increased. As shown in Figure 1, the minimum fluidization decreased until it reached 150 Hz, where a minimum value is attained, after this frequency the minimum fluidization velocity increases again. This phenomenon is repeated for each size range tested, which indicates that the effect of frequency is independent of material size over the range 212-600 μm.The values of the minimum fluidization velocity presented in Figure 1 are the average of the 10 tests completed for each size range, and the bars showed in Figure 1 represented one standard deviation of this average values. The value of the standard deviation for each of the size ranges varies between 0.2 – 0.23 cm/s, which represents approximately 1-2% of the U_{mf}. Thus, Figure 1 clearly showed that there is a significant change in the minimum fluidization velocity due to a change in the frequency.

Similar results were found by Guo et al. [3], Russo et al [4], the difference between the results found in literature and this study are in the value of frequencies at which this phenomenon takes place. The difference between frequencies can be attributed to the natural frequencies of the respective gas – solid fluidized bed.

† Presenting author: David Escudero

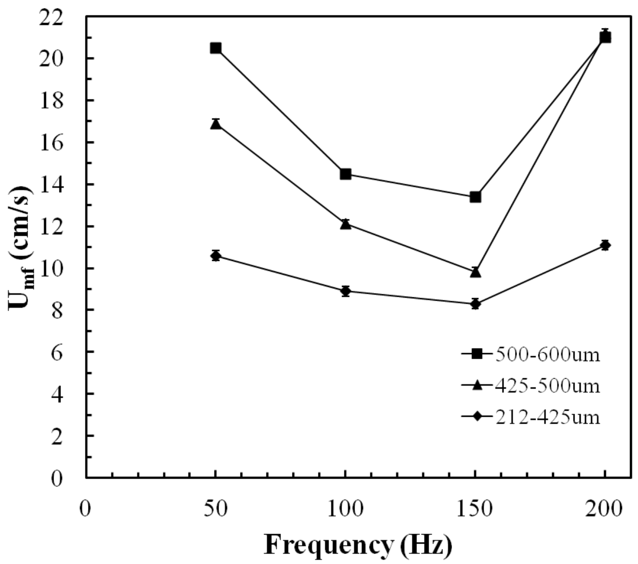

FIGURE 1: MINIMUM FLUIDIZATION VELOCITY AS A FUNCTION OF FRECUENCY FOR GLASS BEADS AT H/D = 0.5.

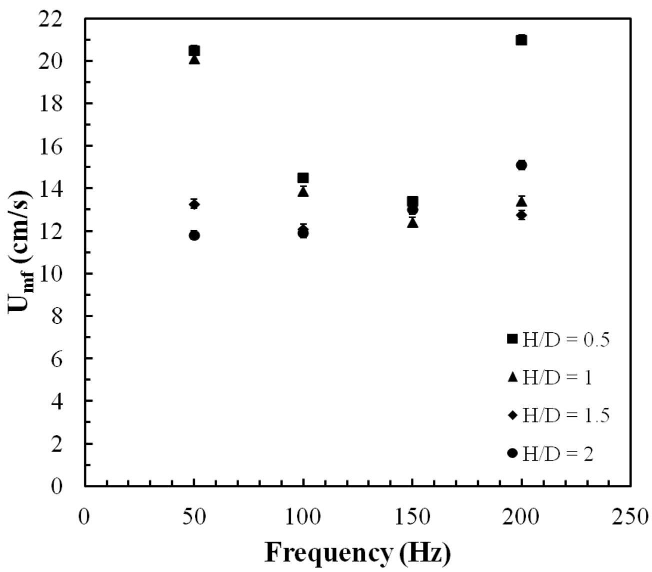

FIGURE 2: MINIMUM FLUIDIZATION VELOCITY AS A FUNCTION OF FREQUENCY FOR 500-600 µm GLASS BEADS AT DIFFERENT BED HEIGHTS.

Figure 2 shows that fluidization is achieved with less superficial gas velocity between 100 and 150 Hz for all H/D ratios except H/D = 2. At H/D = 2, U_{mf} is lowest between 50 and 100 Hz, which implies that as the surface of the bed approaches the acoustic source, lower frequencies are able to fluidized the material and reach homogeneous fluidization without the need of increasing the acoustic frequency.

Leu et al.[5] and Russo et al. [4] showed that the change in the bed weight does not influenced the trend exhibited by the minimum fluidization velocity as a function of frequency, and they results showed similar trends as the ones showed in Figure 2. The possible explanation for this behavior is that the increase in the sound attenuation due to the larger amount of solids decreases the average SPL under which beds of different weights are operated [4].

Conclusions

The presence of an acoustic field on a fluidized bed filled with glass beads at different bed heights improved the fluidization quality of the material in every size range studied.

Minimum fluidization velocity decreased with an increase in acoustic frequency until the material reached a point of homogeneous fluidization, beyond that point, U_{mf} started to increase. The results obtained in this research corroborate previous studies found in the literature.

Fluidized beds enhanced with acoustic sources exhibit dependence between bed height and minimum fluidization velocity. As H/D increases, and the frequency is fixed, there are changes in the minimum fluidization velocity, these changes did not happen when there was not an acoustic field present in the bed material.

Future studies will address the effects of acoustic frequency and sound pressure level on fluidized beds fill with different materials.

References

[1] Ramos Caicedo, G., García Ruiz, M., Prieto Marqués, J. J. and Guardiola Soler, J. (2002). "Minimum fluidization velocities for gas-solid 2D beds." *Chemical Engineering and Processing,* **41**(9): 761-764.

[2] Zhong, W., Jin, B., Zhang, Y., Wang, X. and Xiao, R. (2008). "Fluidization of biomass particles in a gas−solid fluidized bed." *Energy & Fuels,* **22**(6): 4170-4176.

[3] Guo, Q., Liu, H., Shen, W., Yan, X. and Jia, R. (2006). "Influence of sound wave characteristics on fluidization behaviors of ultrafine particles." *Chemical Engineering Journal*. **119**(1): 1-9.

[4] Russo, P., Chirone, R., Massimilla, L. and Russo, S. (1995). "The influence of the frequency of acoustic waves on sound-assisted fluidization of beds of fine particles." *Powder Technology*, **82**(1): 219-230.

[5] Leu, L. P., Li, J. T. and Chen, C. M. (1997). "Fluidization of group B particles in an acoustic field." *Powder Technology,* **94**(1): 23-28.

† Presenting author: David Escudero