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COMMENT

COMMENT ON "MODELING OF SOLIDS GLOBAL FLUCTUATIONS IN BUBBLING FLUIDIZED BEDS BY STANDING SURFACE WAVES" BY SUN *et al.* (1994)

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In recent years, pressure fluctuations and their propagation in gas–solids fluidized beds have attracted considerable attention (Roy *et al.* 1990; Musmara *et al.* 1992; Alzahrani & Wali 1993; Kage *et al.* 1993; Dhodapkar & Klinzing 1993; Kok & Benschop 1994; Bi *et al.* 1995). In a recent paper, Sun *et al.* (1994) related the dominant frequency of pressure waves to the sloshing motion of bed particles. The effect of column diameter was introduced in [17a] in their paper and verified using the literature data listed in table 4. We question whether the data in table 4 justify $f \sim D^{-1/2}$ in the intermediate range of H/D (i.e. $H/D = 0.7$ to 2.0).

It has long been realized that the dominant frequency of pressure fluctuations in gas–solids fluidized beds is a function of static bed height. Based on the concept of mechanical oscillations of particle layers around their equilibrium positions, Verloop & Heertjes derived the equation

$$f = \frac{1}{\pi}\sqrt{\frac{g}{H}(1-\epsilon)/\epsilon} \qquad [1]$$

where ϵ is the dense phase voidage. Baskakov *et al.* (1986), on the other hand, treated the fluidized bed by analogy with a U-tube, with particles rising in the central core region and descending in the annular region, similar to the picture employed by Sun *et al.* The dominant frequency was then derived as

$$f = \frac{1}{\pi}\sqrt{\frac{g}{H}} \qquad [2]$$

Note that [1] and [2] are identical when the dense phase voidage ϵ is 0.5.

Equations [1] and [2] are consistent with the experimental data of Hiby (1967), Verloop & Heertjes (1974), Lirag & Littman (1974), Fan *et al.* (1981), Sadasivan *et al.* (1982), Little (1987) and Alzahrani & Wali (1993) measured at various static bed heights with D from 0.05 to 0.8 m and with $H/D = 0.7$ to 2.0, the intermediate range identified by Sun *et al.* (1994).

In figure 4 of the Sun *et al.* (1994) paper, limited data on dominant frequency listed in table 4 with $H/D = 0.7$ to 2.0 were used to test the effect of column diameter by plotting f against D without considering the variation of H. On this basis, the dominant frequency decreased with increasing D. Figure 1 plots both $H^{1/2}f$ and f against D using the data listed in table 4 of the Sun *et al.* (1994) paper. It is seen that the column diameter has no clear influence when the effect of H is accounted for. When $H^{1/2}f$ is plotted against D, all the data can be reasonably correlated by [2]. However, f appears to decrease with increasing D when f is plotted against D based on the data in table 4. This can be explained when [2] is rewritten as

$$f = \frac{1}{\pi}\sqrt{\frac{g}{D}}\sqrt{D/H} \qquad [3]$$

If f is plotted against D with H/D held constant, f is then expected to be proportional to $D^{-1/2}$, consistent with figure 1 where all data fall within the range predicted by [3] with $H/D = 0.7$ to 2.

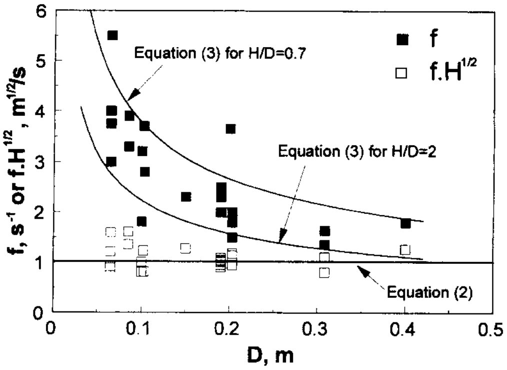

Figure 1. f and $fH^{1/2}$ as functions of D based on the data in table 4 of Sun *et al.* (1994).

Since the dominant frequency can be affected by (i) the plenum volume (Little 1987; Kage *et al.* 1993), (ii) the resistance of the distributor (Fan *et al.* 1981) and (iii) particle size and density (Hiby 1967; Sadasivan *et al.* 1980; Svoboda *et al.* 1984) and system temperature (Kai *et al.* 1985), it is difficult to test the column diameter effect by excluding all these other factors. However, there is no direct evidence at this stage that f varies with column diameter. For example, D has no obvious effect on f in the data of Roy & Davidson (1989) for columns of $D = 0.045$, 0.1, 0.135 and 0.28 m with pressure ranging from 100 to 600 kPa. Our data (see figure 2), from two columns of diameter $D = 0.051$ m and 0.102 m using the same FCC particles of mean diameter 60 μm and density 1580 kg/m^3, indicate that f in the larger column is slightly higher (not lower) than in the smaller column, probably due to differences in distributor design and windbox volume (Little 1987; Kage *et al.* 1993).

It is also worth noting that a similar situation arises with respect to the particle diameter, which is not accounted for in available models. According to Hiby (1967), $f \propto d_p^{-0.8}$ by plotting f versus d_p with $H/d_p = 10$ in a column of $D = 0.19$ m (note that there is a misprint suggesting that $f \propto d_p^{0.8}$ in the original paper, but figure 9 makes the true sign clear). However, following the same procedure as above, it can be shown that f should be proportional to $d_p^{-0.3}$ with H held constant, i.e.

$$f \propto \sqrt{g(d_p/H)}\, d_p^{-0.8} = \sqrt{g/H}\, d_p^{-0.3} \qquad [4]$$

This is consistent with data of Sadasivan *et al.* (1982) and Svodoba *et al.* (1984) who found $f \propto d_p^{-0.31}$ based on data obtained in columns of $D = 0.2$ and 0.085 m, respectively.

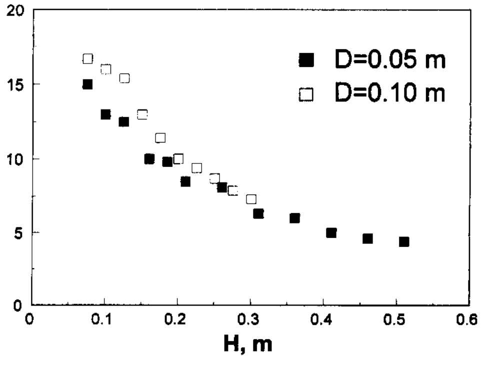

Figure 2. Frequency of absolute pressure fluctuations measured 0.01 m above the distributor as a function of H and D for FCC particles of $d_p = 60\,\mu$m and $\rho_p = 1580$ kg/m^3 at $U = 0.08$ m/s. Column 1: $D = 0.051$ m, perforated plate distributor with 54 holes of diameter 1 mm and a windbox volume of 2.2×10^{-4} m^3; column 2: $D = 0.102$ m, perforated plate distributor with 177 holes of diameter 0.5 mm and a windbox volume of 2.1×10^{-4} m^3.

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