A study of small changes in bed inclination on wall effect in a semi-cylindrical fluidized bed

A STUDY OF SMALL CHANGES IN BED INCLINATION ON WALL EFFECT IN A SEMI–CYLINDRICAL FLUIDIZED BED

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Experiments with a 15 cm semi–cylindrical bed inclined slightly forward and backward were carried out to examine the magnitude of wall effect changes in a semi–cylindrical fluidized bed. Bubbles were observed through a transparent front wall of the bed.

The experiments were conducted with sand particles of an average size of 281 μm at an excess gas velocity above minimum fluidization of 12 cm/s. The bed employed a mild steel perforated plate with 88 holes arranged in square pitch. A static bed 70 cm in height was used in all cases.

No change in bubble size and bubble rise velocity was detected when the bed was inclined at ± 0.8 degrees to the vertical. It was previously a concern that small variances from the vertical in a laboratory scale semicylindrical fluidized bed would indicate small changes in wall effects and prejudice experimental results obtained by direct observation through the transparent front wall of the bed.

Introduction

For analysis, assessment and/or design of fluidized beds, the fundamental characteristics of a swarm of bubbles (for example, bubble size and bubble rise velocity) need to be estimated. Once bubble properties are known, we can caluculate the mass transfer rates of reactants in the bed – e.g. the oxygen diffusion rate from bubbles to the combustion (emulsion) phase in fluidized–bed coal combustion. Since we can't see bubbles in beds without special devices,[5] various indirect methods to investigate bubble characteristics have been reported.[4] Although two–dimensional beds are useful to visually observe bubbles in the beds, there are too many differences to enable results to be quantitatively extended to three–dimensional beds. In a previous paper,[3] a semi–cylindrical bed was demonstrated to give the same results for the average size and rising velocity of bubbles as three–dimensional beds. However, the sensitivity of bubbles to wall effect changes near the front face is still unknown.

In this work, the effect on bubble behavior of the front glass face of a semi–cylindrical bed was investigated by inclinig the bed wall.

1. Experimental

A quartz of d_p = 281 μm*** and ρ_p = 2.50 g/cm^3 was used. The particle size distribution is

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*** $d_p = 1/\Sigma(x_i/d_{pi})$, where x_i is the mass fraction on sieve i, and d_{pi} is the average diameter of particles on each sieve.

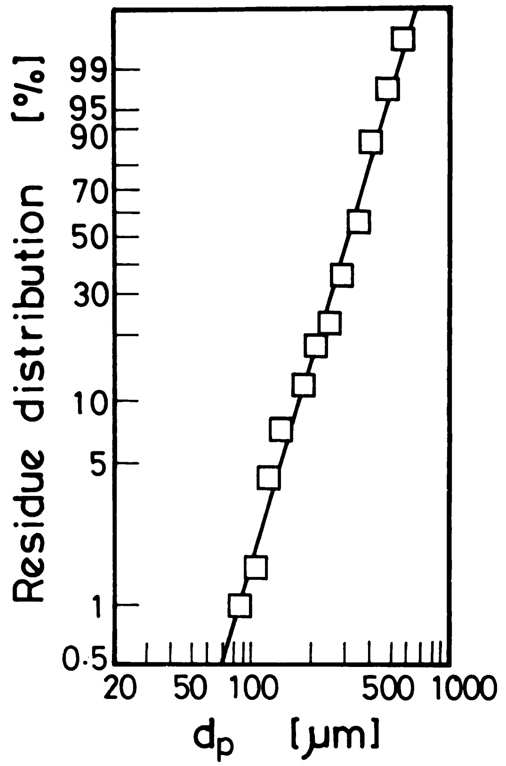

Fig. 1 Rosin–Rammler plot for solid particles used

shown in Fig.1. Air was used as the fluidizing medium. The minimum fluidizing velocity of the sand was 11.7 cm/s at room temperature (≃25°C).

Experimental apparatus and procedure A semicylindrical bed with a perforated semi–circular distributor (88 holes in a square array) was employed. Details of the exprimental equipment has been given previously.[3] Experiments on the magnitude of wall effect changes were conducted by inclining slightly forward and backward –– i.e. with an inclined angle of ± 0.8 degrees to the vertical. The same experimental procedure to measure bubbles with a high speed video camera system as in the previous paper[3] was adopted.

2. Result and Discussion

Since bubbles greater than 20 mm in size are desirable for the visual observation through the front glass face of the semi–cylindrical bed,[3] an excess gas velocity above the minimum fluidization of 12 cm/was chosen. A static bed height of 70 cm was employed, which is the same as the static bed height in the previous experiment with a vertical bed.[3]

Bubble size The effect of bed inclination on the volume average bubble size is shown in Fig.2. $\bar{D}_E$ values at bed heights of 15 ± 5cm, 25 ± 5cm, 40 ± 10cm and 60 ± 10cm from the distributor are represented in the figure as $\bar{D}_E$ at 15, 25, 40 and 60cm. It is evident from the figure that no effect of bed inclination on average bubble size is detectable. Thus there is no wall effect change on the average bubble size near the front glass face of the semi–cylindrical bed. If there were a strong wall

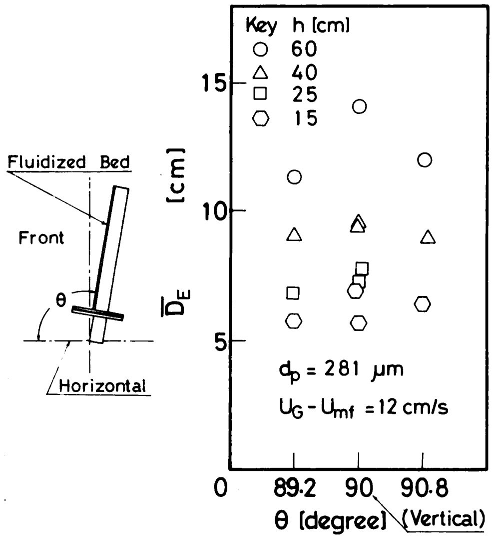

Fig. 2 Effect of bed inclination on $\bar{D}_E$

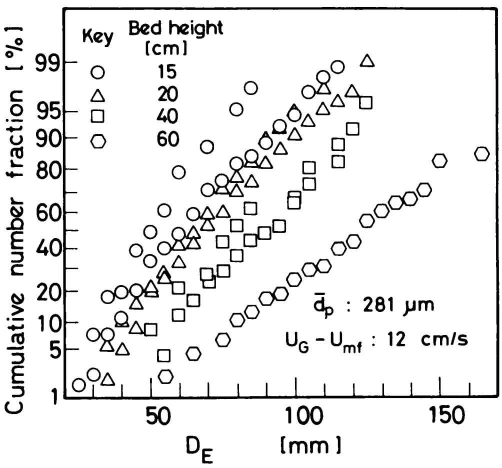

Fig. 3 Normal probability plots for D_E at various bed heights using a vertical bed ($\theta = 90°$)

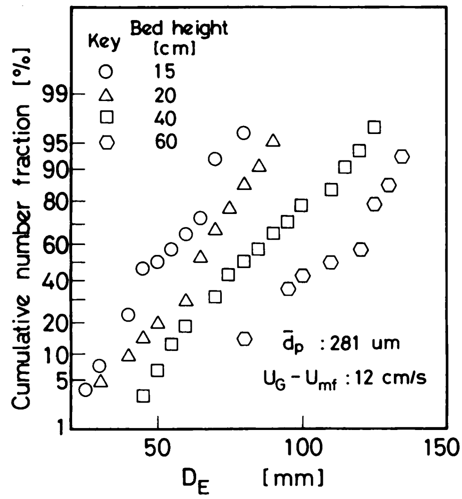

Fig. 4 Normal probability plots for D_E at various bed heights using a forward bed ($\theta = 89.2°$)

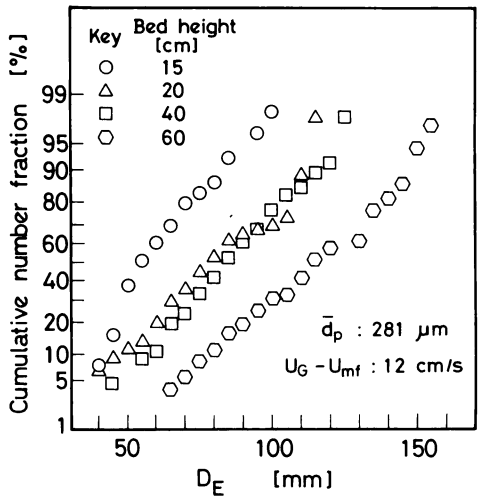

Fig. 5 Normal probability plots for D_E at various bed heights using a backward bed ($\theta = 90.8$)

effect, measured bubble characteristics should have changed when the bed was inclined. This result is in agreement with results in gas–liquid upflow.[2]

The normal probability plots for bubble size distributions at three bed inclinations of $\theta = 90$, 89.2 and 90.8 degrees are shown, respectively, in Figs. 3, 4 and 5. Although experimental reproductivity at a bed height 15 cm in Fig.3 is not perfect, it is evident that these figures show almost the same bubble size distribution —— the normal distribution —— at various bed heights for the three bed inclinations. The normal probability function showed the best fit compared to other probability functions recommended in literature.[1,6,7]

<u>Bubble rise velocity</u> The effect of bed inclination on the arithmetic average rising velocity of bub-

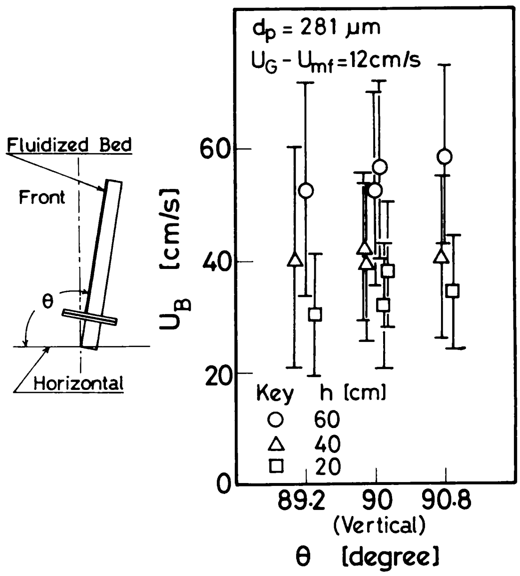

Fig. 6 Effect of bed inclination on U_B

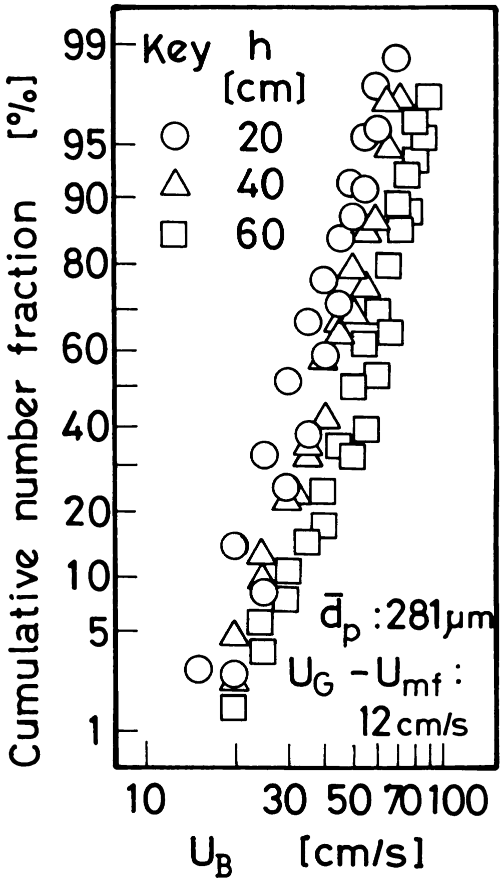

Fig. 7 Logarithmic normal probability plots for U_B at various bed heights using a vertical bed (θ =90°)

bles is shown in Fig.6. Due to the comparative broadness of the distribution, the standard deviation range is also represented for each point in the figure. It is evident from the figure that no effect of bed inclination on bubble rise velocity is detectable. Of course, bubble frequency at the front wall at each bed inclination is different, —— i.e. 2.60, 2.43 and 4.57 bubbles/s at the observation window for θ =89.2, 90.0 and 90.8 degrees to the vertical, respectively.

The logarithmic normal probability plots for bubble rise velocity distributions at θ =90, 89.2 and 90.8 degrees are shown in Figs. 7, 8 and and 9. Comparatively good agreements for bubble rise velocity distribution exist.

From Figs. 6–9, no change in wall effect for bubble rise velocity is evident for bed inclinations of ± 0.8 degrees to the vertical.

Conclusion

To investigate changes in wall effect at the front face of a semi–cylindrical fluidized bed, measurements of bubble size and bubble rise velocity were carried out using a bed slightly inclined about the vertical.

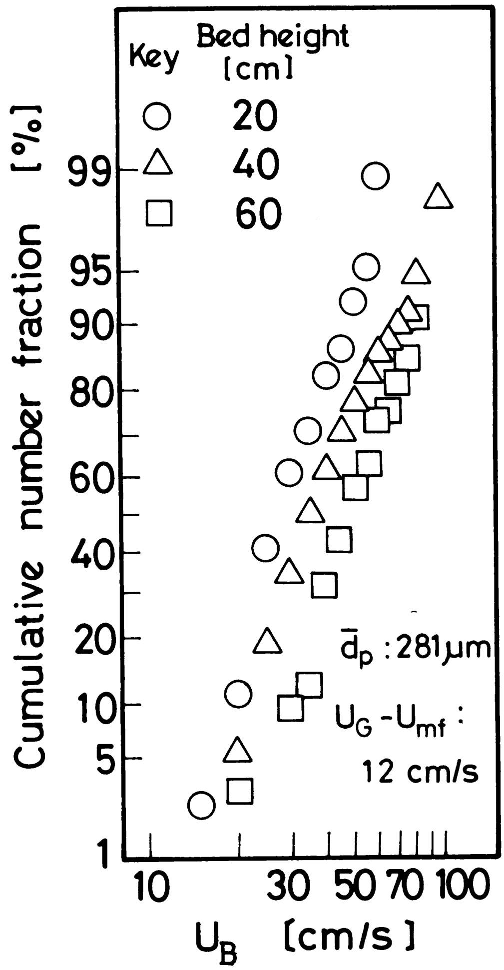

Fig. 8 Logarithmic normal probability plots for U_B at various bed heights using a forward bed (θ = 89.2°)

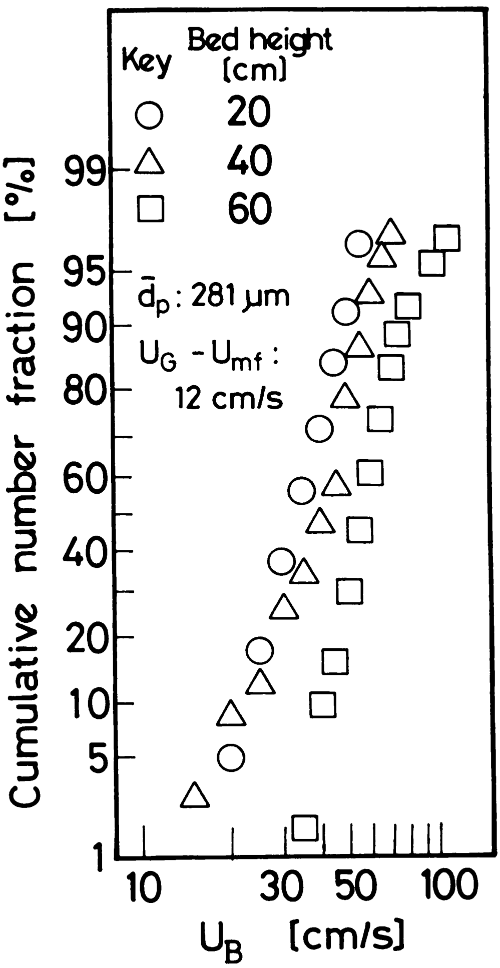

Fig. 9 Logarithmic normal probability plots for U_B at various bed heights using a backward bed (θ = 90.8°)

The following results were obtained.

1) No change in wall effect on bubble size and bubble rise velocity was evident at bed inclinations of ± 0.8 degrees about the vertical. Since the bubbles are not affected by small changes in experimental set–up, our previous conclusions[3)] that results from a semi–cylindrical bed can be directly applied to a 3–dimensional bed still stand.

2) The normal and logarithmic normal probability plots were found to show the best fit for bubble size and bubble rise velocity distributions, respectively.

Nomenclature

D_E	= equivalent diameter of bubble	[cm]
$\bar{D}_E$	= volume average diameter for a swarm of bubbles	[cm]
d_p	= average diameter of solid particles	[μm]

h	= bed height above distributor	[cm]
U_B	= rising velocity of bubble	[cm/s]
$\bar{U}_B$	= arithmetic average rising velocity of a swarm of bubbles	[cm/s]
U_G	= superficial gas velocity	[cm/s]
U_{mf}	= minimum fluidization velocity	[cm/s]
θ	= inclination angle of bed to horizontal	[degree]
ρ_p	= density of used sand	[g/cm^3]

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