EFFECT OF BED TEMPERATURE ON BUBBLE SIZE AND BUBBLE RISING VELOCITY IN A SEMI-CYLINDRICAL SLUGGING FLUIDIZED BED

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Introduction

Bubbles are closely related to gas-solid mixing, so the performance of a gas-solid fluidized bed may be determined by the behavior of bubbles. Bubbles at ambient temperature have been much investigated from various viewpoints to obtain almost the same conclusions about size and resing velocity. However, there exists some conflict among researchers concerning the dependence of temperature on bubble properties.

Sitthiphong *et al.*[6] reported that the eruption diameter in a large particle bed increases with bed temperature. Wittman *et al.*[9] and Sishtla *et al.*[5] reported no effect of temperature on bubble size over the range investigated. Yoshida *et al.*[11], Geldart *et al.*[3] and Stubington *et al.*[7] reported that bubble size decreased with bed temperature from ambient to about 600 K.

To measure bubble size and bubble rising velocity, various methods have been proposed and developed. But it is difficult to determine the movement of each bubble easily and directly by vusual observation in a 3-D fluidized bed. Semi-cylindrical beds have been used to observe the behavior of slugs and jets in fluidized beds and spouted beds, proving that semi-cylindrical beds are a useful tool for direct observation of in-bed phenomena with only minor wall interference[4,8].

In the present work, bubbles and/or slugs at an elevated bed temperature (600 K) were observed using a semi-cylindrical bed to determine their sizes and rising velocities, and these data were compared with the the results obtained at room temperature (300 K).

1. Experimental

The experimental apparatus is the same as that used in a previous paper[4] except that a jacket heater and ceramic wool were installed in the back side of the column to keep the bed temperature at 600 K.

Air preheated to 600 K below the distributor was used as the fluidizing medium in all experiments. Four cuts of sands, covering a wide range of Geldart classification B, were used as solid particles (see **Table 1**). The average sizes of solid particles d_p were determined by a sieve analysis. The values of U_{mf} were measured at 300 K and 600 K. U_{mf} at 600 K is much smaller than that at 300 K for comparatively large particles. The experimental procedure and analytical method for bubble sizes and rising velocities were the same as described in the previous paper[4].

2. Results and discussion

2.1 Bubble size

In general it can be said that not only fluidizing gas viscosity but also particle adhesivity and particle friction characteristics of change with bed temperature[10].

The effect of gas flow rate ($=U-U_{mf}$) on equivalent diameter of bubble D_E at 600 K and $d_p=281\ \mu$m is shown in **Fig. 1.** It is found that D_E increases with increasing height above the distributor (h) and excess gas velocity ($U-U_{mf}$) as well as ambient temperature. The solid lines in the figure show values calculated from the equation by Darton *et al.*[2], which was obtained for bubbles in the bubble regime at ambient temperature.

Figures 2, 3, 4 and **5** show the effect of bed temperature on bubble size for $d_p=75.2\ \mu$m, $d_p=$

Table 1. Physical properties of particles used

d_p[μm]	ρ_p[kg/m^3]	U_{mf}[m/s] 300 K	U_{mf}[m/s] 600 K
75.2	2500	0.980	0.700
189	2500	3.30	2.39
281	2500	10.2	5.35
521	2500	33.2	16.7

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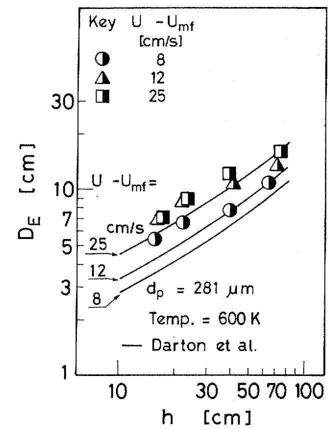

Fig. 1. Effect of gas flow rate on D_E vs. h relation for $d_p = 281\ \mu$m at 600 K

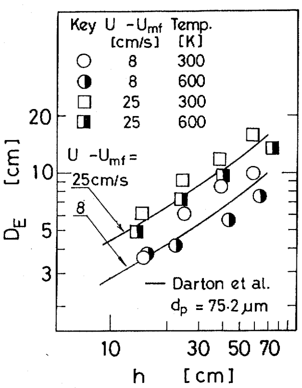

Fig. 2. Effect of temperature on bubble size for $d_p = 75.2\ \mu$m

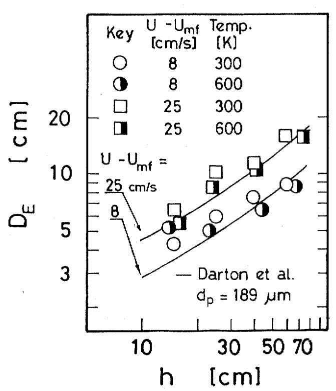

Fig. 3. Effect of temperature on bubble size for $d_p = 189\ \mu$m

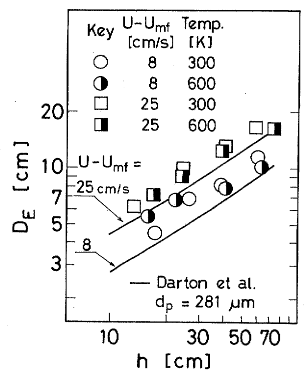

Fig. 4. Effect of temperature on bubble size for $d_p = 281\ \mu$m

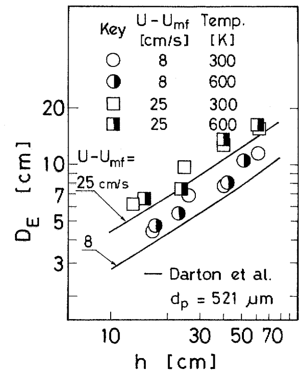

Fig. 5. Effect of temperature on bubble size for $d_p = 521\ \mu$m

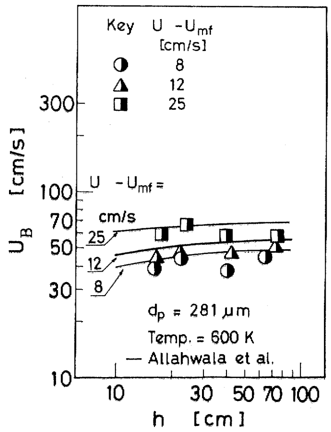

Fig. 6. Effect of gas flow rate on U_B vs. h relation for $d_p = 281\ \mu$m at 600 K

189 μm, $d_p = 281\ \mu$m and $d_p = 521\ \mu$m respectively. From Figs. 2 and 3 for comparatively small particles ($d_p = 75.2\ \mu\text{m} - 189\ \mu$m), it is clear that equivalent diameters D_E at 300 K were slightly larger than those at 600 K at both gas velocities. It is also evident from Figs. 4 and 5 for comparatively large particles ($d_p = 281\ \mu\text{m} - 521\ \mu$m) that the data at 600 K agree well with those at 300 K. That is, no temperature effect on bubble size was observed.

It appears from these figures that the bubble diameter dependency on temperature is significant for fine particles compared to large ones. This fact is consistent with the results obtained previously for fine particles ($d_p = 118\ \mu$m) by Geldart *et al.*[3] and for large particles ($d_p = 1500\ \mu$m) by Sitthiphong *et al.*[6]

2.2 Bubble rising velocity

The effect of gas flow rate on bubble rising velocity U_B at 600 K and $d_p = 281\ \mu$m is shown in **Fig. 6**, which shows that U_B increase with increasing gas flow rate and U_B is insensitive to bed height due to the slugging regime. The solid lines show the calculated relations between U_B and h from the equation by Allahwala *et al.*[1] The calculated values were slightly higher than the experimental data.

Figures 7, 8, 9 and **10** show the effect of temperature on the relation between U_B and h for $d_p = 75.2\ \mu$m,

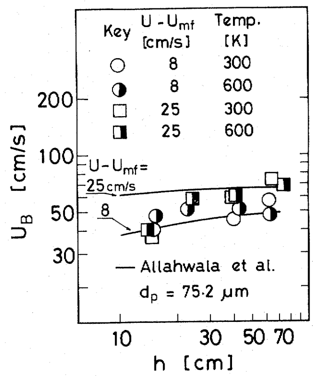

Fig. 7. Effect of temperature on bubble rising velocity for $d_p = 75.2\ \mu m$

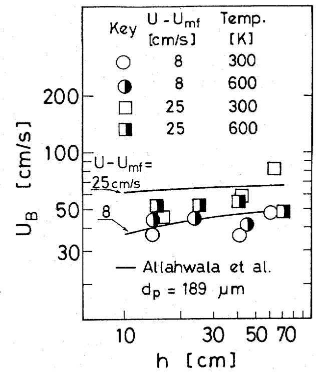

Fig. 8. Effect of temperature on bubble rising velocity for $d_p = 189\ \mu m$

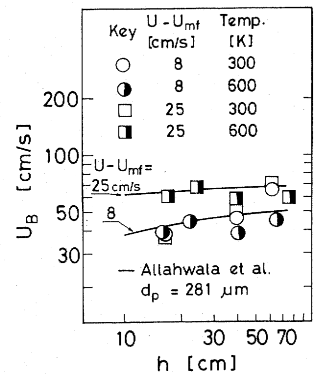

Fig. 9. Effect of temperature on bubble rising velocity for $d_p = 281\ \mu m$

$d_p = 189\ \mu m$, $d_p = 281\ \mu m$ and $d_p = 521\ \mu m$ respectively at two gas flow rates. From these figures, the bubble rising velocity at 600 K in the slugging regime seems to reach a saturated value in the lower bed height region than that at 300 K because of an increase in

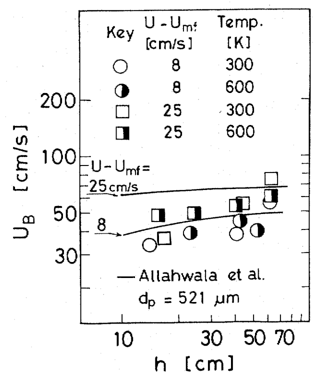

Fig. 10. Effect of temperature on bubble rising velocity for $d_p = 521\ \mu m$

fluidity of the fluidized bed.[10)]

As a whole, however, it was found that the bubble rising velocity is little affected by bed temperature or bed height in the slugging regime.

Nomenclature

D_E	= equivalent diameter of bubble	[cm]
d_p	= average diameter of solid particles by sieve analysis	[μm]
h	= bed height above distributor	[cm]
U_B	= bubble rising velocity	[cm/s]
U	= superficial gas velocity	[cm/s]
U_{mf}	= minimum fluidization velocity	[cm/s]
ρ_p	= particle density	[kg/m³]

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