BEHAVIOR OF BUBBLES IN A CYLINDRICAL FLUIDIZED BED AT AN ELEVATED TEMPERATURE

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In a previous paper,[3] the effect of bed particles on the average size and the average rise velocity of bubbles was reported for a semi-cylindrical fluidized bed.

In the present study, a cylindrical fluidized bed was used to investigate the behavior of a fluidized bed at high temperatures.

A study on the effect of temperature on bubble size by Yoshida *et al.*[8] showed a tendency for decreased bubble size with increased temperature. Recently, however, Stubington *et al.*[7] reported that in a range of temperature between 600 and 1300 K, no measurable change in bubble size occurred, while a 5 to 15% decrease in bubble size was found up to 600 K. As yet, the effect of temperature on minimum fluidization velocity is unclear since different trends have been reported in the literature.[6]

1. Experimental

Spherical glass beads (the details given in **Table 1**) were used as the bed material for the experiments. This particle belongs to "Group B" in Geldart's classification.[1]

The fluidized bed is fabricated of stainless steel with an internal diameter of 147 mm. The top of the upper cylindrical section is covered with a flat plate of Pyrex glass. Through this window bubbles erupting at the bed surface can be observed.

A stainless steel perforated distributor plate of thickness 5 mm was used. The distributor has 177 holes of 1 mm diameter arranged in square pitch.

Table 1. Particles

d_{p32} [μm]	U_{mf} [cm/s]		Density [g/cm^3]
	300 K	600 K	
272	7.0	4.8	2.52

Under a given experimental condition, the bubbles were photographed through the Pyrex glass window by a high-speed video-camera system (exposure time = 0.6 ms, 60 frames/s) and recorded on a VTR. The VTR pictures were analyzed to determine the average size of bubbles. That is, the ordinate and abscissa lengths of each bubble just before erupting were measured by use of a digitizer on the VTR monitor and the average value of the two lengths was taken to be the eruption diameter D_{Er_i}. The volume average calculated from the following equation is regarded as the average bubble size.

$$\bar{D}_{Er}=\left(\sum_{i=1}^{N} D_{Er_i}/N\right)^{1/3} \quad (1)$$

2. Results and Discussion

The experiments were carried out at 300 and 600 K in the ranges of static bed height = 10 − 40 cm and excess gas velocity = 1 − 8 cm/s.

Equivalent bubble diameter was calculated by the following equation.

$$D_E=\left(\frac{3(U_G-U_{mf})D_T^2}{2f}\right)^{1/3} \quad (2)$$

Figure 1 shows the relation between equivalent bubble diameter and eruption diameter for all data at 300 and 600 K. Geldart *et al.*[2] reported that the eruption diameter was 1.5 times the equivalent bubble diameter in experiments using 118-μm particles in a 147-mm column. The broken line in Fig. 3 is that

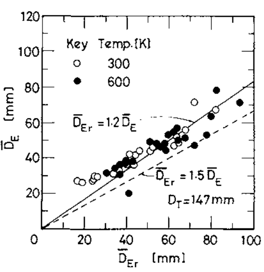

Fig. 1. Comparison of observed $\bar{D}_{Er}$ with calculated $\bar{D}_E$ from Eq. (2)

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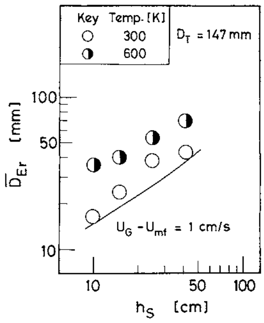

Fig. 2. Effect of temperature on $\bar{D}_{Er}$ *vs.* h_s relation

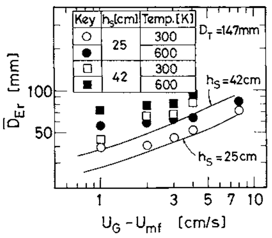

Fig. 3. Effect of temperature on $\bar{D}_{Er}$ *vs.* $U_G - U_{mf}$ relation

calculated from the equation $\bar{D}_{Er} = 1.50\bar{D}_E$. In this work, as the solid line shows, the relation between $\bar{D}_E$ and $\bar{D}_{Er}$ was found to be approximately $\bar{D}_{Er} = 1.2\bar{D}_E$ regardless of temperature.

Figure 2 shows the effect of temperature on bubble diameter for various static bed heights. The solid line in the figure shows the relationship between $\bar{D}_{Er}$ and h_S, where $\bar{D}_{Er}$ is 1.2 times the value of $\bar{D}_E$ calculated by the correlation of Mori and Wen[5] given in Eq. (3).

$$D_E = D_{BM} + (D_{BO} - D_{BM})\exp(-0.3h/D_T) \qquad (3)$$

where

$$D_{BO} = 0.347((U_G - U_{mf})A/n)^{0.4}$$

$$D_{BM} = 0.652((U_G - U_{mf})A)^{0.4}$$

The value of h in Eq. (3) was estimated by use of the pressure drop (ΔP) at each bed height; i.e., h is the bed height at $\Delta P = 0$ obtained by extrapolating the relationship between ΔP and each bed height. It is apparent from the figure that the bubble diameter at 600 K is larger than that calculated by the correlation of Mori and Wen, but theory and experiment agree approximately for the 300 K results. Moreover, at the low excess gas velocities studied, it was clearly found that bubble diameters at 600 K were larger than those at 300 K. This is believed to be caused by an increase in frequency of bubble coalescences due to an enhancement in the motion of bubbles in the transverse direction at higher temperature, as was clarified by observation of the motion of a cluster of bubbles in a semi-cylindrical fluidized bed.[4] As the excess gas velocity was increased, however, it was found that the difference in bubble diameters at 600 and 300 K was diminished.

Figure 3 shows the effect of temperature on bubble diameter for a range of excess gas velocities for a constant static bed height. The solid line in the figure shows the correlation derived by Mori and Wen. It is evident from Fig. 3 that the bubble diameter at 600 K is larger than that at 300 K. This temperature effect is most pronounced for small excess gas velocities.

Nomenclature

A	= cross section area of bed	[cm²]
D_{BM}	= initial bubble diameter at disributor	[cm]
D_{BO}	= maximum bubble diameter due to total coalescence of bubbles	[cm]
D_E	= equivalent diameter of bubble	[cm]
$\bar{D}_E$	= volume average equivalent diameter of bubbles	[cm]
$\bar{D}_{Er}$	= volume average eruption diameter of bubbles	[cm]
D_T	= bed diameter	[cm]
d_{p32}	= volume to surface average diameter of particles by photographic analysis	[μm]
f	= frequency of bubble production	[—]
h	= bed height above distributor	[cm]
h_s	= static bed height above distributor	[cm]
n	= number of orifices in distributor plate	[—]
ΔP	= pressure drop	[Pa]
U_G	= superficial gas velocity	[cm/s]
U_{mf}	= minimum fluidization velocity	[cm/s]

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