EFFECT OF FLUCTUATIONS IN HEIGHT OF BUBBLING LAYER ON GAS HOLDUP IN BUBBLE COLUMNS

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Introduction

Recently, bubble columns in which a gas is dispersed through a deep pool of liquid are increasingly used in industrial applications as gas-liquid reactors and bioreactors because of their simplicity and many other advantages.

In the previous paper it has been reported that for a 16 cm I.D. circular bubble column, fluctuations at the surface of the bubbling layer are caused by bubbles, that their standard deviations increase with V_g and do not depend upon the clear liquid height and the relative fluctuations increase with V_g and decrease with increasing clear liquid height[9]. But the effect of fluctuations in the height of the bubbling layer on gas holdup remains unclear.

In this paper, the effect of fluctuations in the height of the bubbling layer on gas holdup was experimentally determined and the results were analysed and discussed.

1. Experimental

The bubble columns used were all made of transparent acrylic resin. Details of the bubble columns used are listed in **Table 1**. Perforated plates madeof vinyl chloride resin were used as gas spargers. The thickness of the perforated plates was 5 mm.Details of the gas spargers used are listed in Table 1. The liquid used was tap water at room temperature. During each run, liquid was neither fed nor discharged. Air was used as a gas. The height of clear liquid H_L was listed in Table 1. Fluctuations in the height of the bubbling layer were measured in the same way as those in the previous paper[9]. The average gas holdup ε_{gvis} was obtained from the following equations:

$$\varepsilon_{geye} = (h_{z,eye} - H_L) / h_{z,eye} \quad (1)$$

$$h_{z,eye} = (h_{max,eye} + h_{min,eye}) / 2 \quad (2)$$

where $h_{max,eye}$ and $h_{min,eye}$ are maximum height and minimum height of the bubbling layer measured visually during each run, respectively.

ε_{gmax}, ε_{gmin}, ε_{gav} and ε_{gz} are defined by the following equations:

$$\varepsilon_{gmax} = (h_{max} - H_L) / h_{max} \quad (3)$$

$$\varepsilon_{gmin} = (h_{min} - H_L) / h_{min} \quad (4)$$

$$\varepsilon_{gav} = (\bar{h} - H_L) / \bar{h} \quad (5)$$

$$\varepsilon_{gz} = (h_z - H_L) / h_z \quad (6)$$

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Table 1. Details of the bubble columns and gas spargers used

No.	D [cm]	cross section	d [mm]	n [-]	p [mm]	H_L [cm]
1	8	semi-circular	1	19	10	23.8-92.4
2	16	semi-circular	1	77	5	21.8,108.2
3	16	circular	1	193	2.5	46.1-135

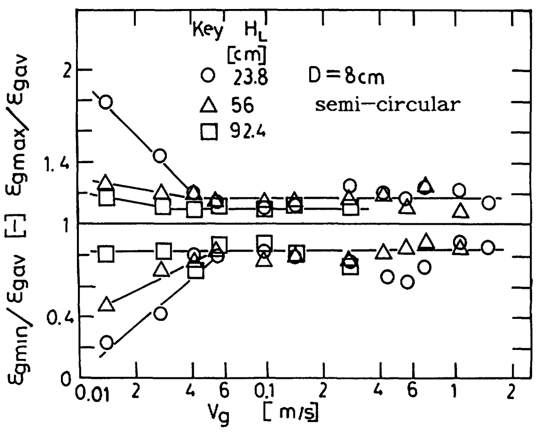

Fig. 1 Effect of fluctuations on gas holdup in 8-cm I.D. semi-circular column

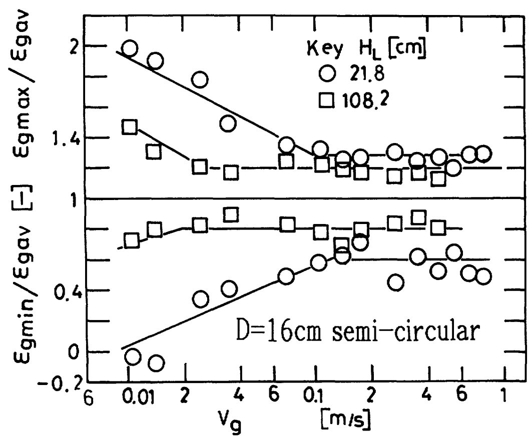

Fig. 2 Effect of fluctuations on gas holdup in 16-cm I.D. semi-circular bubble column

$$h_z = (h_{max} + h_{min})/2 \tag{7}$$

where h_{max} is the maximum of h_u, h_{min} is the minimum of h_d, and $\bar{h}$ is average height of h. h_{max}, h_{min} and $\bar{h}$ were measured by video camera.

2. Experimental Results and Discussion

Figs.1 and **2** show the effect of fluctuations in the height of the bubbling layer on the gas holdup in 8-cm and 16-cm I.D. semi-circular columns, respectively. It is clear from these figures that the ratio of $\varepsilon_{g\,max} / \varepsilon_{gav}$ decreases and the ratio of $\varepsilon_{gmin} / \varepsilon_{gav}$ increases with increasing H_L and superficial gas velocity V_g at small V_g, but that it becomes nearly constant at large V_g. This means that the effect of fluctuations in the height of the bubbling layer on the gas holdup is very large at small V_g and H_L, but that the effect is small at large V_g and H_L. The reason why the effect is very large at small V_g and H_L is because the bubbling height is small at small V_g and H_L.

Table 2. Physical properties used for calculation of gas holdup in Fig.4

ρ_L = 1000 kg/m^3, μ_L = 1×10^{-3} Pa·s, σ_L = 72×10^{-3} N/m
ρ_G = 1.21 kg/m^3, μ_G = 1.81×10^{-7} Pa·s

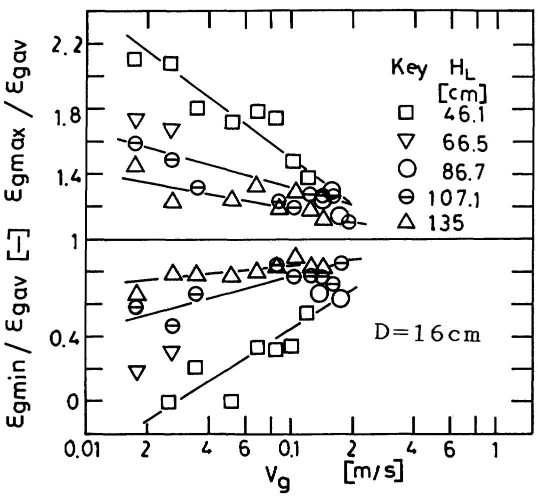

Fig. 3 Effect of fluctuations on gas holdup in 16-cm I.D. circular bubble column

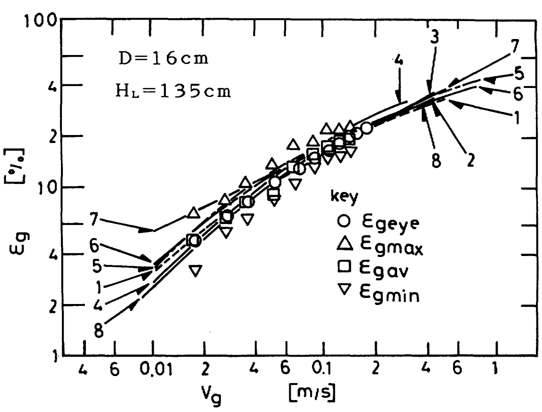

Fig. 4 Comparison between various gas holdups and correlations of gas holdups by previous investigators for air-water system at 293 K
1.Akita *et al.*[1) 4.Hughmark G.A.[4)] 7.Miyauchi *et al.*[8)]
2.Hikita *et al.*[2)] 5.Kato et al.[5)] 8.Yamashita *et al.*[9)]
3.Hikita *et al.*[3)] 6.Mersmann A.[6, 7)]

Fig. 3 shows the effect of fluctuations on gas holdup in the 16-cm I.D. circular column. It is clear from this figure that the effect of fluctuations on gas holdup is very large at small V_g and H_L, but that the effect becomes small at large V_g and H_L.

Fig. 4 shows a comparison between various gas holdup and the correlations of gas holdup by previous investigators[1-8, 10)] in a 16-cm I.D. circular bubble column for air-water system at 293 K. Physical properties used for calculation of gas holdup are listed in **Table 2**. It is clear from this figure that ε_{gav} is nearly equal to ε_{geye} and gas holdups calculated by correlations of the previous investigators[1-8, 10)], and that differences between correlations of

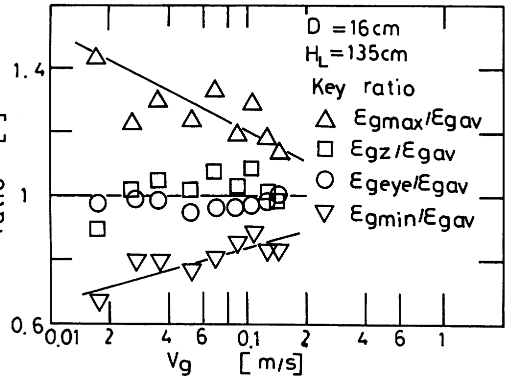

Fig. 5 Ratio of gas holdup vs. V_g in 16 cm I.D. circular bubble column

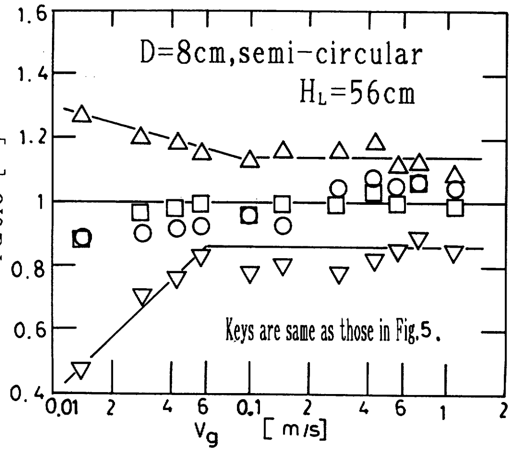

Fig. 6 Ratio of gas holdup vs. V_g in 8 cm I.D. semi-circular bubble column

the previous investigators[1-8, 10] are relatively small.

Figs. 5-7 show the ratios of gas holdup vs. V_g in the 16-cm I.D. circular and 8-cm and 16-cm I.D. semi-circular bubble columns, respectively. It is clear from these figures that ε_{gz} and ε_{gvis} are nearly equal to ε_{gav}. This means that ε_{gz} and ε_{gvis} can be used as average gas holdups in order to visually measure average gas holdup accurately. The reason why ε_{gz} is nearly equal to ε_{gav} is that $h_{max} - \bar{h}$ is nearly equal to $\bar{h} - h_{min}$.

It is concluded that the effect of fluctuations in height of the bubbling layer on gas holdup in the bubble columns is large at small V_g and H_L and becomes small at large V_g and H_L and that ε_{gz} and ε_{geye} can be used as average gas holdups.

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Nomenclature

d	=	diameter of hole	[m]

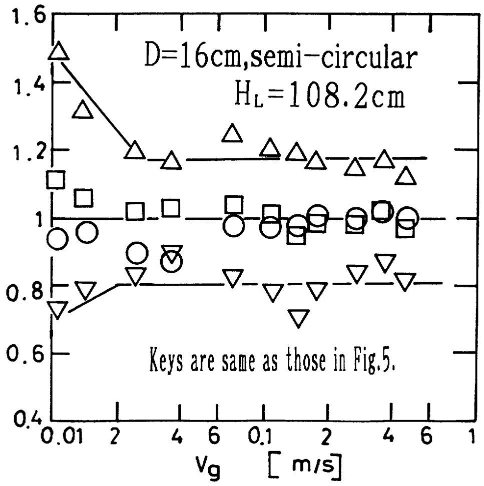

Fig. 7 Ratio of gas holdup vs. V_g in 16 cm I.D. semi-circular bubble column

D	=	diameter of bubble column	[m]
h	=	height of surface of bubbling layer(= $(h_u + h_d)/2$	[m]
$\bar{h}$	=	average of h	[m]
h_d	=	minimum height of bubbling layer	[m]
h_{max}	=	maximum of h_u	[m]
$h_{max,\,eye}$	=	h_{max} measured visually	[m]
h_{min}	=	minimum of h_d	[m]
$h_{min,\,eye}$	=	h_{min} measured by visually	[m]
h_u	=	maximum height of bubbling layer	[m]
h_z	=	average height defined by Eq.(7)	[m]
$h_{z,\,eye}$	=	average height defined by Eq.(2)	[m]
H_L	=	clear liquid height	[m]
n	=	number of holes or nozzles	[-]
p	=	pitch of holes	[m]
V_g	=	superficial gas velocity	[cm/s]
ε_{gav}	=	average gas holdup defined by Eq.(5)	[-]
ε_{geye}	=	average gas holdup defined by Eq.(1)	[-]
ε_{gmax}	=	maximum gas holdup defined by Eq.(3)	[-]
ε_{gmin}	=	minimum gas holdup defined by Eq.(4)	[-]
ε_{gz}	=	average gas holdup defined by Eq.(6)	[-]
μ_G	=	viscosity of gas	[Pa·s]
μ_L	=	viscosity of liquid	[Pa·s]
ρ_G	=	density of gas	[kg/m^3]
ρ_L	=	density of liquid	[kg/m^3]
σ_L	=	surface tension of liquid	[N/m]

Literature Cited

1) Akita, F. and F. Yoshida: *Ind. Eng. Chem. Process Des. Dev.*, **12**,76-80(1973)
2) Hikita, H., S. Asai, K. Tanigawa, K. Segawa and M. Kitao: *The Chem. Eng. J.*, **20**,59-67 (1980)
3) Hikita, H. and H. Kikukawa: *Bull. Univ. Osaka Prefect., Ser.A*, **22**,151-160 (1973)
4) Hughmark, G.A.: *Ind. Eng. Chem. Process Des. Dev.*, **6**,218-220 (1967)
5) Kato, Y. and A. Nishiwaki: *Kagaku Kogaku*, **35**,912-916 (1971)
6) Mersmann, A.:*Chem. Ing. Tech.*, **49**,679-691 (1977)
7) Mersmann, A.:*Ger. Chem. Eng*, **1**, 1-6 (1978)
8) Miyauchi, T. and C.N. Shyu: *Kagaku Kogaku*, **34**, 958-964 (1970)
9) Yamashita, F.: *J. Chem. Eng. Japan*, **27**,415-417 (1994)
10) Yamashita,F. and H. Inoue: *J. Chem. Eng. Japan*, **8**,334-336 (1975)