

EFFECTS OF PARTITION PLATES ON GAS HOLDUP IN A BUBBLE COLUMN WITH AND WITHOUT A DRAUGHT TUBE

FUKUJI YAMASHITA*

Department of Chemical Technology, Kanagawa Institute of Technology, Atsugi, 243-02

Key Words: Gas Holdup, Bubble Column, Partition Plate, Perforated Plate, Draught Tube, Multi-Stage Column, Gas Layer

Introduction

Bubble columns are widely used as gas-liquid reactors and bio-reactors. Gas holdup is a very important parameter in the bubble column and has been widely investigated. The effects of many parameters such as gas and liquid velocity, column diameter, conditions of gas distributors, liquid properties, draught tube and various internals have been clarified¹⁻⁸⁾.

Fukuda *et al.* reported that the bubble column with a draught tube and partition plates (= perforated plates) is the best bio-reactor, that the maximum gas holdup in their bubble column reaches about 70 %, and that gas layers form under the partition plates^{2, 3)}. But there are few reports about the effects of the partition plates and the gas layers on gas holdup in the bubble column with or without a draught tube.

In this paper, the effects of partition plates and gas layers on gas holdup in the bubble column with and without a draught tube are experimentally determined, and the results are discussed and correlated.

1. Experimental

Figure 1 shows the bubble column used with two partition plates and a draught tube. The bubble column used was made of transparent acrylic resin. The inner diameter and the height of the bubble column were 16 cm and 243 cm, respectively.

The gas distributor used (D in Fig. 1) was a perforated plate made of vinyl chloride resin ($d = 1$ mm, $n = 191$, $p = 2.5$ mm and $t = 5$ mm). Holes were drilled in the central part of the cross section of the bubble column.

The partition plates used (A and B in Fig. 1) were perforated plates made of vinyl chloride resin. At $N = 1$, one partition plate was set 102 cm above the gas distributor. At $N = 2$, two partition plates were set 102 cm and 123 cm above the gas distributor. The conditions of the partition plates used were as follows: $d = 0.1$ -1.0 cm, $n = 9$ -777, $p = 0.5$ -4.0 cm, $N = 1$ -2, $N/d = 1$ -20. Holes were set by square pitch on the whole cross section of the partition plates.

Two kinds of draught tubes were used. They were all made of vinyl chloride resin. Details of the draught

tubes used are listed in Table 1. The draught tubes were set 5 cm above the gas distributor.

The liquid used was tap water at room temperature. During a run, liquid was neither fed nor discharged. The clear liquid height was 134-135.3 cm. Air was used as gas.

Gas layers were formed under the partition plates of small holes. The thickness of gas layer L was measured.

The average gas holdup was obtained from the difference in height of the bubbling and clear liquid layer. The two kinds of average gas holdup ϵ_g and ϵ_{g1} were used. ϵ_g is the superficial gas holdup which includes the effects of the gas layers and ϵ_{g1} is the true gas holdup which excludes the effects of gas layers.

2. Experimental Results and Discussion

2.1 Effect of a draught tube and partition plates

Figure 2 shows the effects of a draught tube and partition plates on ϵ_g in the bubble column. From this figure, it is found that ϵ_{gd} , gas holdup in the bubble column with a draught tube and without the partition plates (see A in Fig. 2) was nearly equal to ϵ_{g0} , gas holdup in the bubble column without a draught tube and partition plates (see B in Fig. 2). Therefore, it is clear that the effect of the draught tube on the gas holdup in the bubble column without the partition plates is small.

Figure 2 also shows the effects of H , the height of the draught tube on ϵ_g in the bubble column with two partition plates. From this figure it is found that ϵ_{gpd} was nearly constant and equal to ϵ_{gp} at $H \leq H_c$, and that ϵ_{gpd} increased very much with H at $H > H_c$. Therefore, it is clear that the draught tube does not influence gas holdup much at $H \leq H_c$, but that the draught tube increases gas holdup at $H > H_c$ very much.

At $H \leq H_c$ the clearance between the top of the draught tube and the partition plate is large, so the head is enough for the circulation of the liquid, and ϵ_{gpd} is nearly equal to ϵ_{gp} .

But at $H > H_c$ the clearance is small and the gas layer became very large (see Fig. 1) and the circulation of the liquid through the draught tube became gradually discontinuous with V_g and stopped at large V_g and small

* Received January 18, 1993. Correspondence concerning this article should be addressed to F. Yamashita.

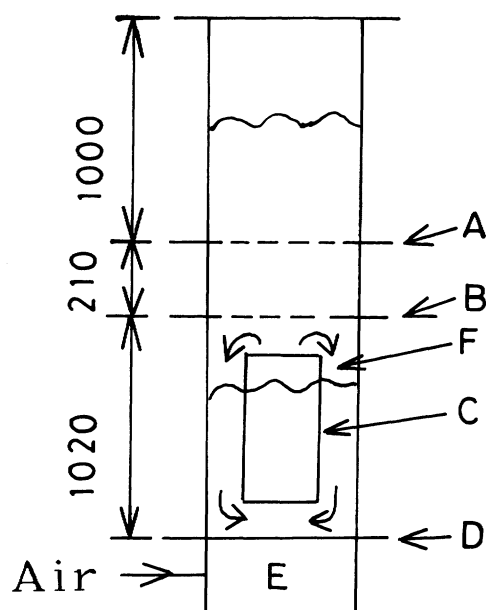


Fig. 1 Sketch of bubble column with two partition plates and a draught tube at large V_g and $H > H_c$
A, B = partition plate, C = draught tube, D = gas distributor, E = gas chamber, F = gas layer

Table 1. Details of draught tubes used

No.	d_i [cm]	d_o [cm]	H [cm]
1	10.7	11.4	78
2	8.3	8.9	10-95

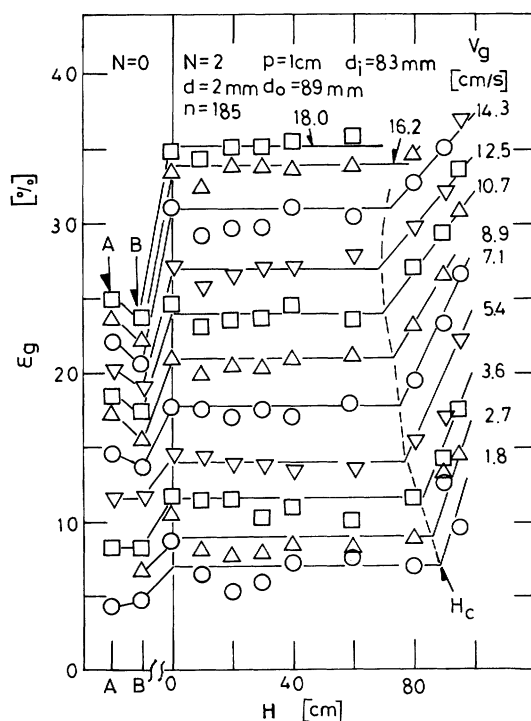


Fig. 2 Effect of draught tube and partition plates on gas holdup at $d_o = 8.9$ cm and $d_i = 8.3$ cm, A = ϵ_{gd} , B = ϵ_{g0}

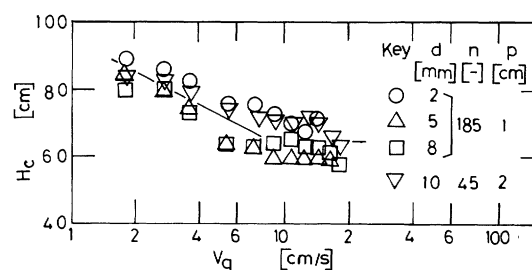


Fig. 3 H_c vs. V_g at $d_o = 8.9$ cm and $d_i = 8.3$ cm

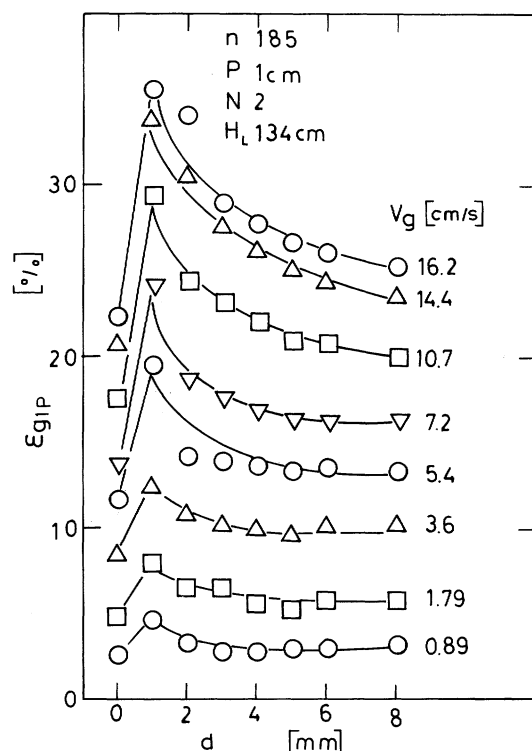


Fig. 4 Effect of hole diameter d of partition plates on gas holdup

d . Moreover, though in the bubble column with the partition plates and without the draught tube no gas layer formed under the partition plates for $d \geq 4$ mm, a gas layer formed in the bubble column with the partition plates and the draught tube even for $d = 10$ mm. Therefore, ϵ_{gpd} increased very much at $H > H_c$.

Figure 3 shows that H_c vs. V_g . H_c decreased with increasing V_g at small V_g and became nearly constant at large V_g .

2.2 Effect of partition plates

1) Effect of hole diameter d and number n of the holes

Figure 4 shows the effects of d in the condition of $n = 185$, $p = 10$ mm and $H_L = 134$ cm. $d = 0$ means ϵ_{g1} in case of no partition plates. The number N of the partition plates was 2. From this figure, it is found that the gas holdup ϵ_{g1p} decreases with increasing hole diameter d .

ϵ_{g1p} was independent of n in the range of $n = 45$ –777 at $d = 0.2$ cm and $N = 1$. The reason might be that $n = 45$ is too large to change gas holdup.

2) Correlation of experimental results

To correlate the

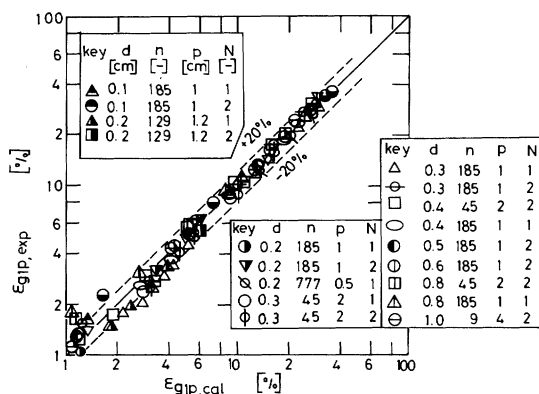


Fig. 5 Comparison with $\varepsilon_{glp, exp}$ and $\varepsilon_{glp, cal}$

effects of the partition plates, the following equation is derived.

$$\varepsilon_{glp} / \varepsilon_{g0} = 1 + 0.03 (N / d) \quad (1)$$

where the range of parameters are $d = 0.1\text{--}1.0$ cm, $N \leq 2$ and $N/d \leq 20$, respectively. **Figure 5** compares $\varepsilon_{glp, exp}$ experimental values of gas holdup, with $\varepsilon_{glp, cal}$ values calculated by Eq. (1), using experimental values of ε_{g0} . It is clear from this figure that Eq. (1) shows fairly good agreement with the experimental results.

The reason why $\varepsilon_{glp}/\varepsilon_{g0}$ depends on N is that each section performs like an independent bubble column, and that the gas holdup increases with the decreasing liquid height as reported by the author⁷⁾ and Kawagoe *et al.*⁵⁾. As the hole diameter d of the partition plates decreases, the bubble sizes generated from the partition plates become smaller and liquid circulation through the partition plates becomes more difficult. This might be the reason why $\varepsilon_{glp}/\varepsilon_{g0}$ depends on d .

Table 2 shows the comparison of Eq. (1) and the results of Kato *et al.*⁴⁾. From Table 2, it is clear that Eq. (1) is nearly equal to the result of Kato *et al.*

3) Effect of gas layer under the partition plates

The gas layers formed under the partition plates for $d \leq 0.3$ cm. **Figure 6** shows α defined by the following equation:

$$\alpha = 1 - (\varepsilon_{glp} / \varepsilon_g) \quad (2)$$

From this figure it is found that the effects of the gas layers are very large at small V_g and d , and decreases with increasing V_g and d . The effects become very small at $V_g > 10$ cm/s.

Acknowledgement

The author wishes to thank Messrs K.Sakamaki, N. Satsukawa and M. Sugiyama, former and present students at the Department of Chemical Technology, Kanagawa Institute of Technology, for their experimental work.

Nomenclature

a	=	V/A	[cm]
A	=	cross-sectional area of bubble column	[cm ²]
d	=	diameter of holes	[cm ²]
d_i	=	inner diameter of draught tube	[cm]

Table 2. Comparison of Eq. (1) and the result of Kato *et al.*⁴⁾

$N = 3$ $d = 0.6$ cm	Kato <i>et al.</i> ⁴⁾	Eq. (1)
$\varepsilon_{glp} / \varepsilon_{g0}$	1.2	1.15

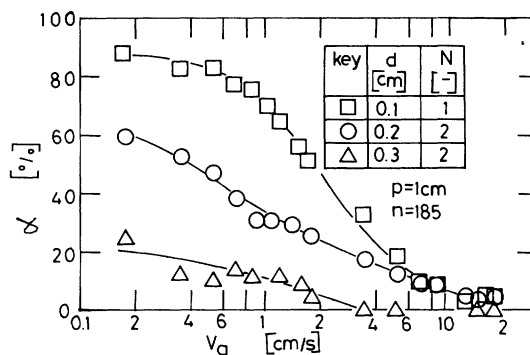


Fig. 6 Effect of gas layers on gas holdup

d_0	=	outer diameter of draught tube	[cm]
H	=	height of draught tube	[cm]
H_C	=	critical height of draught tube	[cm]
H_L	=	clear liquid height	[cm]
H_T	=	bubbling height	[cm]
L	=	thickness of gas layer	[cm]
n	=	number of holes	[-]
N	=	number of partition plates	[-]
p	=	pitch	[cm]
t	=	thickness	[cm]
V	=	total volume of draught tube and partition plates	[cm ³]
V_g	=	superficial gas velocity	[cm/s]
α	=	effect of gas holdup defined by Eq. (2)	[-]
ε_g	=	average gas holdup $(= (H_T - H_L)/(H_T - a))$	[-]
ε_{gd}	=	ε_g in case of draught tube and no partition plates	[-]
ε_{gp}	=	ε_g in case of partition plates and no draught tube	[-]
ε_{gpd}	=	ε_g in case of partition plates and draught tube	[-]
ε_{g1}	=	average gas holdup $(= (H_T - H_L - L)/(H_T - a - L))$	[-]
ε_{glp}	=	ε_{g1} in case of partition plates and no draught tube	[-]
$\varepsilon_{glp, cal}$	=	ε_{glp} value calculated by Eq. (1)	[-]
$\varepsilon_{glp, exp}$	=	experimental value of ε_{glp}	[-]
ε_{g0}	=	average gas holdup in the bubble column without draught tube and partition plates	[-]

Literature cited

- 1) Akita, K. and F. Yoshida: *Ind. Eng. Chem. Process Des. Dev.*, **12**, 76-80 (1973)
- 2) Fukuda, H.: *Hakko Kogaku*, **59**, 259-270 (1981)
- 3) Fukuda, H., T. Shiotani, W. Okada and H. Morikawa: *J. Ferment. Technol.*, **56**, 619-625 (1978)
- 4) Kato, Y. and A. Nishiwaki: "Kihoto.Kendaku Kihoto No Souchi Sekkei", 107-112, Society of Chem. Eng. Japan (1985)
- 5) Kawagoe, M., T. Inoue, K. Nakao and T. Otake: *Kagaku Kogaku*, **38**, 733-739 (1984)
- 6) Koide, K., S. Iwamoto, Y. Takasaka, S. Matsuura, E. Takahashi, M. Kimura and H. Kubota: *J. Chem. Eng. Japan*, **17**, 611-618 (1984)
- 7) Yamashita F.: *J. Chem. Eng. Japan*, **18**, 349-353 (1985)
- 8) Yamashita F.: *J. Chem. Eng. Japan*, **20**, 204-206 (1987)