EFFECTS OF MULTIPLE DRAFT TUBES WITH PERFORATED PLATES ON GAS HOLDUP AND VOLUMETRIC MASS TRANSFER COEFFICIENT IN A BUBBLE COLUMN

HIROYUKI KAWASAKI, HIROHITO HIRANO AND HISAYA TANAKA
Department of Chemical and Biochemical Engineering, Toyama University, Toyama, 930

Key Words: Mass Transfer, Bubble Column, Gas Holdup, Mass Transfer Coefficient, Draft Tube, Perforated Plate

Introduction

Since bubble columns are widely used in industry, numerous investigations of their performance have been carried out[7]. Most of them were done in standard bubble columns. Recently, many invesigators have proposed various types of bubble columns for a variety of uses[1, 2, 4, 6]. Odawara *et al.*[6] discussed fundamental characteristics in bubble columns containing multiple draft tubes with perforated plates and pointed out the efficiency of multiple draft tubes with regards to volumetric mass transfer coefficient.

In this study, we experimentally investigated the effects of multiple draft tubes with perforated plates on gas holdup ϕ and volumetric mass transfer coefficient k_La in a bubble column with a single-hole sparger as a gas distributor.

1. Experimentals

The inner diameter and height of the bubble column used were 0.15 m and 2.0 m, respectively.

The diameter and length of each draft tube were both 0.10 m. The cross-sectional area of the draft tube and the annular part were 0.00785 and 0.00817 m^2, respectively. Details of the perforated plates (0.003 m thick) are listed in **Table 1**. The holes were set in a square pitch over the whole cross section of the plates. The various types of draft tubes are shown in **Fig. 1**.

Air was used as the gas and the liquid used was tap water at 303 K. The unaerated liquid height Z_0 was kept at 1.05 m. Details of the measurement and the calculation methods for ϕ and k_La are shown elsewhere[5].

The flow patterns observed in this bubble column were similar to the observations of Odawara *et al.*[6] Under the conditions of this study, no lumps of gas were visually observed below any of the perforated plates. A lump denotes a gas layer[4, 8] forming within the inner diameter of the draft tube.

* Received March 18, 1994. Correspondence concerning this article should be addressed to H. Kawasaki.

2. Results and Discussion

2.1 Effects on ϕ

Figure 2 shows the effect of the superficial gas velocity u_{G0} and the number N of draft tubes with perforated plates (hole diameter $d = 0.003$ m) on ϕ. From this figure, it is found that ϕ for each N increases with u_{G0} and that plots reveal two straight regions with different slopes. As the number of bubbles per unit volume becomes large, bubble collision frequency becomes higher[3]. Therefore, compared with the case at low u_{G0}, the value of ϕ at high u_{G0} gradually increases with u_{G0} due to greater bubble coalescence. Since ϕ is directly proportional to N at the same u_{G0} in both regions, the performance of each draft tube with perforated plates is identical.

From a study of the effect of d of the perforated plate on ϕ at $N = 5$, it is found that the highest ϕ value is given at $d = 0.003$ m and that at $d = 0.009$ m little effect on ϕ is observed. This shows that a bubble generated from the distributor has a mean diameter of about 0.009 m. Also, when a single hole sparger with a diameter of 0.003 m is used as a distributor, ϕ at $d = 0.003$ m is considerably large compared with ϕ at $d = 0.006$ and 0.009 m. This result suggests that an optimal size exists for the hole diameter or the area ratio of the holes to the cross section of the draft tube.

2.2 Effects on k_La

Figure 3 shows the effects of u_{G0} and N on k_La measured under the same conditions ($d = 0.003$ m) for ϕ measurement. From this figure, it is found that k_La for each N increses with u_{G0} and there are two linear regions. Since the dependency of u_{G0} on ϕ at high u_{G0} decreases due to greater bubble coalescence, it seems that the dependency of u_{G0} on k_La declines due to a decrease in interfacial area. Also, the figure shows that the value of k_La at $N = 5$ is highest and that each draft tube with a perforated plate has identical performance for k_La.

The dependency of u_{G0} on k_La at low u_{G0} is slightly greater than that on ϕ. This difference between the dependency of u_{G0} on ϕ and k_La shows that there are other effects in addition to that on ϕ. From this fact, we consider that interfacial renewal, which is caused by transformation, coalescence, break up and other processes involving

Table 1. Details of perforated plates used

	d [m]	n [-]	p [m]	r [-]
a	0.003	161	0.007	0.145
b	0.006	161	0.007	0.580
c	0.009	78	0.010	0.632

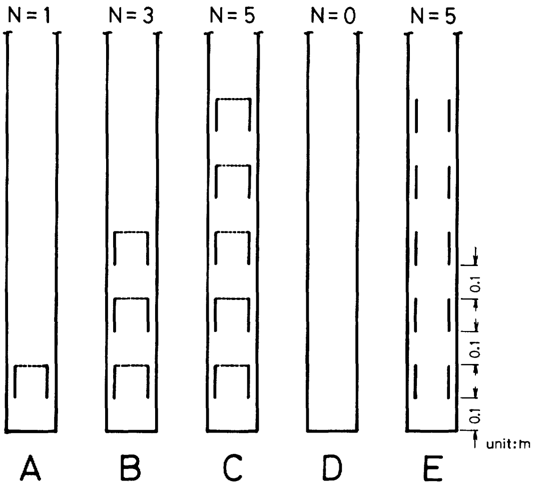

Fig. 1 Schematic diagram of various types of contained draft tubes with perforated plates

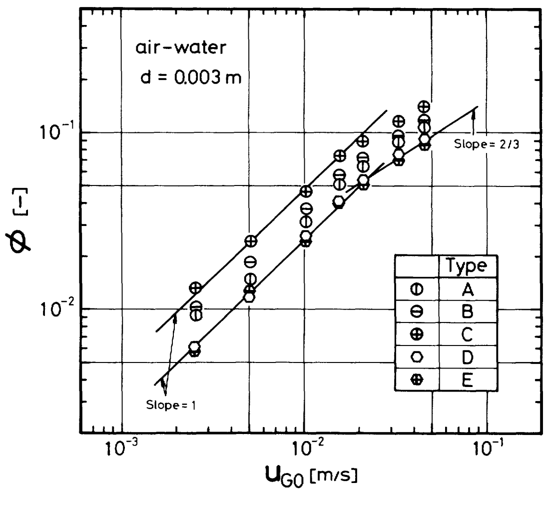

Fig. 2 Effect of u_{G0} and N on ϕ

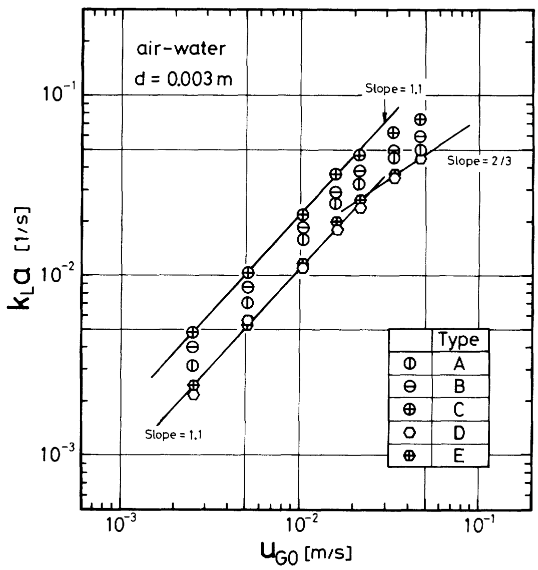

Fig. 3 Effect of u_{G0} and N on k_La

bubbles, influences mass transfer rate. Here, transformation describes the case of passing through a hole, which has the smaller diameter than the mean bubble one, without bubble subdivision. As a result, it seems to influence the k_L value.

From analysis of the effects of d on k_La at $N = 5$, it is found that the highest k_La value is given at $d = 0.003$ m and that the value at $d = 0.006$ m is nearly equal to the highest k_La. The effect of multiple draft tubes with perforated plates at $d = 0.006$ m on ϕ was minor, although the effect on k_La was large. In this case, it seems that both interfacial renewal and the rise of the gas-liquid interfacial area caused by transformation and bubble subdivision effectively enhances k_La. Even in the case of $d = 0.009$ m, a small increase in k_La was observed.

Nomenclature

A_H	=	total area of hole	[m^2]
A_P	=	cross sectional area of perforated plate	[m^2]
a	=	gas-liquid interfacial area per unit aerated liquid volume	[1/m]
d	=	hole diameter of perforated plate	[m]
k_La	=	volumetric mass transfer coefficient	[1/s]
N	=	number of draft tube	[-]
n	=	number of hole	[-]
p	=	pitch	[m]
r	=	area ratio defined by A_H/A_P	[-]
u_{G0}	=	superficial gas velocity	[m/s]
ϕ	=	average gas holdup	[-]

Literature Cited

1) Bando, Y., M. Kuraishi, M. Nishimura, M. Hattori and K. Toyoda: *Kagaku Kogaku Ronbunshu*, **14**, 663-669 (1988)
2) Bello, R. A., C. W. Robinson and M. Moo-Young: *Chem. Eng. Sci.*, **40**, 53-58 (1985)
3) Chisti, M. Y. and M. Moo-Young: *Biotechnol. Bioeng.*, **31**, 487-494 (1988)
4) Fukuda, H., T. Shiotani, W. Okuda and H. Morikawa: *J. Ferment. Technol.*, **56**, 619-625 (1978)
5) Kawasaki, H., T. Yamamoto and H. Tanaka: *J Chem. Eng. Japan*, **27**, 666-667 (1994)
6) Odawara, Y., T. Yamaguchi, Y. Suganuma and H. Fukumori: *Hakko Kogaku*, **59**, 253-258 (1981)
7) Shah, Y. T., B. G. Kelker, S. P. Godbole and W. D. Deckwer: *AIChE J.*, **28**, 353-379 (1982)
8) Yamashita, F: *J. Chem. Eng. Japan*, **26**, 742-744 (1993)