GAS-LIQUID INTERFACIAL AREA AND LIQUID-PHASE MASS TRANSFER COEFFICIENT IN SIEVE-PLATE COLUMNS HAVING LARGE FREE AREAS WITH DOWNCOMERS

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In a previous paper[3] the authors presented the hydrodynamic characteristics of sieve-plate columns having large free areas with downcomers, especially the pressure drop, liquid holdup and stable operating range.

In the present study, experiments were conducted for plates with downcomers having large free areas which are capable of being operated at high gas velocities. Gas-liquid interfacial area and the liquid-phase mass transfer coefficient of the sieve plate column were investigated for a cobalt-catalyzed oxidation of aqueous sulfite solutions by air.

1. Experimental Apparatus and Procedure

The experimental apparatus used was a 10.4 cm-diameter Plexiglas column fitted with three plates with downcomers at a plate spacing of 60 cm, the same equipment used previously by the authors.[3]

Sieve plates were made of 1 mm-thick aluminum sheet with hole diameters of 1–2 mm arranged in equilateral triangles, the details of which are shown in **Table 1**. They are the same as those described in a previous paper.[3] The ranges of superficial gas and liquid velocities were 0.17–3.5 m/s and 0.081–0.7 cm/s respectively.

The method for determining the gas-liquid interfacial area and liquid-phase mass transfer coefficient is the same as that described in a previous paper[4] except for the method of taking liquid samples at the bottom downcomer as outlet liquid; in this study, cobalt-oxidation of aqueous sodium sulfite solution with oxygen was used. The amount of liquid on each plate was measured by the same method as that described in a previous paper.[3]

2. Results and Discussion

From visual observation of two-phase dispersion on a plate, the operation range can be classified into two regimes depending on gas velocities: froth regime (liquid continous) and transition regime (partially developed spray), which is quite similar to the behavior of the two-phase dispersion for gas-liquid counter-

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Table 1. Geometries of sieve plates employed

Plate	Plate thickness $t\times10^3$ [m]	Hole dia. $d\times10^3$ [m]	Pitch $P\times10^3$ [m]	Free area F [—]	Weir height H_w [m]	Key
P-1	1.0	1.0	2.0	0.207	0.01	○
					0.02	●
					0.03	△
P-2	1.0	1.5	2.5	0.307	0.01	▲
					0.02	▽
					0.03	▼
P-3	1.0	2.0	3.0	0.354	0.01	□
					0.02	■

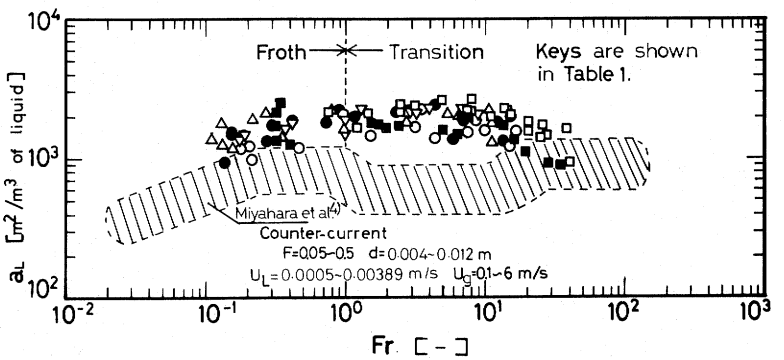


Fig. 1. Gas-liquid interfacial area

current flow.[4]

Figure 1 shows the values of the gas-liquid interfacial area against Fr.[4] The shaded area is the results of the authors[4] for sieve plates without downcomers having large free areas. It is seen that the interfacial areas are a little larger for crosscurrent flow than for countercurrent flow. As seen in the figure, the interfacial area in the froth regime increases with increasing Froude number up to 1.0, which is the critical value described previously,[4] whereas the effect of the Froude number on the interfacial area is not significant in the transition regime. At large Froude numbers, probably close to the apray regime (gas continuous), a decrease in the interfacial area can be seen. This is most likely due to a lack of liquid weeping from the plate in crosscurrent flow as compared with countercurrent flow, where the complete spray regime does not occur because of the simultaneous passage of gas and liquid through holes.[4]

Figure 2 shows the correlation of gas-liquid interfacial areas on the basis of unit bubbling area against the Weber number proposed by Zuiderweg.[5] As seen from the figure, no effect of free area on the interfacial area can be found in both regimes, whereas we noticed the effect of free area in the froth regime for countercurrent flow.[4] This is also probably due to the lack of liquid weeping. For comparison, the results of Nagy *et al.*[2] and Zuiderweg[5] are also shown. The difference between the present results and the

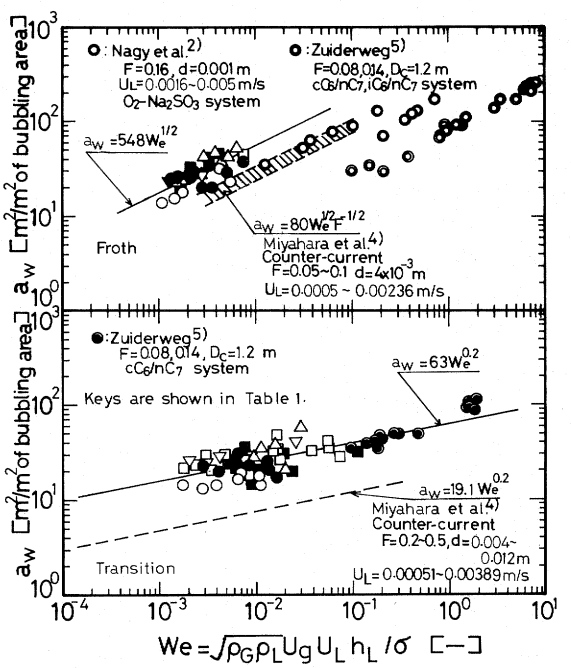


Fig. 2. Correlation of gas-liquid interfacial area

results of Nagy *et al.*[2] and Zuiderweg[5] in the froth regime is most likely due to different methods of liquid supply. The data for each regime, taking into account the results of Zuiderweg,[5] can be correlated by

$$a_w = a_L h_L = 548\,We^{0.5} \qquad 10^{-3} < We < 10^{-2}$$

froth regime (1)

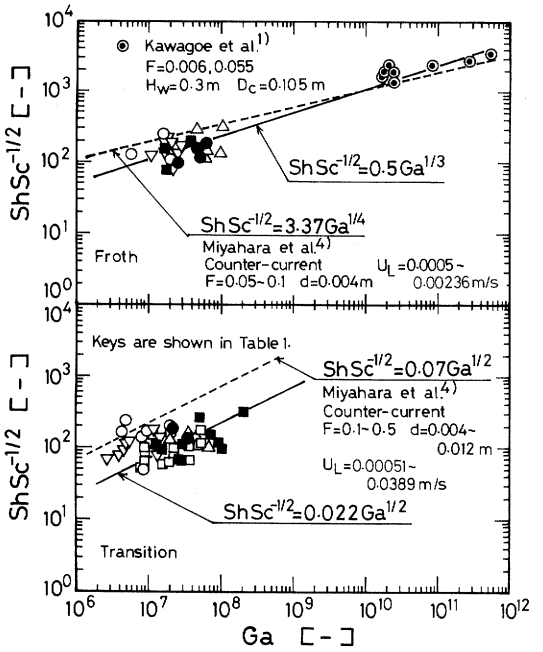


Fig. 3. Correlation of liquid-phase mass transfer coefficient

$$a_w = a_L h_L = 63 We^{0.2} \qquad 2\times10^{-3} < We < 2$$

transition regime
(partially developed spray/mixed froth) (2)

Figure 3 shows the correlation of the mass transfer coefficient.[4] The mass transfer coefficient as the Sherwood number for both the froth regime and the transition regime would be expressed by the following equations as a function of the Schmidt number and the Galilei number, taking into account the results of Kawagoe *et al.*[1] for crosscurrent flow.

$$Sh = 0.5 Sc^{1/2} Ga^{1/3} \qquad 6\times10^{6} < Ga < 6\times10^{11}$$

froth regime (3)

$$Sh = 0.022 Sc^{1/2} Ga^{1/2} \qquad 3\times10^{6} < Ga < 2\times10^{8}$$

transition regime
(partially developed spray/mixed froth) (4)

The mass transfer coefficients are smaller for crosscurrent flow than for countercurrent flow obtained by the authors.[4]

Nomenclature

a_L	=	effective interfacial area per unit volume of liquid	[m^2/m^3]
a_w	=	effective interfacial area per unit bubbling area $= a_L h_L$	[m^2/m^2]
D_A	=	diffusivity of solute gas in the solution	[m^2/s]
D_c	=	column diameter	[m]
d	=	hole diameter	[m]
F	=	free area	[—]
Fr	=	Froude number $= U_g^2/(gh_L)$	[—]
g	=	gravitational acceleration	[m/s^2]
Ga	=	Galilei number $= gh_L^3/v_L^2$	[—]
H_w	=	weir height	[m]
h_L	=	liquid depth	[m]
k_L	=	liquid-phase mass transfer coefficient	[m/s]
P	=	pitch	[m]
Sc	=	Schmidt number $= v_L/D_A$	[—]
Sh	=	Sherwood number $= k_L h_L/D_A$	[—]
t	=	plate thickness	[m]
U_g, U_L	=	superficial velocity of gas and liquid	[m/s]
We	=	Weber number $= h_L \rho_G^{0.5} U_g \rho_L^{0.5} U_L/\sigma$	[—]
μ_L	=	viscosity of liquid	[Pa·s]
ρ_G, ρ_L	=	density of gas and liquid	[kg/m^3]
σ	=	surface tension	[N/m]
v_L	=	kinematic viscosity $= \mu_L/\rho_L$	[m^2/s]

Literature Cited

1) Kawagoe, M., K. Nakao and T. Otake: *J. Chem. Eng. Japan*, **8**, 254 (1975).
2) Nagy, E., O. Borlai, E. Laurent and J.-C. Charpentier: *Int. Chem. Eng.*, **15**, 637 (1975).
3) Miyahara, T., M. Asoda and T. Takahashi: *Kagaku Kogaku Ronbunshu*, **16**, 177 (1990).
4) Miyahara, T., M. Kurihara, M. Asoda and T. Takahashi: *J. Chem. Eng. Japan*, **23**, 280 (1990).
5) Zuiderweg, F. J.: *Chem. Eng. Sci.*, **37**, 1441 (1982).