Simulation of effect of baffle plates on gas holdup in a bubble column

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Bubble columns are widely used as gas-liquid contactors and bioreactors. To save resources and energy, it is very important to improve the efficiency of the bubble columns. In order to improve the efficiency of the bubble columns, baffle plates, draft tubes and mesh wires have been used in bubble columns. In this work, the effect of circular baffle plates on gas holdup in a bubble column was simulated by CFX software. The results of the simulation showed a good agreement with the experimental results by the author (1985).

1. Introduction

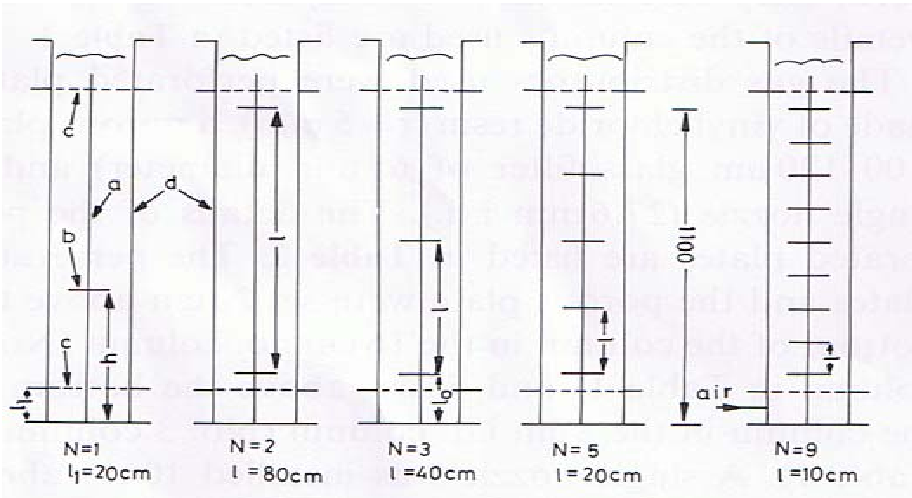
Recently, much attention has been paid to simulation by CFD, because the simulation by CFD is very useful for research and design of chemical equipments and plants. Bubble columns are widely used as gas-liquid contactors and bioreactors. To save resources and energy, it is very important to improve the efficiency of the bubble columns. In order to improve the efficiency of the bubble columns, baffle plates, draft tubes and mesh wires have been used in bubble columns. In this work, the effect of circular baffle plates on gas holdup in a bubble column was simulated by CFX software.

2. Previous study

The author (1985) studied the effect of circular baffle plates on average gas holdup E_G in a 16 cm I.D. and 2.7 m high bubble column and obtained the following correlation for $0 < N/(N+) < 0.9$, $0 < S/S_T < 0.879$ and 1.66 cm/s $< U_G < 47$ cm/s.

$$E_G = E_{G0}\,[1 + U_G^{-0.4}(S / S_T)\{N / (N+1)\}] \qquad (1)$$

where E_{G0} means E_G at no baffle plates. U_G means superficial gas velocity. S and S_T mean cross sectional area of baffles and the bubble column, respectively. N means number of baffle plates. Fig.1 shows the arrangement of circular baffle plates in the



previous experiment.

Fig.1 Arrangement of circular baffle plates:
a = center pole, b = baffle plate; c = support plate for center pole, d = bubble column, l = distance between baffle plates; l_0 = 30 cm, l_1 = 20 cm.

3. Simulation by CFX software

The simulation was done by using CFX software. The conditions of simulation are as follows: D_T = diameter of the bubble column = 16 cm, height of bubble column = 130 cm, d = diameter of baffle = 4-12 cm, t = thickness of baffle plate =5 mm, N = number of baffle plates = 0-9, mesh size = 10 mm, gas = air, liquid = water, diameter of bubbles = 5mm, three dimensional simulation.

SST model was used as a turbulent model. The simulation was done under unsteady conditions and in the range of U_G =0-12.8 cm/s and U_L=0 cm/s. The arrangement of baffle plates is the same as that in the previous experiment. However, the 3D model of bubble column for the simulation had no center pole and support plate.

4. Simulation results

4.1 Effect of N on gas holdup

Fig.2 shows contours of the effect of N on gas holdup in the range of U_G = 5cm/s, N = 0-9 and t = 3 min. d is 12 cm. It is clear that gas bubbles are trapped under the baffle plates. It is clear from this figure that the quantity of gas bubbles trapped per one baffle plate decreases as *N* increases

Fig.3 shows the effect of *N* on gas holdup. From this figure, it is found that when *N* is small, gas holdup increases rapidly with *N*, however, that when *N* is larger than 4, gas holdup increases gradually. The reason has been guessed in the previous paper (Yamashita, 1985) because it becomes more difficult for gas bubbles to enter the spaces between baffle plates. It is clear from Fig.2 that this guess is true.

Fig.4 shows the effect of *N / (N+1)* on gas holdup at *d* =12cm. It is clear from Fig.5 that E_{Gsim} is proportional to *N / (N+1)*.

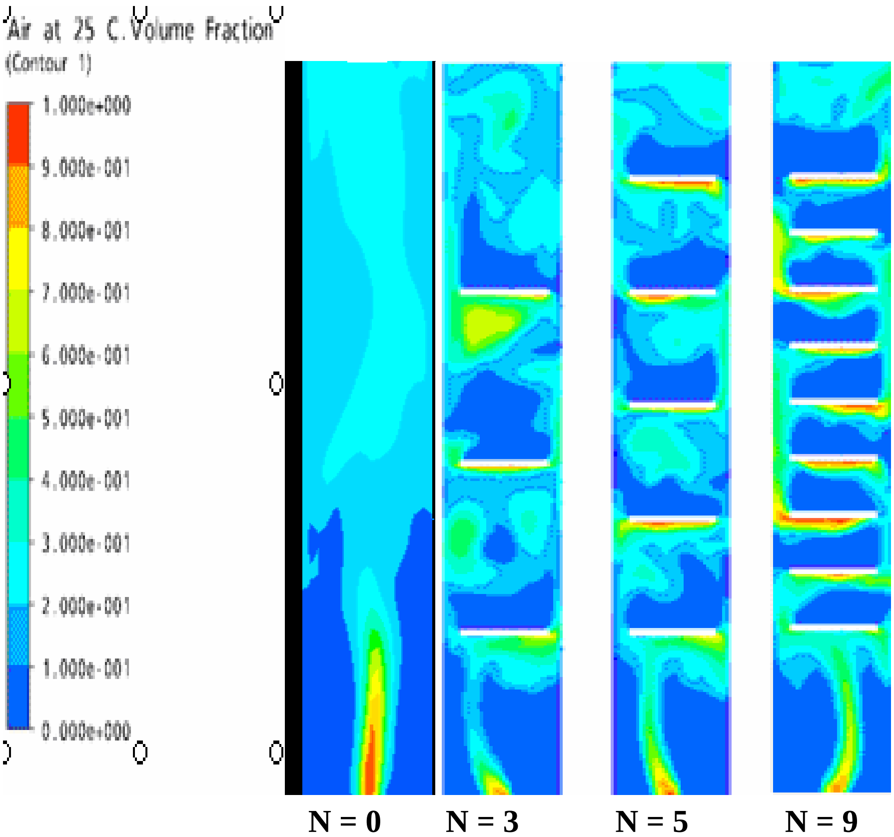


Fig.2 Contours of gas holdup in the range of U_G =5 cm/s and N = 0 – 9.

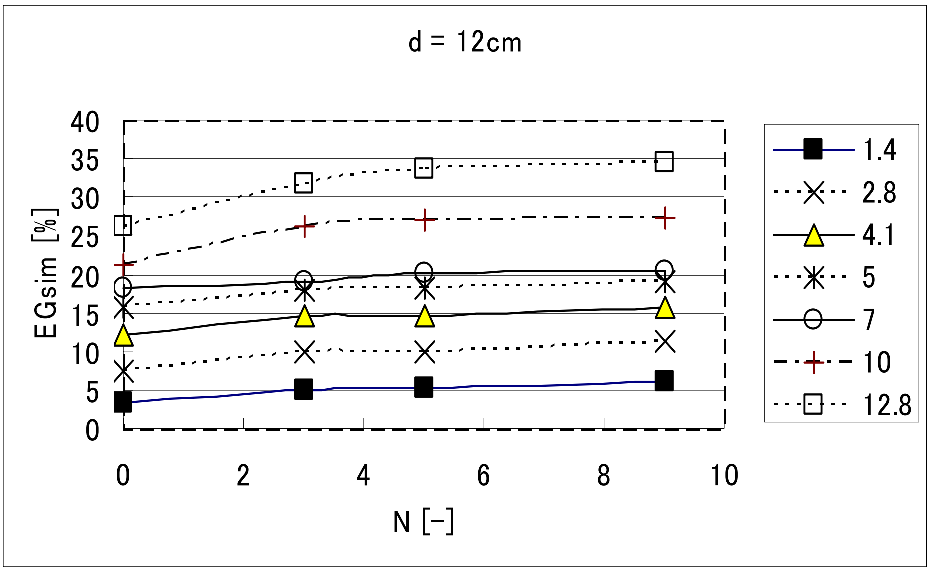


Fig.3 Effect of N on gas holdup at d =12 cm.
Keys mean U_G [cm/s].

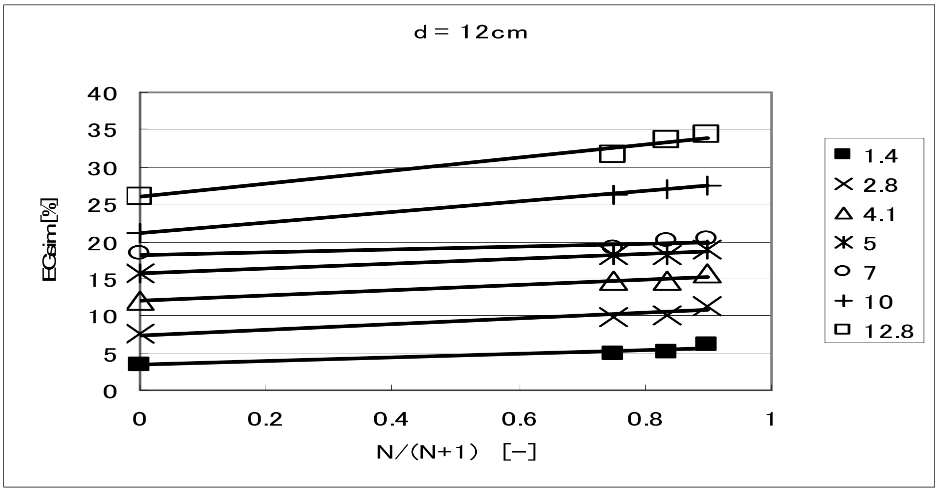
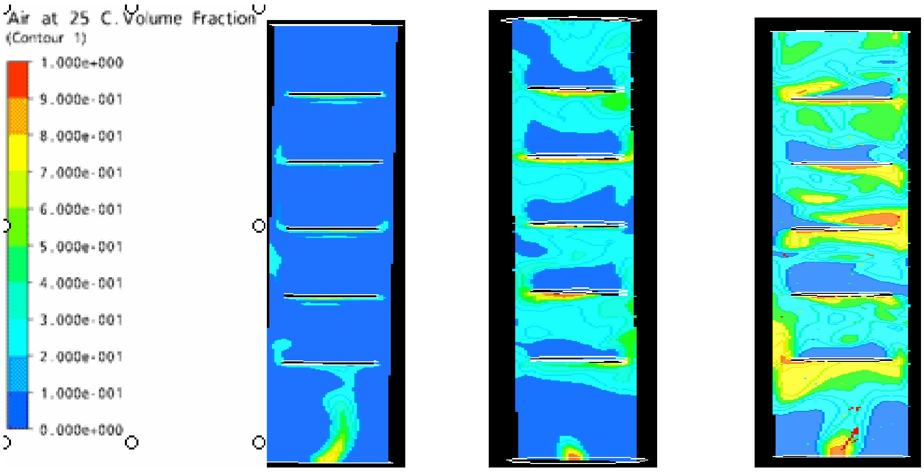


Fig.4 Effect of $N / (N+1)$ on gas holdup at d = 12 cm.
Keyes mean U_G [cm/s].

4.2 Effect of U_G on gas holdup

Fig.5 shows the effect of U_G on gas holdup at d =12cm and N = 5. It is clear from this figure that gas holdup increases with U_G.



U_G = 1.4 cm/s U_G = 5 cm/s U_G = 12.8 cm/s

Fig.5 Effect of U_G on gas holdup at d = 12 cm and N = 5.

4.3 Fluidization gas and liquid in the bubble column

Fig.6 shows water superficial velocity at U_G = 5 cm/s and d = 12 cm in the bubble column. It is clear that water velocity fluctuates very much and that liquid circulates between baffle plates.

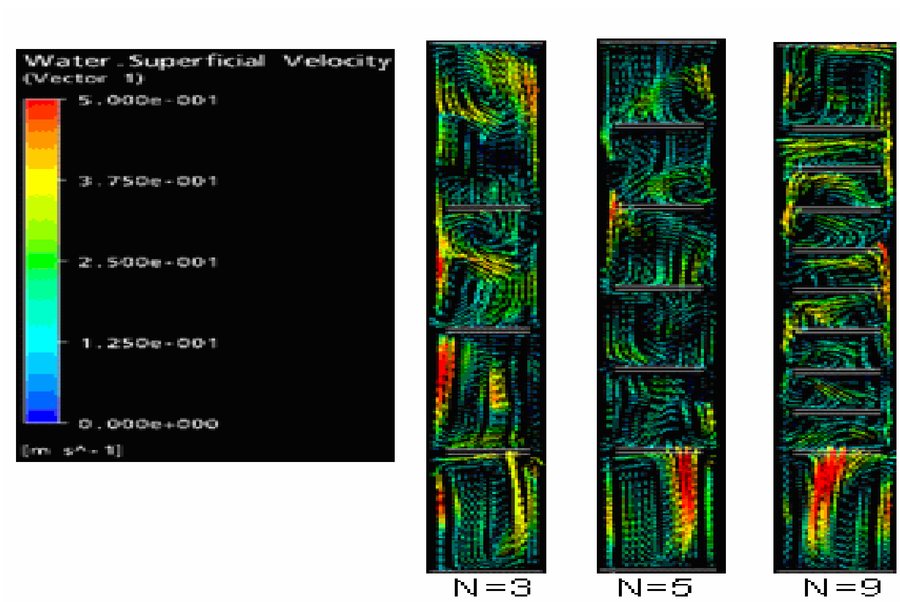
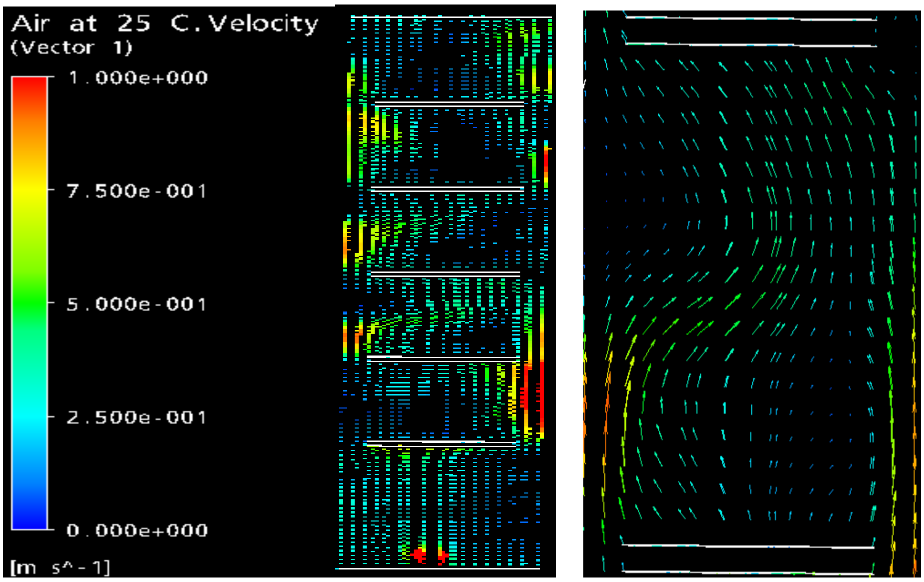


Fig.6 Water superficial velocity at U_G = 5cm/s and d = 12 cm.



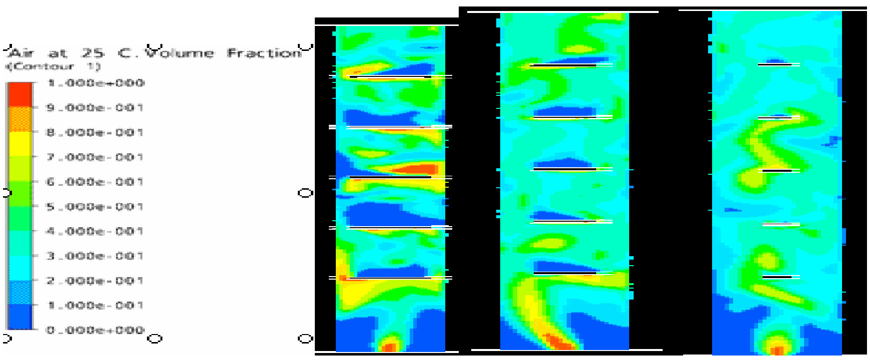
(a) (b)

Fig.7 Gas velocity at n = 5, U_G = 5cm/s and d = 12cm in the bubble column.

Fig.7 shows gas velocity vectors at N = 5, U_G = 5 cm/s and d = 12 cm in the bubble column. Fig.7 (a) shows gas velocity in the whole column, and (b) shows gas velocity in the space between the second and third plate from the bottom. It is clear from this figure that gas velocity fluctuates very much.

4.4 Effect of diameter *d* of baffle plates on gas holdup

Fig.8 shows the effect of d on gas holdup by contours at N = 5 and U_G = 12.8 cm/s. It is clear from this figure that gas holdup increases with d. Fig.9 shows the effect of $S / (S+1)$ on E_{Gsim} at N = 5. From this figure, it is clear that E_{Gsim} is proportional to $S / (S+1)$.



d = 12cm d = 8cm d = 4 cm

Fig.8 Effect of d on gas holdup at N = 5 and U_G = 12.8 cm/s in the range of d = 4-12 cm.

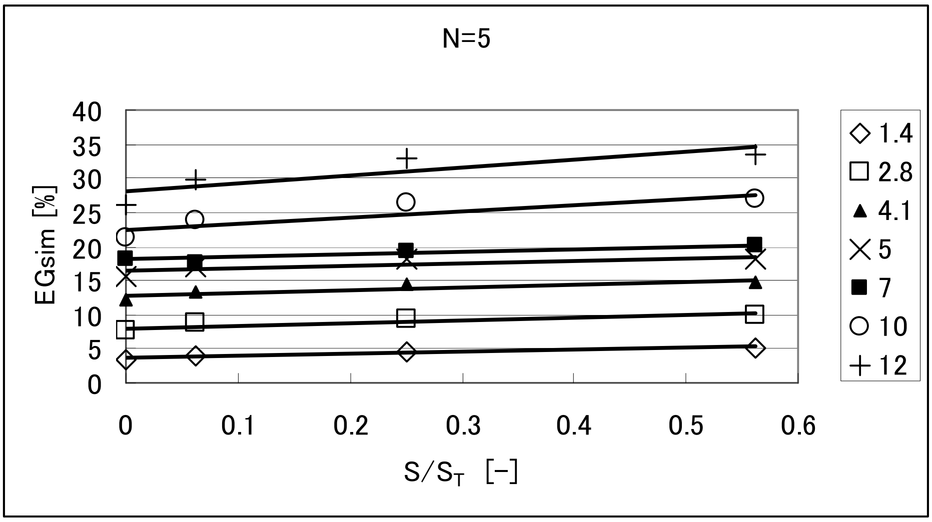


Fig.9 Effect of $S / (S+1)$ on E_{Gsim} at $N = 5$.

Keyes mean U_G.

4.5 Comparison between E_{Gsim} and E_{Gcal}

Fig.10 shows the comparison between E_{Gsim} and E_{Gcal}. It is clear from this figure that E_{Gsim} is nearly equal to E_{Gcal}.

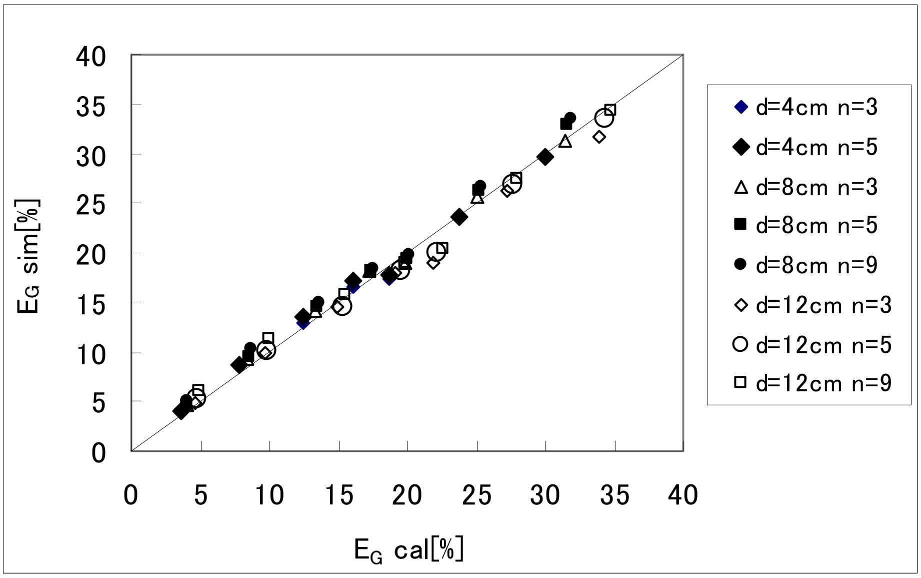


Fig.10 Comparison between E_{Gsim} and E_{Gcal}.

n means number of baffle plates.

5. Conclusion

The effect of baffle plates on gas holdup was simulated by CFX software. Average gas holdup E_{Gsim} increased with increasing number and diameter of baffle plates in the same way as the previous experimental results. E_{Gsim} obtained by the simulation was well expressed by the experimental correlation of the author (Yamashita, 1985).

Nomenclature

d = diameter of baffle plate [m]
E_G = average gas holdup [-]
E_{G0} = E_G at N = 0.
E_{Gcal} = E_G obtained from Eq.(1)
E_{Gsim} =E_G obtained by simulation [-]
n = number of baffle plate [-]
N = number of baffle plate [-]
S = cross sectional area of baffle plate [m2]
S_T = cross sectional area of bubble column [m2]

5. References

Yamashita, F. 1985, Journal of Chemical Engineering Japan, 18, 349