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Effect of Impeller Diameter to Vessel Diameter Ratio on Gas Holdup

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ABSTRAK

Banyak sekaitan tahanan gas telah dikembangkan untuk meramalkan tahanan gas di dalam bekas teraduk. Meskipun demikian kajian tahanan gas terbatas kepada penggunaan nisbah garis pusat pendesak : garis pusat bekas (D_I/D_T) kira-kira 1/3. Tidak ada sekaitan yang mempertimbangkan kesan perubahan (D_I/D_T) terhadap tahanan gas. Karya ini dijalankan untuk menyiasat kesan ini. Keputusan karya ini menunjukkan bahawa tahanan gas meningkat dengan nisbah D_I/D_T. Kesan perubahan (D_I/D_T) terhadap tahanan gas disekaitkan untuk campuran udara-air dengan $\varepsilon = 2.0(N_a N_{Fr})^{0.6} N_{Re}^{\ 0.1}\left(\frac{D_I}{D_T}\right)^{2.5}$. *Nisbah ($D_I/D_T$) yang digunakan berada dalam julat 0.36 hingga 0.53.*

ABSTRACT

Numerous gas holdup correlations have been developed for predicting gas holdup in agitated vessels. However, gas holdup studies were only limited to the use of impeller diameter to vessel diameter ratio (D_I/D_T) of approximately 1/3. None of the available correlations considered the effect of (D_I/D_T) variation on gas holdup. This work was carried out to investigate this effect. The results of this investigation showed that the gas holdup increases with D_I/D_T ratio. The effect of (D_I/D_T) variation on gas holdup was correlated, with $\varepsilon = 2.0(N_a N_{Fr})^{0.6} N_{Re}^{\ 0.1}\left(\frac{D_I}{D_T}\right)^{2.5}$, *for an air-water mixture. The (D_I/D_T) used in this work ranged from 0.36 to 0.53.*

INTRODUCTION

Gas holdup information is useful as an indicator of mass transfer capability of a gas-liquid contacting device. Gas holdup is defined as the volume fraction occupied by the gas in a vessel. The definition of gas holdup is given in the following equation.

$$\varepsilon = \frac{V_g}{V_g + V_L} \tag{1}$$

Numerous investigations have been conducted to study the dependency of gas holdup on physical and chemical properties of the liquid and the gas phases, vessel geometry, gas and liquid flow rates, agitation parameters and presence of solid particles (Rewatkar & Joshi 1993; Smith 1991; Taterson 1991 and Ying et al. 1980).

A more recent work by Sensel et al. (1994) investigated the gas holdup at high aeration rates. Sensel et al. (1994) conducted their experiments in an open-top vessel with an impeller diameter to vessel diameter ratio (Di/DT) equal to 1/3. Their data is correlated as a function of aeration number, Reynolds number and Froude number in a dimensionless form as the following.

$$\varepsilon = 0.105\,(N_a N_{Fr})^{0.5}\,N_{Re}^{\;0.1} \tag{2}$$

The aeration number which gives the ratio of the gas flow rate to the impeller speed is defined by the following equation.

$$N_a = \frac{Q_g}{ND_i^3} \tag{3}$$

It appears that the effects of liquid physical properties, agitation parameters and gassing rate are well taken into account in this correlation. However, the correlation fails to take into account on the effect of (D_i/D_T) variation on gas holdup. This work was carried out to investigate the effect of (D_i/D_T) on gas holdup.

MATERIALS AND METHODS

The investigation was conducted in a closed two-stage agitated vessel with 24.15 cm inside diameter. Each stage was 24.15 cm high with centre hole opening. Two interstage opening diameters (D_o) of 2.54 cm and 5.207 cm were used. Agitation was provided in each stage by a centrally mounted 6-bladed disk impeller. Two impeller diameters were studied: 8.89 cm and 12.7 cm. A schematic diagram of the experimental setup is presented in Figure 1.

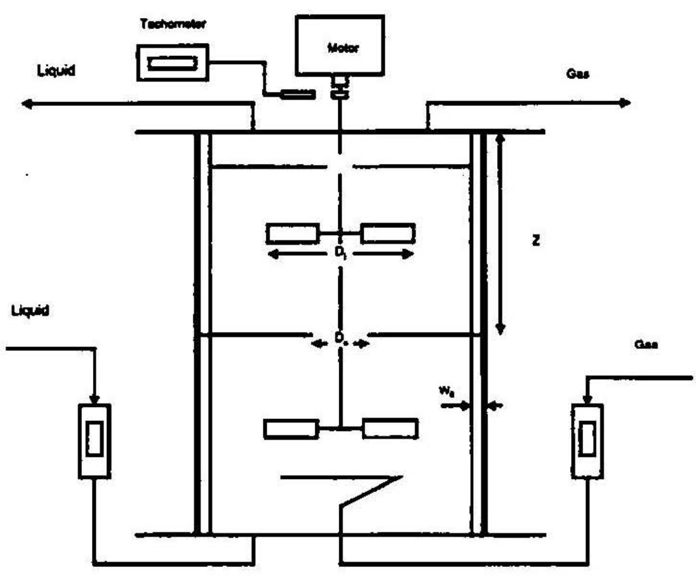

FIGURE 1. Schematic diagram of experimental apparatus

Water was used as the continuous phase and air was used as the dispersed phase. The liquid flow rate used in this study ranged from 0.0 cm^3/s to 93 cm^3/s. While the maximum gas flow rate available was 4.0 scfm. The gas holdup is measured as the difference in liquid level under gassed and ungassed conditions.

RESULTS AND DISCUSSION

Data collected in this work are presented in Figure 2. The data trend is consistent with the results of Sensel et al. (1994) even though their experiments were conducted in a single stage, open-top vessel. Gas would escape easier in an open-top vessel compare to a closed one. In a closed vessel, the gas may only escape from the vessel via a provided opening. The presence of stage divider would also provide resistance to the upward flow of gas bubbles. For these reasons, the gas was expected to remain longer in the closed vessel compare to an open-top vessel and the gas holdup should also be expected to be higher in a closed vessel.

Sensel et al. 1994 correlating method was used as a basis to correlate the data. The comparison of the experimental data and the values predicted by Sensel et al. 1994 correlation are presented in Figure 3. This figure shows that Sensel et. al, 1994 correlation predicted lower values than the experimental data which indicates that it is more difficult for the gas to escape from a closed vessel. The data were better fitted with the following correlation which was compared with the experimental data in Figure 4.

$$\varepsilon = 0.165\ (N_a\ N_{Fr})^{0.6}\ N_{Re}^{\ 0.1} \qquad (4)$$

This correlation predicts gas holdup well for Di/DT ratio of approximately 1/3 but give very poor prediction for other values of (D_i/D_T). Figure 5 shows that at constant value of $(N_a N_{Fr})^{0.6} N_{Re}^{\ 0.1}$ the gas holdup was greater for higher value of (D_i/D_T). An additional term is required in Equation (2) to account for the effect of (D_i/D_T) on gas holdup. It was found that adding

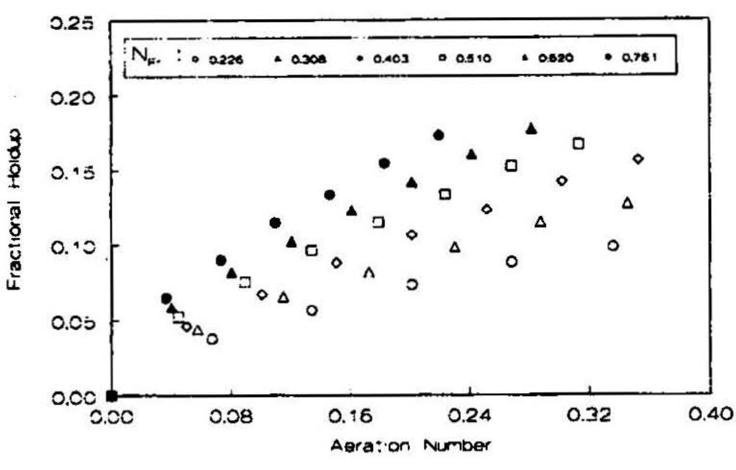

FIGURE 2. Experimental data

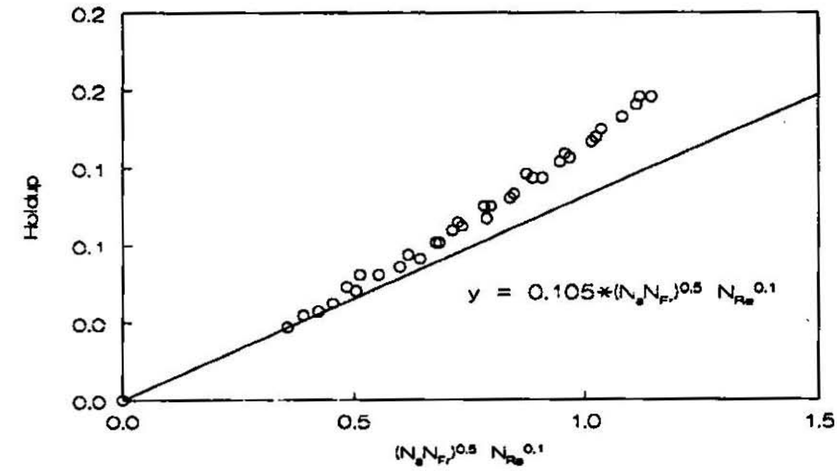

FIGURE 3. Experimental data vs. Sensel et. al. correlation

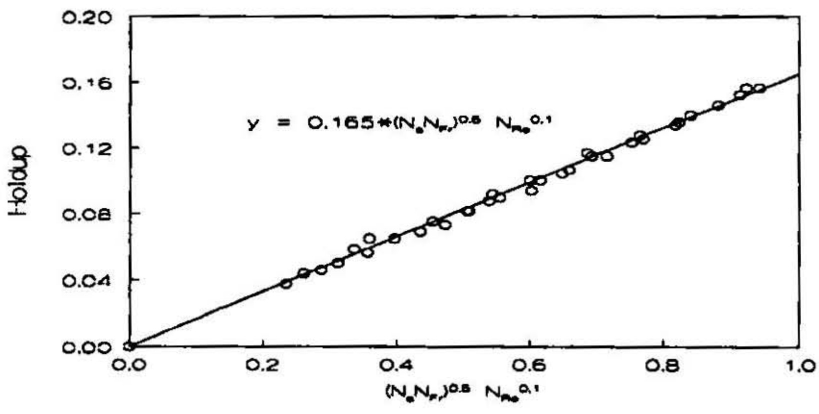

FIGURE 4. Corrected gas holdup correlation for $(D_i/D_T) = 1/3$

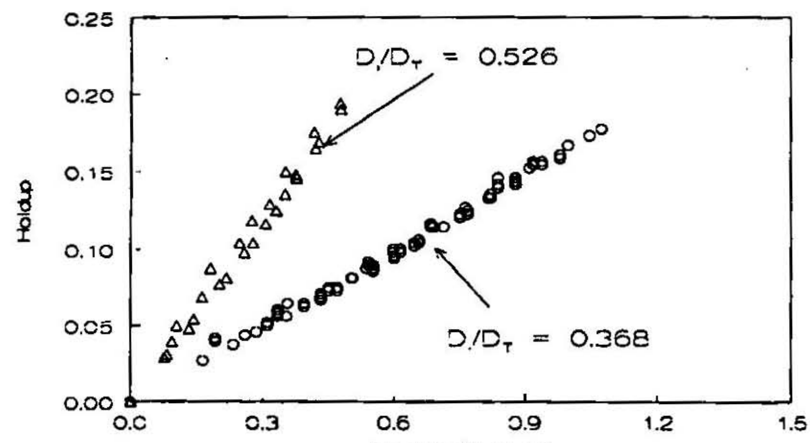

FIGURE 5. Gas holdup at different D_i/D_T ratio.

a (D_i/D_T) term accounted for the effect of Di /DT variation on gas holdup. Raising (D_i/D_T) to 2.5 power collapsed all the experimental data into a single line as shown in Figure 6.

$$\varepsilon = 2.0\left(N_a\, N_{Fr}\right)^{0.6} N_{Re}^{\;0.1} \left(\frac{D_i}{D_T}\right)^{2.5} \tag{3}$$

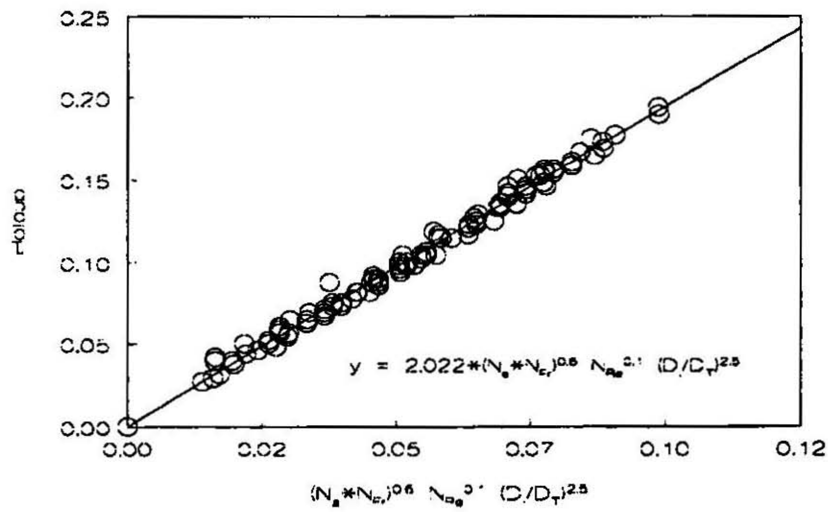

FIGURE 6. Gas holdup correlation

The average error of this correlation over the range of the experimental data was about 4.0 percent. Since the correlation was developed based on data collected in air-water system in a closed vessel, this correlation may be used to predict gas holdup in gas-liquid mixture with properties close to that of water-air mixture in closed agitated vessels. As indicated in the preceding discussion, this correlation may not be suitable to predict gas holdup in open-top vessel. Application of this correlation to predict gas holdup in open-top vessel will give higher gas holdup value.

CONCLUSION

Gas holdup was found to increase with D_i/D_T ratio. As anticipated, a larger diameter would impart more power into the a gas-liquid mixture to produce smaller gas bubbles and as a result higher gas holdup was observed. Therefore, (D_i/D_T)is an important variable that must be included in the gas holdup correlation. The correlation developed in this work may be used to predict gas holdup in gas liquid mixing in closed agitated vessels.

NOMENCLATURE

D_i Impeller diameter, cm
D_T Vessel diameter, cm
g gravity acceleration, m/s^2
N Impeller speed, rps
N_a Aeration number, $Q_g/(ND_i^3)$
N_{Fr} Froude number, (N^2D_i/g)
N_{Re} Impeller Reynolds number, $ND_i^2\rho/\mu$
Q_g Gas flow rate, m3/s
ε Gas hold-up

REFERENCES

Rewatkar, V. B. & Joshi, J. B. 1993. Role of Sparger Design on Gas Dispersion in Mechanically Agitated Gas-Liquid Contactors. *The Canadian Journal of Chemical Engineering* 71:278.

Sensel, M. E., Myers, K. J. & Fasano, J. B. 1994. Gas dispersion at high aeration rates in low to moderately viscous newtonian liquids. *AICHE Symposium Series* 89(293):76.

Smith, J. M. 1991. Simple performance correlation for agitated vessel. *European Conference on Mixing*, p. 223

Taterson, G. B. 1991. *Fluid Mixing and Gas Dispersion in Agitated Tanks*. New York: McGraw-Hill.

Ying, D. H., Givens, E. N. & Weimer R. R. 1980. Gas holdup in gas-liquid and gas-liquid solid glow reactors. *Ind. Eng. Chem. Process Des. Dev*, p 635.

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