EFFECT OF GAS DENSITY ON POWER CONSUMPTION IN AERATED VESSEL AGITATED BY A RUSHTON TURBINE

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Introduction

Gas dispersion in an agitated vessel is a common operation in the chemical and fermentation industries. Much of the research concerned with power consumption has been restricted to air-water systems, but the effect of gas density on power has rarely been studied. Changing gas density is equivalent to changing working pressure. The effect of pressure on power consumption in an aerated vessel is of practical importance.

Thus the aim of the work reported in this paper is to investigate the effect of gas density—and, by implication, pressure—on the power drawn under gassed conditions.

1. Experimental

A Rushton turbine was studied because its gassed power characteristics and its flooding-loading behaviour are well known. An open-top 0.29 m-diameter (T) cylindrical vessel was used. The liquid height was the same as the vessel diameter T, the impeller size was $T/3$ and its clearance from the base was $T/4$. Four $0.1\,T$ baffles were used and gas was introduced through a point sparger.

The gases used were helium, air and carbon dioxide of molecular weights 4, 29 and 44 respectively. The liquids used were deionized water and water saturated with CO_2 with pH values of about 6.0 and 4.0 respectively. The latter was used because working with CO_2 automatically saturated the water and changed the pH. It was also considered important to establish whether this pH change, which clearly altered the coalescence behaviour[4], had any effect on power characteristics.

Power was measured by using an air-bearing torque table system.

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Table 1. Gas flow number at flooding-loading transition

N [s^{-1}]	Experimental System				Calculated		
	He-D*	Air-D*	Air-S**	CO_2-S**	Eq. (1)	Eq. (2)	Eq. (3)
3.33	0.0664	0.0553		0.0587	0.0703	0.0544	0.0450
5.00	0.103	0.111	0.107	0.108	0.158	0.122	0.101

D*: Deionized water. S** Water saturated with CO_2.

2. Results and Discussion

Figure 1 shows that the relationship between gassed power number and gas flow number for air in deionized water and water saturated with CO_2 is the same, with a step increase at the point at which flooding occurs. The saturation of CO_2 in water was reported[4] to reduce bubble size by about 10%. As can be seen from the figure, the repressed coalescence had no effect on power drawn. The correlations for the flooding-loading transition proposed by several investigators[1,3] were tested;

Nienow *et al.*[3]

$$(Fl_G)_F = 30(D/T)^{3.5}(Fr)_F \tag{1}$$

Bujalski[1]

$$(Fl_G)_F = 118(D/T)^{4.97}(Fr)_F \tag{2}$$

$$(Fl_G)_F = 13.3(x_2/D)^{-0.472}(D/T)^{4.63}(Fr)_F \tag{3}$$

where $(Fl_G)_F$ and $(Fr)_F$ are the gas flow number and the Froude number at the flooding-loading transition and x_2 is the blade thickness. The calculated and experimental values of $(Fl_G)_F$ are summarized in **Table 1**, which shows that the data can be expressed by Eq. (2) or Eq. (3).

Figure 2 shows the equivalent data for the various gases. Essentially, there is no difference except for a minor and practically unimportant one in the flooding region. This result implies that the effect of pressure is negligible on the power characteristic of gassed agitators and on the flooding transition, provided the correct volumetric flow rate is used. The experimental values of $(Fl_G)_F$ are compared with the calculated ones in Table 1. Again, the correlations proposed by Bujalski[1] were found to give satisfactory results. On the other hand, in tall vessels with multiple agitators where the static head is significant the different volumetric flow rates at different levels will change the power drawn by the various agitators.[2]

Conclusion

Gassed power and the flooding-loading transition are independent of gas density. This implies that pressure should have no effect other than change in volumetric flow rate.

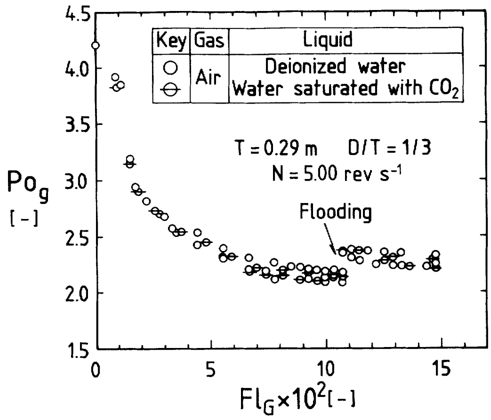

Fig. 1. Effect of saturation of CO_2 into water on gassed power number

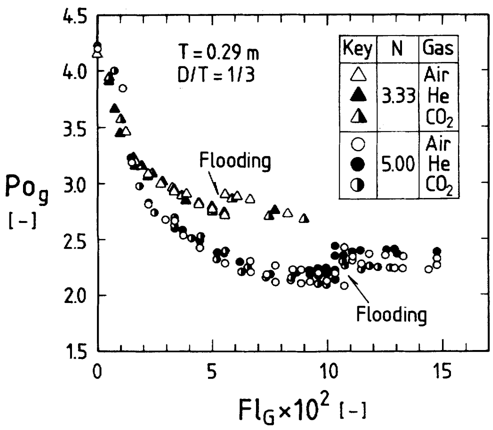

Fig. 2. Effect of gas density on gassed power number

Nomenclature

D	= impeller diameter	[m]
Fl_G	= gas flow number ($=Q_G/ND^3$)	[—]
Fr	= Froude number ($=N^2D/g$)	[—]
g	= gravitational constant	[$m\,s^{-2}$]
N	= impeller speed	[s^{-1}]
P_g	= gassed power	[W]
Po_g	= gassed power number ($=P_g/\rho N^3D^5$)	[—]
Q_G	= gas flow rate	[$m^3\,s^{-1}$]
T	= vessel diameter	[m]
x_2	= blade thickness	[m]
ρ	= liquid density	[$kg\,m^{-3}$]

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