Prosimy cytować jako: Inż. Ap. Chem. 2009, 48, 1, 103-105

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An effect of the impeller position on the dispersion of floating particles in an agitated vessel

Introduction

Zwietering criterion [1–3] is often used to determine the just suspended conditions of settling particles, The purpose of the experimental studies was to determine the effects of the position and impeller type, as well as number and shape of the baffles on the conditions of the draw down of the floating solids in the agitated vessel. The critical just draw down agitator speed n_{JD} for the floating particles was determined visually from the speed at which no particles stayed longer than 2 sec on the free surface of the liquid.

Experimental

The measurements were carried out in the flat – bottomed agitated vessel of inner diameter $D = 0.295$ m, filled with the liquid up to height $H = D$. The impeller of diameter $d = 0.33D$ was placed on the shaft with the clearance $h = 0.33H$ or $0.67H$ from the bottom of the vessel. Standard six bladed Rushton turbine or up-pumping pitched blade turbine were used. The agitated vessel was equipped with the J planar baffles of the full length ($L = H$) or partial length L. The baffles of width $B = 0.1D$ were arranged symmetrically or asymmetrically in the vessel. Asymmetric location of the baffles in the agitated vessel may create an eccentric vortex in which the floating baffles are drawn down [4–6]. Liquid phase was distilled water.

The particles of polyethylene of mean diameter $d_p = 3.82$ mm and density $\rho_p = 952$ kg/m^3 were used as a solid phase. The concentration X of solid phase was changed from the 1% to 4 % w/w.

Results

Successive stages of the suspension of the floating particles were fixed using a digital camera. The technique of computer image analysis was employed to analyse the level of the particle dispersion in the liquid. Capability of the dispersion of the floating particles in the agitated vessels of different geometry is compared in Fig. 1 for a impeller speed $n = 2.5$ 1/s and particle concentration $X = 1\%$. These results represent the data for Rushton or pitched blade turbine operating in the vessel equipped with four standard baffles or two asymmetrically arranged short baffles. Better dispersion is obtained in the agitated vessel with the impeller, located at the distance $h = 0.67H$ from the vessel bottom. For this position of

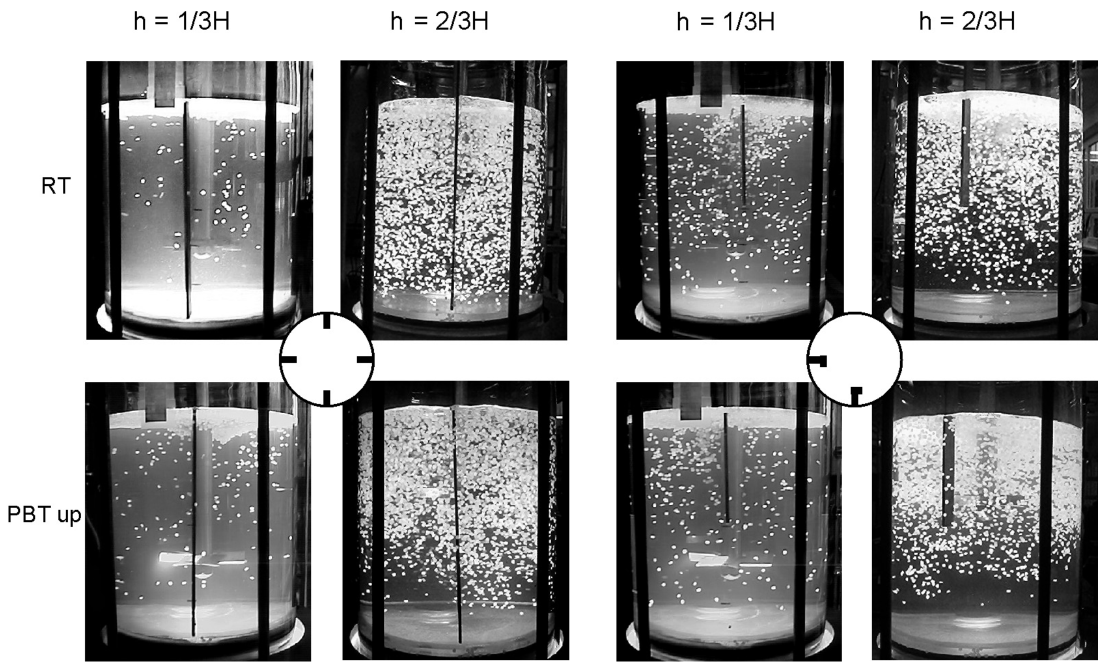

Fig. 1. Comparison of the *Rushton* (RT) and up – pumping pitched blade turbines (PBT up) capability to disperse floating particles in the agitated vessel; $h = 0.33H$ or $h = 0.67H$; $n = 2.5$ 1/s; $X = 1\%$; a) four standard baffles; b) two short baffles ($L = 0.5H$) asymmetrically located

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the impeller and standard baffles, lower critical speeds are characteristic for pitched blade turbine.

The critical impeller speeds n_{JD} have been determined for the suspension of floating solids produced in the agitated vessel. The relationships for the just draw down agitator speed n_{JD} have been analysed for different turbines located at positions $h = 0.33H$ or $h = 0.67H$, as well as for different arrangement and length of the baffles.

The effect of the impeller position in the vessel, i.e. geometrical parameter h/H, on the impeller speed n_{JD} is compared in Fig. 2, where the dependences $Fr_{JD} = n_{JD}^2 d/g = f(h/H, J, L/H, X)$ are presented for different configurations of the baffles as well as for up-pumping pitched blade turbine. For a given type of the impeller and baffles configuration, the lower values of the Fr_{JD} number are characteristic for the parameter $h/H = 0.67$ (Fig. 2b). Moreover, the effects of the number J and length L of the baffles on the Fr_{JD} number are significantly reduced for the value $h/H = 0.67$ comparing with those obtained for the lower position of the impeller ($h/H = 0.33$, Fig. 2a). A significant effect of the baffle length L on the critical impeller speeds n_{JD} has been found for the agitated vessel equipped with the up-pumping pitched blade turbine located at the lower position (Fig. 2a). In this case, *Froude* numbers Fr_{JD} are lower evidently for the short baffles ($L = 0.5H$) than those ascribed for the baffles of full length ($L = H$). When *Rushton* turbine located at upper position ($h/H = 0.67$) in the vessel is used then this effect significantly reduces. In all the cases shown in Fig. 2 the values of the n_{JD} increase with the increase of the particles concentration X.

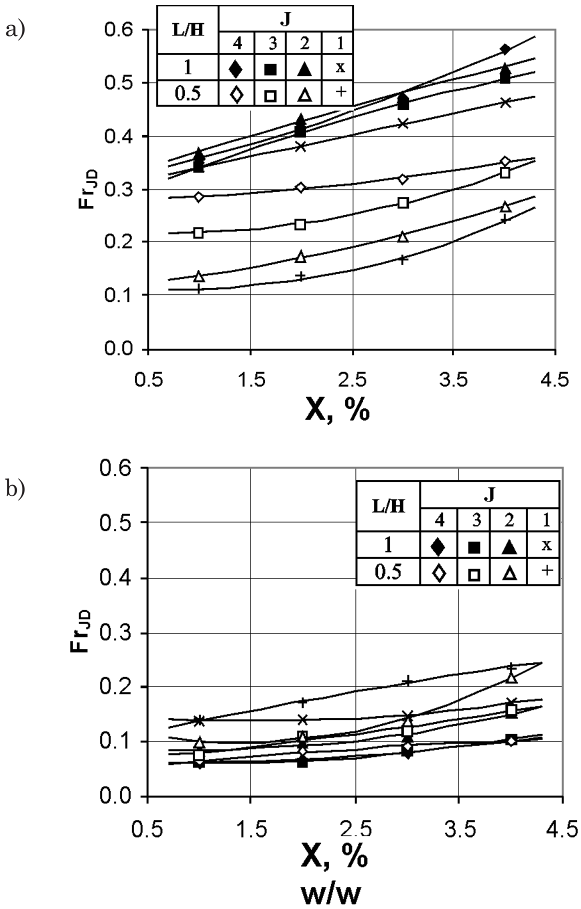

Fig. 2. Comparison of the dependences $Fr_{JD} = f(X, J, L/H)$ for up – pumping pitched blade turbine (asymmetrical arrangement for $J = 2$); a) $h = 0.33H$; b) $h = 0.67H$

The dependence of the minimum impeller speeds n_{JD} on the baffle arrangements, height h of the impeller in the vessel and particles concentration X has been described using a function $Fr_{JD} = f(J, L/H, h/H, X)$. The following equation has been obtained on the basis of the 160 experimental data for both pitched blade turbine and *Rushton* turbine

$$Fr_{JD} = \frac{dn_{JD}^2}{g} = K\left(\frac{J}{4}\right)^{b_1}\left(\frac{L}{H}\right)^{b_2}\left(\frac{3h}{H}\right)^{b_3} X^{b_4} \qquad (1)$$

Model coefficients of the Eq. (1) and errors Δ of the approximation are given in Table 1. Eq. (1) describes experimental data within the turbulent regime of the liquid flow ($Re_{JD} \in \langle 5 \cdot 10^4; 10^5 \rangle$) and following range of the variables: $h/H \in \langle 0.33; 0.67 \rangle$; $J \in \langle 1; 4 \rangle$; $L/H \in \langle 0.5; 1 \rangle$ and $X \in \langle 0.01; 0.04 \rangle$.

Table 1

The coefficient K and exponents b_i in Eq. (1) for different agitators

Agitator		K	b_1	b_2	b_3	b_4	Δ, %
Rushton turbine (RT)		0.174	0.253	0.508	– 0.225	0.385	± 14.3
Pitched blade turbine (PBT↑)	$L/H = 0.5$	0.190	0.207	1	– 0.801	0.381	± 16.7
	$L/H = 1$	0.362	0.030	1	– 2.142	0.265	± 22.6

Power consumption P_{JD} has been calculated for each configuration of the agitator and baffles tested. The criterion of the specific power consumption has been used to compare the efficiency of the draw down of the floating solids in the agitated vessel of the different geometry. The conditions of agita-

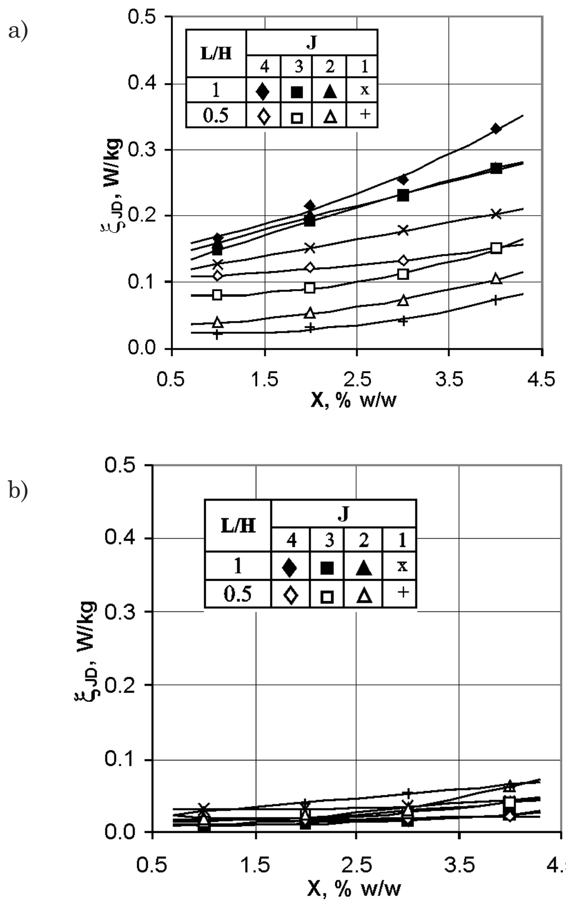

Fig. 3. Comparison of the dependences $\varepsilon_{JD} = f(X, J, L/H)$ for pitched blade turbine (asymmetrical arrangement for $J = 2$); a) $h = 0.33H$; b) $h = 0.67H$

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tion at which floating particles are all just dispersed in the vessels with short non – standard baffles require less mechanical energy than with standard ones.

As the data in Fig. 3a show, specific energy ε_{JD} increases with the increase of the number J and the length L of baffles and mean concentration X of the floating particles in the liquid for the agitated vessel equipped with the impeller located at the position $h = 0.33H$. Specific energy ε_{JD} decreases significantly when each of the impeller is replaced at the upper position ($h/H = 0.67$, Fig. 3b). Moreover, the effect of the baffling in the vessel on the ε_{JD} is reduced in this case (Fig. 3b).

Conclusions

The results of the experimental analysis of the floating solids suspension in the agitated vessel show that within the range of the performed measurements

Critical impeller speeds n_{JD} depend significantly on the position h of the impeller in the vessel and impeller type. Just draw down agitator speeds n_{JD} decrease with the increase of the geometrical parameter h/H. Up-pumping pitched blade turbine located at the position $h = 0.67H$ is more advantageous for draw down of the floating particles than *Rushton* turbine.

Baffling of the agitated vessel affects significantly just draw down agitator speeds n_{JD} for the standard position ($h/H = 0.33$) of the impeller in the vessel. The effect of the baffling reduces when the impellers are replaced to the upper position ($h/H = 0.67$).

Agitated vessel equipped with the up-pumping pitched blade turbine at the position $h = 0.67H$ and non-standard baffles ($J = 4$; $L/H = 0.5$) can be recommended for the suspending of the floating particles into liquid phase.

Nomenclature

B – width of the baffle, [m]
D – inner diameter of the agitated vessel, [m]
d – agitator diameter, [m]
d_p – particles diameter, [m]
Fr – *Froude* number, (dn^2/g)
g – acceleration due to gravity, [m/s^2]
H – liquid height in the agitated vessel, [m]
h – off–bottom clearance of the agitator, [m]
J – number of baffles
L – length of baffle, [m]
n – agitator speed, [1/s]
n_{JD} – just draw down impeller speed, [1/s]
P – power consumption, [W]
Re – *Reynolds* number, ($nd^2\rho_L/\eta_L$)
V_L – liquid volume, [m^3]
X – mass fraction of the particles, w/w
Z – number of blades
ε – specific energy dissipated, [W/kg]
β – pitch of the blade of the agitator, [deg]
ρ – density, [kg/m^3]
η – liquid viscosity, [Pas]

Indices

JD – just draw down
L – refers to liquid phase
p – refers to particles

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