PARTICLE SUSPENSION WITH A TX445 IMPELLER

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Abstract. The aim of paper is to determine just-suspension speed of TX445 impeller produced by TECHMIX and to compare its suspension effects and efficiency necessary for particle suspension with standard pitched six-blade turbine. Suspension measurements were carried out with glass balotine of diameters in range from 0.18 to 0.9 mm and its volumetric concentration changed in the range from 0.025 to 0.4. The just suspension impeller speed was stated visually. The measurements were carried out in dish-bottomed vessel with diameter 300 mm equipped with four standard baffles at the wall. The ratio of vessel to impeller diameter D/d = 3. Turntable with tensometric pick-up of torque was used in power consumption measurements. From the results presented in the paper it follows that TX 445 impeller needs higher just suspension impeller speed but lower power consumption for particle suspension than pitched six-blade turbine.

Keywords: Mixing, pitched six-blade turbine, TX445 impeller, particle suspension, power, efficiency.

1. INTRODUCTION

The aim of this paper is to determine the just-suspension speed of the TECHMIX TX445 impeller, in order to compare its suspension effects and the efficiency necessary for particle suspension with a standard pitched six-blade turbine. Particle suspension with a pitched six-blade turbine has been presented in [1], which reported on the just-suspension speed and the efficiency of a pitched six-blade turbine.

2. THEORETICAL BACKGROUND

In order to design apparatuses for mixing suspensions, it is important to know the reference state of a just off-bottom particle suspension, which is usually defined as the state at which no particle remains in contact with the vessel bottom for longer than a certain time. The impeller speed corresponding to this state is referred to as the critical (just-suspended) impeller speed.

On the basis of an inspection analysis of the continuity equation, the Navier-Stokes equation and the equation expressing the balance of forces affecting the suspended particle, Rieger and Ditl [2] proposed the following relationship among the modified Froude number $Fr'$, the dimensionless particle diameter $d_p/D$, and the mean volumetric concentration of the solid phase $c$. 

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This relation holds for geometrically similar mixing equipment and a turbulent regime.

The results of critical (just-suspended) impeller speed measurements for the given solid phase concentration \( c \) can be correlated in the power form

\[
Fr' = n^2 \frac{d \rho}{g \Delta \rho} = f \left( \frac{d}{D} c \right). \tag{1}
\]

The values of coefficients \( C \) and \( \gamma \) depend on particle volumetric concentration \( c \). A mathematical description of these dependencies was proposed by Rieger [3] in the form

\[
C = A \exp(BC) \tag{3}
\]

and

\[
\gamma = \alpha + \beta c. \tag{4}
\]

The dimensionless criterion

\[
\pi_s = Po \sqrt{Fr^\gamma (d/D)^\gamma} \tag{5}
\]

was proposed in [4] for comparing the agitator power consumption necessary for suspending solid particles.

3. EXPERIMENTAL

The TX 445 hydrofoil impeller shown in Fig.1 was used in model measurements. The ratio of the vessel to agitator diameter \( D/d \) was 3. The measurements were carried out in dish-bottomed vessel 300 mm in diameter.

The height of the impeller above the vessel bottom was equal to 0.75 \( d \). The impeller was operated to pump the liquid down towards the bottom of the vessel. The vessel was equipped with four radial baffles \( b = 0.1 \cdot D \) in width. The height of the liquid level was equal to the vessel diameter \( H = D \).

Suspensions of glass particles in water solutions were used in the suspension measurements. The diameters of the glass ballotine particles varied within the range from 0.18 to 0.9 mm, and their volumetric concentration varied within the range from 0.025 to 0.4. The just suspension impeller speeds were measured visually as the speed at which no particles remained on the vessel bottom longer than approximately 1 s.

A turntable with tensometric pick-up of torque was used in the power consumption measurements.
4. EXPERIMENTAL RESULTS

The experimental primary suspension data was transformed into dimensionless criteria, and was plotted as the suspension characteristics. The suspension characteristics for the turbulent region are the dependencies of the modified Froude number $Fr'$ on the dimensionless particle size $d_p/D$ at constant volumetric particle concentration $c$. These dependencies obtained from visual measurements for selected concentrations are depicted in Fig. 2. This figure shows that the speeds necessary for particle suspension, and also $Fr'$, increase with increasing particle size and concentration.

![Figure 2. Dependencies of $Fr'$ on $d_p/D$ for selected concentrations $c$.](image)

The regression of the suspension characteristics was evaluated in the power form according to Eq. (2). The plot of exponent $\gamma$ on particle volumetric concentration $c$ is shown in Fig. 3. This figure shows that it rises linearly with increasing $c$. This is in agreement with Eq. (4).

![Figure 3. Dependence of exponents $\gamma$ on $c$.](image)
The dependence of the corresponding coefficients $C$ on particle concentration $c$ is shown in Fig. 4, which shows that the dependence can be approximated in semi-logarithmic coordinates by a straight line. This is in agreement with Eq. (3).

$$y = 5.286e^{20.607x}$$

$R^2 = 0.998$

Figure 4. Dependence of coefficients $C$ on concentration $c$.

The power consumption measurements with the TX 445 impeller were evaluated in the form of a power number – the Reynolds number dependence shown in Fig. 5. This figure shows that the power number in the turbulent regime is constant irrespective of the Reynolds number.

Figure 5. Power characteristic of TX 445 impeller.

5. DISCUSSION

The dependence of $Fr'$ on the $d_p/D$ ratio calculated from Eqs. (2-4) and the corresponding dependence for a standard pitched six-blade turbine is depicted in Fig. 6. This figure shows that the values of $Fr'$ and also the agitator speeds for particle suspension are greater for TX445 than for a standard turbine.
The values of criterion (5) were calculated from the results of suspension and power consumption measurements. A comparison between this dependence and the corresponding dependence for a pitched six-blade turbine for selected values of $c$ is depicted in Figs. 7 and 8.
These figures show that a TX 445 impeller requires lower power consumption for particle suspension than a pitched six-blade turbine. However, this difference decreases with increasing particle concentration.

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6. SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>A, B</td>
<td>constants in Eq.(3)</td>
</tr>
<tr>
<td>(c_v)</td>
<td>volumetric concentration of particles</td>
</tr>
<tr>
<td>C</td>
<td>coefficient in Eq.(2)</td>
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<tr>
<td>d</td>
<td>agitator diameter</td>
</tr>
<tr>
<td>(d_p)</td>
<td>particle diameter</td>
</tr>
<tr>
<td>D</td>
<td>vessel diameter</td>
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<tr>
<td>(Fr')</td>
<td>modified Froude number, (Fr' = \frac{n^2 d \rho}{g \Delta \rho})</td>
</tr>
<tr>
<td>g</td>
<td>gravity acceleration</td>
</tr>
<tr>
<td>n</td>
<td>agitator speed</td>
</tr>
<tr>
<td>P</td>
<td>power</td>
</tr>
<tr>
<td>(P_o)</td>
<td>power number, (P_o = \frac{P}{\rho n^3 d^5})</td>
</tr>
<tr>
<td>Re</td>
<td>Reynolds number, (Re = \frac{nd^2 \rho}{\mu})</td>
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<tr>
<td>(\alpha, \beta)</td>
<td>constants in Eq.(4)</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>exponent in Eq.(2)</td>
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<tr>
<td>(\mu)</td>
<td>viscosity</td>
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<td>(\rho)</td>
<td>liquid density</td>
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<td>(\Delta \rho)</td>
<td>solid-liquid density difference</td>
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7. REFERENCES