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LETTER TO EDITOR

COMMENTS ON *FLOW CHARACTERISTICS OF AXIAL HIGH SPEED IMPELLERS* (CHEM. PROCESS ENG., 2010, 31, 661)

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Fořt et al. (2010) have written another useful article on flow characteristics generated by axial high speed impellers. I agree with the authors that the knowledge of flow patterns is crucial for developing reliable design procedures for instance, for mixing and blending (Baldyga and Bourne, 1997; Nienow, 1997; Ranade et al., 1991), for solid suspension (Raghva Rao et al., 1988; Zwietering, 1958), for gas induction (Joshi and Sharma, 1977) and bioreactions where controlled shear is important (Joshi et al., 1996). With this context, the work of Fořt et al. (2010) needs some clarification and further extension.

1. The commented paper recommends pitched blade downflow turbine ($\alpha = 45°$, $n_b = 6$, $W/D = 0.2$) for mixing and blending. For their experiments, they have employed $D/T = C/T = 1/3$. For such a geometrical arrangement, Nienow (1997) has comprehensively analysed published literature, supported the analysis by sound theory and proposed the following correlation

$$N_P N \theta_{mix} (D/T)^{1/3} = \text{constant} \tag{1}$$

   Patwardhan and Joshi (1999) estimated the mixing time for 35 designs of axial downflow impellers and observed that

$$\theta_{mix} = \frac{12.66 N_P^{1/3} T^{2/3}}{N_{QS} (P/M)^{1/3}} \tag{2}$$

   The 35 designs included wide variations in the number of blades, blade angles, blade width, variations in blade angle (twist) and blade width from hub to tip. The observations indicated that the six bladed downflow pitched turbine ($\alpha = 45°$) is not the most efficient. As compared to this impeller, ten other designs have shown higher potential for mixing efficiency.

2. Authors have further recommended that the most convenient impeller for suspension of solid particles in liquid seems to be the axial impeller with profiled blades TX 335. The reason behind this recommendation is that the impeller TX 335 exhibits the highest efficiency (N_{QP}/N_P) of the transformation capacity of power to flow. It may be pointed out that, in the published literature, there are at least ten impeller designs having superior values of efficiency than TX 335. Further, authors will agree that the direct correlation of hydraulic efficiency (N_{QP}/N_P) with efficient solid suspension is difficult with the present status of knowledge. The available published literature may not be sufficient to develop clear recommendations over a wide range of fluid and solid properties and geometrical details of stirred tanks (Bourne and Sharma, 1974; Chapman et al., 1983; Dohi et al., 2004; Lali et al., 1989; Musil et al., 1978; Nienow, 1968; Raghav Rao et al.

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1988; Rewatkar et al., 1991a; 1991b; Zhu and Wu, 2002; Zweitering, 1958). Substantial additional work is needed for the development of relationship between the efficiency of solid suspension and the hydraulic efficiencies (N_{QP}/N_P or N_{QS}/N_P).

3. Authors have nicely compiled the values of N_P, N_{QP}, N_{QS} and the other parameters for four impeller designs. The published literature (Armenante and Chou, 1996; Armenante et al., 1997; Bakker and Oshinowo, 2004; Bakker and van den Akker, 1994; Bakker et al., 1996; Bakker et al., 1997; Brucato et al., 1998; Bugay et al., 2002; Derksen, 2001; Fentiman et al., 1998; Firoz et al., 2004; Fokema et al., 1994; Harvey et al., 1995; Harvey et al., 1996; Jahoda et al., 2007; Jaworski et al., 1996; Kumaresan et al., 2005; Li et al., 2005; Mavros et al., 1998; Murthy et al., 2007; Murthy et al., 2008; Nere et al., 2001; Nurtono et al., 2009; Ranade et al., 1989; Ranade et al., 1992; Ranade et al., 2002; Roussinove et al., 2003; Roy et al., 2010; Rutherford et al., 1996; Sahu and Joshi, 1995; Sahu et al., 1998; Sahu et. al., 1999; Schafer et al., 1998; Tomas et al., 2003; Tyagi et al., 2007; Xu and McGrath, 1996; Zhou and Kresta, 1996) gives some information about fifty different impeller designs. There are some cases where one research group has investigated 25 impeller designs. These studies may be useful. On the basis of outstanding track record of the author's group, it will be a good idea to present a comprehensive comparison and make recommendations for optimum design for blending, heat transfer, suspension, dispersion, etc.

SYMBOLS

C	impeller clearance from tank bottom, m
D	impeller diameter, m
M	mass of fluid in the tank, kg
N	impeller speed, rps
N_P	power number, $P/\rho N^3 D^5$ (-)
N_{QP}	primary flow number, Q_P/ND^3 (-)
N_{QS}	secondary flow number, Q_t/ND^3 (-)
n_b	number of blades, (-)
P	power consumption, W
Q_P	flow directly generated by impeller, m^3 s^{-1}
Q_t	total flow which equals primary flow plus entrained flow, m^3 s^{-1}
T	tank diameter, m
W	blade width, m

Greek symbols

α	blade angle, degrees
ρ	liquid density, kg m^{-3}
θ_{mix}	mixing time, s

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