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Comments on "Suspension Mixing Tank - Design Heuristic"

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Abstract

The study deals with analysis of the process characteristics of agitated system with a pitched blade impeller and radial baffles (impeller power input and impeller pumping capacity) under turbulent regime of flow of agitated batch. Original experimental data are compared with results of CFD simulation in a pilot plant mixing system published in literature.

KEYWORDS: Pithched blade impeller, Impeller power input, Impeller pumping capacity, Turbulent flow, CFD

Comments on "Suspension Mixing Tank – Design Heuristic"

The article written by Lea (2009) consists of application of Computation of Fluid Dynamics (CFD) to calculation of the main integral process characteristics of mechanically agitated system – impeller power input and impeller pumping capacity. The Author used CFD modeling way to determine influence of the main geometric characteristics on the above mentioned process characteristics under turbulent regime of flow of agitated batch.

Impeller power input plays important role at the scaling up of the solids suspension (Paul et al., 2001) and axial impeller pumping capacity can be used for calculation of its effectivity for this process (Wu and Zhu, 2001). Down pumping pitched blade impeller (DPBI) in cylindrical vessel with radial baffles at its wall can be considered as a typical representative system for this operation.

The commented study covers both results of many geometric arrangements of agitated system with six blade 45° DPBI and dependences of both investigated process characteristics on the geometric parameters considered – impeller vessel diameter ratio *D/T* relative impeller off-bottom clearance *C/T* , number of baffles N_B and their relative size *B/T*, and relative width of impeller blade *W/D*. All the results of CFD simulations can be expressed in dimensionless form as the Power number :

$$Po = P/\rho N^3 D^5 = f(Re_M, D/T, C/T, W/D, N_B, B/T) \quad (1)$$

and the Flow rate number:

$$N_Q = m'/\rho N D^3 = f(Re_M, D/T, C/T, W/D, N_B, B/T) \quad (2)$$

As dependent variables in Eqs. (1) and (2) are the impeller power input *P* and the mass flow rate *m'*, i.e. the product of impeller pumping capacity *Q* and liquid density ρ. Under turbulent regime of flow when impeller Reynolds number

$$Re_M = ND^2\rho/\mu > 1.0 .10^4 \quad (3)$$

both considered integral characteristics do not depend on this variable (Medek, 1990, Beshay et al., 2001, Fořt, 1986). For the commented study the impeller Reynolds number exceeds one hundred thousand and from the shown results of CFD simulations it follows (Eqs. 14 and 16):

$$P = k_1 N^{3.02} \quad (4)$$
$$m' = k_2 N \quad (5)$$

So results of Eqs.(4) and (5) agree very well with definitions of the quantities *Po* and N_Q and effect of the impeller Reynolds number in Eqs.(1) and (2) can be neglected.

Experimental investigations of the power characteristics of DPBI were carried out by Medek (1980) and Beshay et al. (2001). The latter authors correlated results of their experiments as well as the results of Medek made on the pilot plant mixing equipment by power correlation

$$Po = 1.507\, N_B^{0.701} (\sin\alpha)^{2.077} (H/T)^{0.140} (D/T)^{0.365} (C/T)^{-0.165}, Re_M > 1.0 .10^4 \quad (6)$$

where N_B is number of impeller blades, *H* is the height of agitated liquid at rest, *T* is vessel diameter and α is impeller blade pitch angle. Fort (1986) published for the Flow rate number a correlation following from his experiments in the form

$$N_Q = 1.014 (D/T)^{0.21} (C/T)^{-0.17}, Re_M > 1.0 .10^4 , \alpha = 45^o, N_B = 6, D/T \in \langle 0.2; 0.5\rangle, C/T \in \langle 0.2; 0.5\rangle \quad (7)$$

Eqs. (6) and (7) are valid for the cylindrical vessel provided with four baffles ($N_B = 4$) of the width B/T = 0.1 and relative width of impeller blades $W/D = 0.2$. Rearranging of Eq. (6) for geometric conditions valid for Eq. (7) we have

$$Po = 2.576\,(D/T)^{0.365}\,(C/T)^{-0.165},\ Re_M > 1.0\,.10^4 \qquad (8)$$

Geometry of DPBI and the whole agitated system correspond to the Czech Standard ON 691020.

Table 1 contains a comparison of the Power number and the Flow rate number calculated from Eqs. (7) and (8) and corresponding values taken from the commented study.

Table 1: Comparison of experimental and calculated values of Power number and the Flow rate number of the six blade 45° DPBI ($Re_M > 1.0\,.\,10^4$, $D/T = 0.5$, $W/D = 0.2$, $B/T = 0.1$)

C/T	Po_{exp}	P_{calc}	$N_{Q,exp}$	$N_{Q,calc}$
0.15	2.73	3.00	1.210	0.878
0.20	2.61	2.64	1.152	0.911
0.30	2.44	2.30	1.076	0.954
0.40	2.33	2.31	1.024	0.963
0.50	2.24	2.32	0.987	0.960

For comparison in Table 1 the values of geometric simplex C/T were chosen for conditions of mixing of suspensions of solid particles when their density is higher than density of the second phase – liquid. Calculated results of Lea (2009) correspond to the values of the simplexes

$$W/D = 0.23 \quad \text{and} \quad B/T = 0.071 \qquad (9)$$

while experimental data were found under conditions

$$W/D = 0.20 \quad \text{and} \quad B/T = 0.1 \qquad (10)$$

Therefore the CFD results (Lea, 2009) were recalculated to the conditions (10) according to the correlations mentioned in this study.

From comparison of the results published in the commented study and the results of experimental investigations it follows very good agreement of the Power number values. Values of the Flow rate number slightly differ above all owing to the application of Eq. (7) at the boundary of its validity (D/T = 0.5). Nevertheless except for the shortest off-bottom clearance $C/T = 0.15$ with probably significant interference of the DPBI and vessel bottom the agreement of corresponding values of $N_{Q,calc}$ and $N_{Q,exp}$ seems to be satisfactory.

Finally it can be concluded that the CFD procedure for calculation of the power input and the flow rate of the pitched blade down pumping impeller under turbulent regime of flow of agitated liquid presented by Lea (2009) can be considered as a suitable background for following simulation of two phase solid-liquid agitated suspension. Moreover the size of investigated system (vessel diameter $T = 2$ m) and water as a working liquid (density $\rho = 1000$ kg/m^3, dynamic viscosity $\mu = 1$ mPa s) give guaranty of sufficient engineering data for design of industrial mixing equipment.

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