Transitional mixing in a vessel equipped with triple eccentric impellers

Introduction

Multiple-impeller systems are used in many industries, because of the advantages of the longer residence time, lower decrease of heat exchange area in scale-up treatment, lower power consumption per impeller as compared to single-impeller systems. Moreover, the use of eccentric multiple impeller systems can improve mixing. Eccentricity was found to be equivalent to baffling where eccentric position of the impeller maximized power consumption. Eccentric configurations have been even less studied, but probably they have a wider practical interest, as the off-centre impeller positioning improves the mixing [1]. The effect of impeller eccentricity on mixing has been experimentally investigated in few works [2–5] but knowledge of these systems is still rather incomple-te. For the laminar regime, the effect of the shaft position on the flow field has been experimentally investigated by Alva-rez et al. [6], who found important changes in the flow structure and major enhancement in mixing behaviour even for low eccentricity conditions.

The aim of this work was to determine the impact of the eccentricity ratio on mixing efficiency (mixing time and mixing power) in a vessel equipped with triple turbine impellers.

Experimental part

Experimental set-up consisted of a motor, inverter, speed sensor, PC computers, interface, torque meter, conductivity probe, conductometer and injection device (Eppendorf EDOS 5222). The vessel had diameter $T = 0.19$ m and the height of liquid level was taken $3T$. The three types of impellers ($D = 0.065$ m) were used: Rushton turbine (RT), six flat blade turbine (FBT) and six pitched up blade turbine (PBT). The bottom clearance of the lowest turbine was $T/2$ and the spacing between turbines was chosen $T$, which is the safe distance to prevent hydrodynamic interaction between them in turbulent agitation, according to Hudcova et al. [7]. The working viscous Newtonian fluid was 75% glycerol solution ($\eta = 0.0345$ Pa s, $\rho = 1194$ kg/m$^3$). The mixing time $t_{ma5}$ at a 5% deviation from homogeneity was determined by use of the conductivity method. A small part (10 ml) of NaCl solution has been injected into the vessel containing a glycerol solution and after that the conductivity of the solution was measured. The eccentricity ratio was changed as follows: $E/R = 0$ (centrically mounted), $E/R = 0.21$, $E/R = 0.32$, $E/R = 0.42$ and $E/R = 0.52$.

Results

It follows from the analysis of data that the shortest mixing time in baffled system was obtained for triple Rushton turbines RT-RT-RT. The values of mixing time in relation to an impeller type were arranged as follows:

$(t_{ma5})_{RT-RT-RT} < (t_{ma5})_{FBT-FBT-FBT} < (t_{ma5})_{PBT-PBT-PBT}$

The longest values were obtained for axial impellers. In the range of Reynolds number values $Re_{in} = 299–1170$ the mixing time decreases with increase of $E/R$, but in range of $Re_{in} = 1170–3000$ this relation progressively decays. This fact can be explained by the peculiarities of transitional flow characteristics. At Reynolds number values $Re_{in} > 1170$ the turbulence is gradually increasing, and the dependence between the eccentricity and mixing time becomes weaker and finally in turbulent flow regime is negligible. For all impeller systems in the range of Reynolds numbers $Re_{in} = 299–1170$ the
The above relationships were obtained according to mixing power and mixing time for RT-RT-RT system (eq. (2)), FBT-FBT-FBT system (eq. (3)) and for PBT-PBT-PBT system (eq. (4)) in an un baffled vessel. The increase of $E/R$ brings about on enlargement of mixing power and will progressively approach its values to the values of mixing power typical of baffled vessel.

### Summary

Measurements of mixing time, mixing power in Newtonian viscous solutions in vessel equipped with a triple turbine showed that the dimensionless quantity $t_m/\tau$ is dependent on Reynolds number in the transitional regime. Moreover, this variable is dependent on eccentricity ratio $E/R$. In un baffled vessel mixing time decreases with an increase of $E/R$.

### Notation

- $A, B, C, m$ – constant
- $D$ – impeller diameter, [m]
- $E$ – distance between impeller shaft and stirred tank axis, [m]
- $E/R$ – eccentricity ratio
- $R$ – radius of stirred tank, [m]
- $T$ – inside diameter of stirred tank, [m]
- $N$ – agitator speed, [s$^{-1}$]
- $t_m$ – mixing time, [s]
- $\eta$ – viscosity, [Pa·s]
- $\rho$ – density, [kg·m$^{-3}$]

### REFERENCES