HYDRODYNAMICS OF UNBAFFLED VESSELS STIRRED WITH ECCENTRICAL IMPELLERS

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So far, most of the computations aimed at providing detailed predictions of the flow field of mechanically stirred vessels have regarded baffled tanks, while less effort has been devoted to unconventional stirred vessels. Unbaffled vessel with eccentrical impeller can be adopted as an alternative to baffled vessels as this configuration is less prone to superficial vortexing: examples of application can be found in the food, paint, pharmaceutical and chemical industries. The flow field in unbaffled tanks provided with impellers located eccentrically presents a quite complex turbulence structure and its prediction represents a difficult target for turbulence models.

The hydrodynamics of this system has, therefore, been studied using a combination of experiments and computational fluid dynamics (CFD) simulations. The flow field data provided by these methods are complementary. The experiments provide an accurate representation of the time averaged flow fields at a relatively low spatial density. Time series of instantaneous two-dimensional velocities in individual planes can be measured, but a complete, transient volumetric representation of the three-dimensional flow field can not be easily determined. Instead, such information is available from the CFD simulations.

However, validations of the CFD predictions for these flow fields are not yet available in the literature. And, as already shown for the case of single phase and solid-liquid unbaffled vessels with co-axial mixers, simulations of the flows characterised by strong swirl and anisotropy cause severe difficulties, the usually adopted RANS simulations based on eddy-viscosity turbulence models leading to unrealistic results (Ciofalo et al., 1996, Cokljat et al., 2004).

In this work, CFD simulations of an unbaffled vessel stirred with an eccentrical Rushton turbine is presented. In particular, a cylindrical tank (tank diameter, T=23.6 cm, tank height, H=T) provided with a flat base and a lid on the top is considered. Agitation is provided with a standard six-bladed Rushton turbine of diameter D=T/3 placed at the distance C=T/2 from the vessel base and at the distance of 93 cm from the vessel axis. The working liquid is water at room temperature. The impeller rotational speed is fixed at 400 rpm, corresponding to a velocity of the blade tip, V_{tip}, equal to 1.65 m/s, and producing an impeller Reynolds number, Re, equal to $4.1\cdot10^4$.

The simulation technique employed for obtaining the dynamic turbulent flow field is described. The predicted velocity field is compared with original experimental data, obtained by means of Particle Image Velocimetry (PIV) on several vertical and horizontal planes. Comparison of the results obtained from the solution of the Reynolds Averaged Navier Stokes (RANS) equations coupled with the eddy-viscosity and the Reynolds Stress turbulence models is provided. The complex flow structure characterised by the presence of two vortexes departing from the impeller, as obtained from the simulation, is shown to be accurately predicted.

REFERENCES

Ciofalo M., Brucato A., Grisafi F., Torraca N., Turbulent Flow in Closed and Free-Surface Unbaffled Tanks Stirred by Radial Impellers, Chem. Eng. Sci., 51, 3557-3573, (1996).

Cokljat, D., Slack, M., Vasquez, S.A., Bakker, A., Montante, G., Reynolds-Stress Model for Eulerian Multiphase, submitted, Progress in Computational Fluid Dynamics, (2004).