

DIRECT NUMERICAL SIMULATION OF A TURBULENTLY STIRRED TANK

J. J. J. Gillissen *, H. E. A. van den Akker

*Department of Multi-Scale Physics
J.M. Burgers Centre for Fluid Mechanics, Delft University of Technology,
Prins Bernhardlaan 6, 2628 BW Delft, Netherlands; e-mail: j.j.j.gillissen@tudelft.nl*

Abstract.

Stirred tanks are encountered in a large variety of industrial processes, especially as chemical reactors. Consequently a good understanding of the associated turbulent flow is crucial for detailed process design. As in many industrial relevant flows, the simulation of the full range of turbulent length- and time-scales is a very demanding task. This problem can be overcome by using Large Eddy Simulation (LES), in which the small turbulence scales are unresolved while their effect on the resolved, large scales are incorporated using the viscosity hypothesis. The first stirred tank LES appeared 10 years ago [1] and to date LES is still considered the state of the art in reactor engineering and can provide very accurately the large scale turbulent motion in industrial geometries. However LES is less reliable concerning flow behavior at the small scales. For instance molecular mixing, involved in chemical reactions, strongly depends on the small scales and it is unclear whether current LES models correctly capture these phenomena.

A complete and reliable picture of turbulence can be obtained by Direct Numerical Simulation (DNS), a technique which provides the full energy spectrum without making any modeling assumptions. With the aid of the the dutch national supercomputer we are the first to report on a stirred tank DNS. The incompressible and isothermal Navier Stokes equations are discretized using a Lattice Boltzmann method [2] and the no-slip boundary condition is enforced using an adaptive force field technique [3]. The turbulent flow inside the baffled, cylindrical tank is driven by a six-bladed Rushton turbine and the Reynolds number based on turbine diameter and turbine frequency $Re=5000$. To resolve all turbulent scales during 20 turbine revolutions, a total of 10^9 grid-points and 10^5 time-steps are computed. The job was performed during one month on 128 CPU cores.

The research possibilities on our data are numerous. In the paper we focus on the comparison between LES and DNS. We point out where LES fails and suggest ways for improving the sub-grid modeling. Also we show visualizations of the vortical structures in the wake of a single turbine blade.

Key words: Stirred Tank; Mixing; Turbulence; Direct Numerical Simulation; Lattice Boltzmann;

REFERENCES

1. Derksen J. J., van den Akker H. E. A., 1999. Large eddy simulation of the flow driven by a Rushton turbine, *AIChE J.*, **45**, 209-221.
2. Eggels J. G. M., Somers J. A., 1995. "Numerical simulation of free convective flow using the lattice-Boltzmann scheme", *Int. J. Heat and Fluid Flow*, **16**, 357.
3. Derksen J. J., Kooiman J. L. van den Akker H. E. A., 1997. "Parallel fluid flow simulations by means of a Lattice Boltzmann scheme", *Lect. Notes Comput. Sci.*, **1225**, 542.