

# Cost-effective Ship Hull Design

Turbulent flow around the hull of a very large crude oil carrier was the focus of a recent international workshop in ship hydrodynamics held in Gothenburg, Sweden. A FLUENT simulation for a 1:58 scale model of this hull was presented at the meeting (Kim, 2000). The results were compared with the data from the Korea Research Institute of Ship and Ocean Engineering (KRISO) (Van *et al.*, 1998). The Reynolds number of the scaled model based on its length was 4.6 million, which corresponds to a 5.5 m long scaled model towed at a speed of 1.05 m/s. Approximately 200,000 hexahedral cells were used in the simulation. Turbulence closure was effected using the Reynolds stress transport model (RSTM) in conjunction with wall functions for near wall treatment. The computation was carried out on a Sun Ultra (SunOS 5.6) workstation.

Many aspects of the flow past the hull were examined including the resistance (drag), stern boundary layer, streamwise vortices, and velocity field at the propeller plane. The FLUENT predictions were found to be in excellent agreement with the experimental data in all aspects. One of the most salient features of the flow around "full" ships is the unique shape of the axial velocity contours in the propeller plane, as exhibited by the measured velocity contours in Figure 1 (Van *et al.*, 1998). This structure, which looks very much like a rabbit's ear or hook, is in fact a cross-sectional image of the free vortex sheet originating from the stern boundary layer and rolling up as it evolves downstream. The FLUENT results, which were based on the RSTM, impressively captured this characteristic shape of the velocity contours, as shown in Figure 2.

Another quantity of vital interest to ship designers is the total resistance or drag acting on the

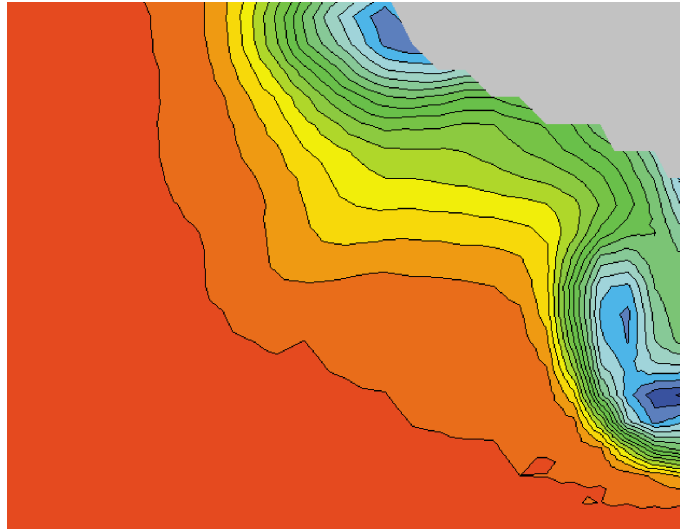


Figure 1. Contours of axial velocity in the propeller plane taken from the KRISO towing tank data

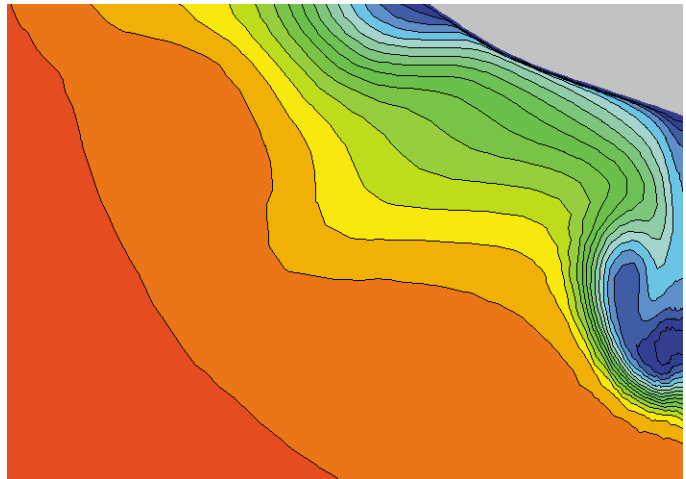


Figure 2. Contours of axial velocity predicted by FLUENT using the Reynolds stress transport model

ship hull. The FLUENT prediction of the total drag was found to be remarkably close to the measured value. The total resistance coefficient predicted by the RSTM calculation for the present hull was approximately  $4.06 \times 10^{-3}$ , while the measured value

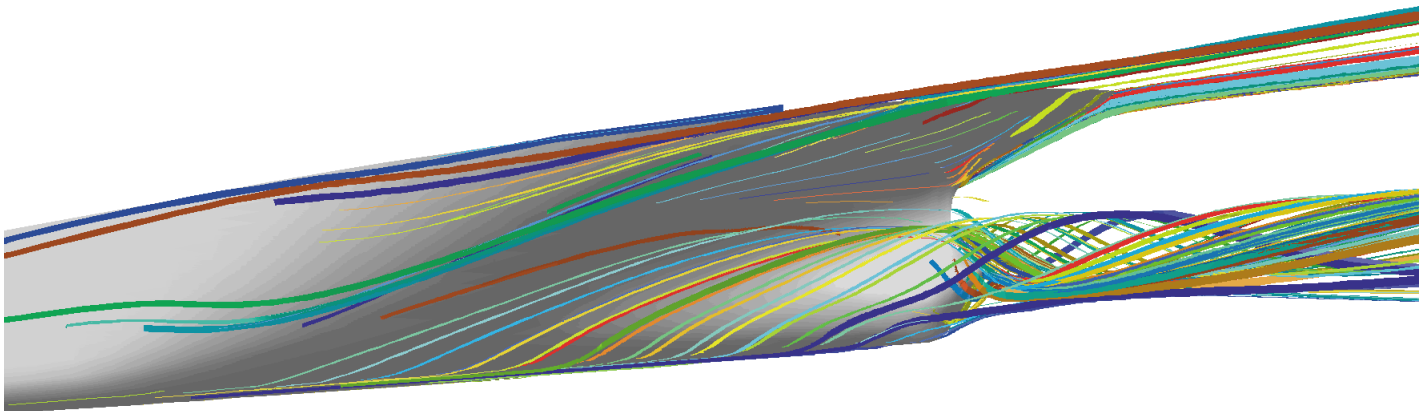
is around  $4.11 \times 10^{-3}$  (Kim *et al.*, 1999). Most of the other predictions presented at the workshop, which adopted simpler turbulence models, such as k-e models, severely overpredicted the drag.

The present study demonstrates that CFD is a useful tool in ship design. In particular, the RSTM, in conjunction with the cost-effective wall function approach, proved to be highly accurate. The accuracy of this prediction demonstrates that FLUENT can be relied upon not only for qualitative assessments of alternative hull designs but also for accurate prognoses of the flow and other quantities related to resistance and propulsion performance of ships.

Due to ongoing increases in computer speed and memory, RSTM should no longer be considered out of reach to engineers seeking the most accurate return from a RANS calculation of turbulent flow. This is especially true when the application of interest involves streamline curvature, vortices, and rotation, like the flow around a ship.

**References:**

1. Kim, S.E., "Reynolds Stress Transport Modeling of Turbulent Shear Flow Past a Modern Tanker Hull Form", Proceedings of Gothenburg 2000, A Workshop on Numerical Ship Hydrodynamics, Chalmers University of Technology, Gothenburg, Sweden, 2000.
2. Kim, W.J., Kim, D.H., and Van, S.H., "Calculation of Turbulent Flows around VLCC Hull Forms with Stern Frame Modification", Presented at the 7th Symposium on Numerical Ship Hydrodynamics, Nantes, France, July, 1999.
3. Van, S.H. et al., "Technology for Enhancing Resistance Performance of Ships", KRISO Report, November, 1998.



**Figure 3. Streamwise vortex shedding off the stern as predicted by FLUENT**