Complete propulsion system simulation with ReFRESCO

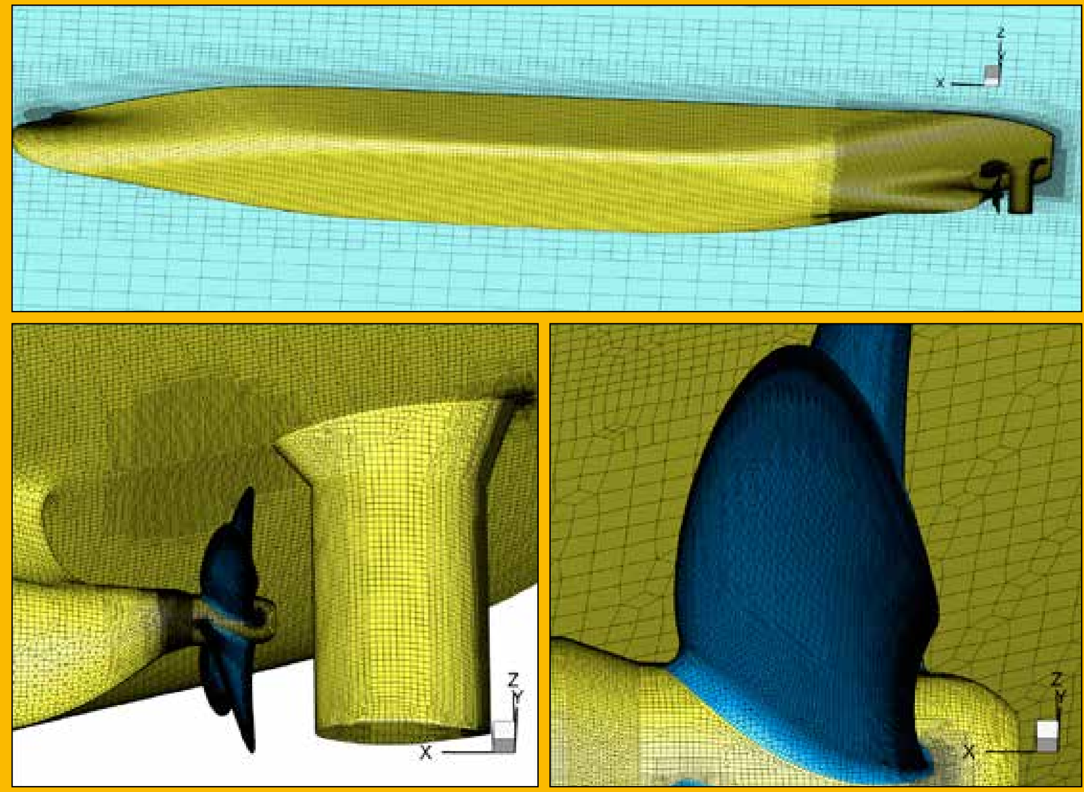

Figure 1: Streamline tanker geometry and grid layout

See also MARIN YouTube channel for the latest ReFRESCO CFD simulation movies.

Within the EU project STREAMLINE, the ReFRESCO team developed new techniques facilitating advanced simulations of the complete (ship-propeller-rudder) propulsion system. This article outlines this achievement and how the research work is already opening new doors.

Guilherme Vaz
g.vaz@marin.nl

In the framework of numerical simulations, analysis of the flow around a ship is usually done in several independent stages: ship resistance tests, propulsor analysis, seakeeping behaviour and manoeuvring tests. However, this obviously disregards the interaction between them. One relevant interaction that should be considered is the ship propulsion system (Figure 1 illustrates an example of a ship, propeller and rudder configuration).

Traditional approaches The traditional numerical approach for this propulsion problem has been to analyse the different components separately. This would involve examining the flow around the ship using steady viscous-flow RANS codes, extracting the wake field at the propeller plane, and analysing the propulsion characteristics of the propeller by using an unsteady potential-flow BEM code, together with the so-called "effective-wake" field (which has to be determined using simplified models). A more integrated approach is to directly couple the RANS and BEM codes. This RANS-BEM approach (also used at MARIN) has low CPU costs and for design purposes is a suitable choice. However, it is still a split approach based on potential-flow and modelling simplifications. The new numerical features facilitate an accurate analysis of this complex problem with no simplifications, by modelling less and simulating more.

Achievements ReFRESCO could already accurately predict the flow around open and ducted propellers in open-water configurations, at both model and full-scale, back in 2010 [1]. The prediction of the flow on a propeller in-behind conditions and the complete ship+propulsion system needed three major CFD-related developments: modelling rigid-body motions, non-conformal interfaces and sliding-interfaces. These developments have been accomplished within the European Union FP7 STREAMLINE project, where innovative marine propulsion concepts have been proposed, experimentally tested, and computed using newly developed tools. With the first feature we now have the possibility to simulate any kind of imposed motion in different reference systems and with the second we can simulate the quasi-steady interaction of objects having different imposed motions. In the third we consider the fully unsteady interaction of these different moving objects. Important numerical aspects such as boundary conditions, conservation properties close to these interfaces and parallelisation of the algorithms have been addressed.

For tackling the propulsion system problem MARIN can now fully simulate the translating ship+rudder system together with the rotating propeller, (see Figure 1), in one unsteady viscous-flow RANS calculation. The calculation costs increase significantly: from hours with a RANS-BEM approach to days for a full RANS approach in a modern HPC cluster. Nevertheless, the amount of information and correct interaction effects that can be simulated are also considerable. Figure 2 shows the flow (velocity, pressure field and limiting streamlines) around the stern and close aft of the propeller before the rudder location. The influence of the propeller load on the hull flow and of the propeller slipstream on the rudder flow (and the opposite effects) are captured here without simplifications. The analysis of these complex phenomena is now possible.

New possibilities The new ReFRESCO Code makes the unified simulation of translating and/or rotating systems in one grid/calculation possible. This is relevant not only for the propulsion system situation illustrated here but also for thrusters and DP systems, roll-damping simulations, offshore VIV/VIM problems, manoeuvring ships, passing ships, active rudders and fins etc. In the near future MARIN envisages self-propulsion numerical tests for ship propulsion using ReFRESCO.

1. D. Rijpkema and G. Vaz, "Viscous Flow Computations on Propulsors: Verification, Validation and Scale Effects". In Proceedings of RINA-CFD2011, London, UK, March 2011.

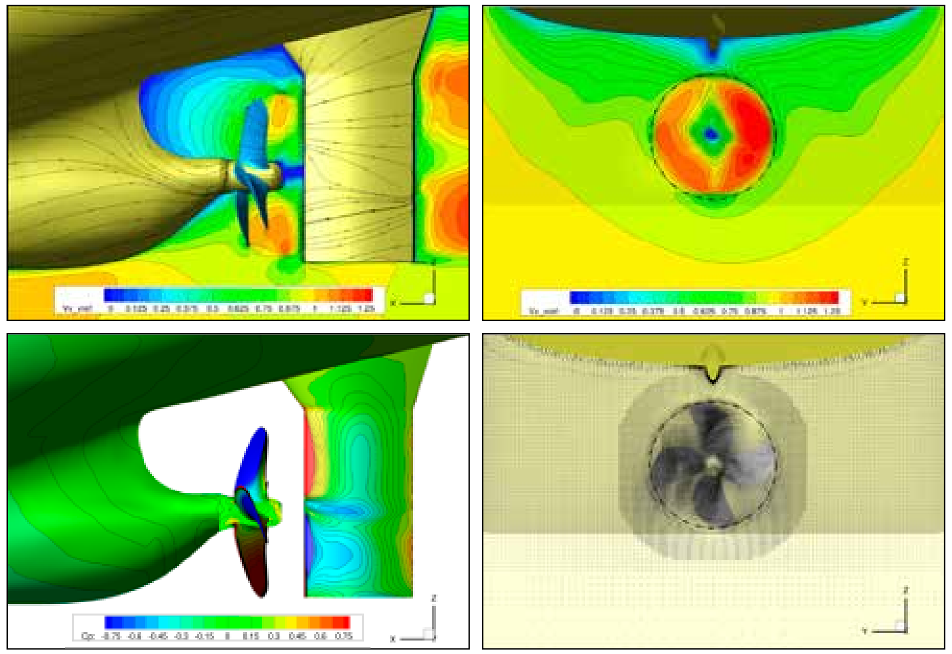

Figure 2: (left) Pressure field and limiting streamlines at stern region. (right) Axial and tangential velocity field at a station between the propeller and rudder.