Optimisation of Energy Saving Devices using SHIPFLOW

Ship based CO_2 emissions have been of increasing concern for many years. Emissions are projected to grow despite market driven efficiency improvements which caused the International Maritime Organization (IMO) to develop measures to reduce the emissions within an agreed timetable.

The Energy Efficiency Design Indexing (EEDI) shall be adopted for the initial design phase of new ships. This leads to greater demands for ship designers to develop more energy efficient hull and propulsion systems. SHIPFLOW can provide the designer with valuable tools for a better understanding and evaluation of the ship design alternatives. In addition to newbuildings requiring optimisation there is also great demand for retrofitting existing ships. In some cases it is to improve their efficiency and in other situations to improve their operational characteristics.

One distinguishing feature of SHIPFLOW is its specialisation for ship design. It provides automatic grid generation and configuration of the flow solvers. Besides the direct advantages for the users it also makes it well suited for integration with CAD/CAM and optimisation software - a key factor when it comes to reducing the lead time of design projects. The SHIPFLOW FRIENDSHIP Design Package is an integration of the CFD software SHIPFLOW and the computer aided engineering (CAE) software FRIENDSHIP-Framework. The software is tightly coupled which means that the user can configure, run and post-process the SHIPFLOW grid generators and flow solvers directly from the FRIENDSHIP-Framework. The automatic grid generation capabilities will be inherited and allows a full utilisation of the optimisation capabilities in the FRIENDSHIP-Framework. The ship can be defined using both fully and partial parametric modelling. In the first case the ship can be defined by key parameters such as ship dimensions, volume entrance angles. The latter case uses a conventional hull definition as the base and only the changes are parametised.

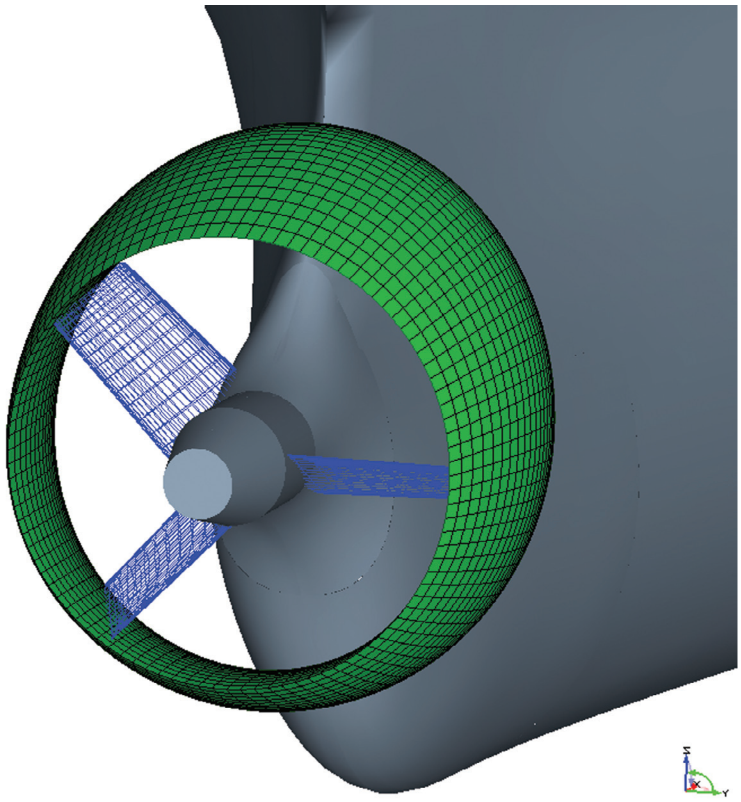


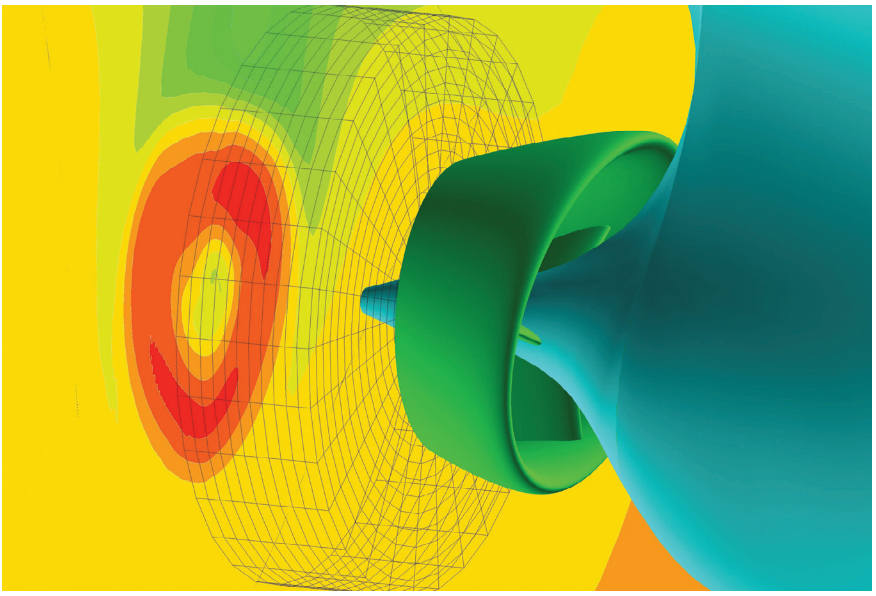
Figure 1: Surface grids for duct and fins.

Variants of the ship are easily generated and the technique is well suited for shape optimisation. The designer can control the variants by defining form parameter, constraint and dependencies. Systematic variations or automatic optimisation can then be applied to search for the best design. The tight integration provides a unified graphical user interface for the configuration, running the simulation and managing the variants.

As a standard, SHIPFLOW Design is provided to customers purchasing only SHIPFLOW. SHIPFLOW Design is a subset of the FRIENDSHIP-Framework and provides a graphical user interface and variant managements to the CFD solver. However, it does not contain the parametisation capabilities and optimisation tools that the full FRIENDSHIP-Framework does.

The overlapping grid capability in SHIPFLOW is suitable for appendage optimisation. An advantage with overlapping grids is that only the interpolations between the grid components, not the grids, needs to be updated when the appendages are repositioned. SHIPFLOW comes with parametised appendage objects that can be used directly or combined into more complex appendages. Alternatively, appendages can be modelled in Framework. Surface grids can then be

Figure 2: Self-propulsion simulation. Propeller grid, velocity contours in a transverse plane aft of propeller plane.



generated and exported to SHIPFLOW that creates volume grids around the appendages. Shape and position can be varied without losing the automatic grid generation.

The full potential of the CFD solution is illustrated with an example of an Energy Saving Device (ESD). SHIPFLOW has been successfully applied to various projects involving the optimisation of ESD's in the past few years. A case study based on a well known VLCC tanker appended with a generic ducted three bladed pre-swirl stator is outlined below, though due to strict confidentiality rules we cannot name the vessel.

The computational configuration includes a background grid and several overlapping component grids. The background grid constituting the main computational domain discretises the volume surrounding the bare hull surface. The non-axisymmetric converging duct has both varying chord and local angle of attack and it's component grid is based on a surface mesh created with the Framework (see Figure 1), and the hyperbolic grid generator available in SHIPFLOW's RANS solver. The fins are generated with a wing component (rudder object) which is built into the solver. All parts can be parametised which greatly simplifies optimisation tasks. The size, shape and positioning of the device, therefore, can be controlled by the optimiser using design variables.

Due to an extreme complexity of the flow propeller efficiency, the ship performance cannot be evaluated easily even by a very experienced designer based on the wake field and resistance components. This is why many of our users utilise self-propulsion numerical simulations using SHIPFLOW, ranking alternatives with the overall performance expressed as the delivered power for the specified ship speed. The computations are, therefore, performed with a working propeller modelled with a lifting line method inbuilt in the CFD code or an external propeller model linked to SHIPFLOW. The propeller forces are transferred to the computational domain via an additional embedded cylindrical grid, Figure 2. The propeller model rpm is adjusted during the computations to balance the total ship resistance. The flow field is illustrated in Figures 2 and 3 where the axial velocity contours are shown at a transverse plane behind the propeller and a longitudinal plane close to the ship's centre plane. The pre-swirl stator (PSS) creates more rotational flow especially to the port side by directing the flow downwards equalising the tangential velocities components at the propeller plane. As a result the rotational energy loss is reduced increasing the propulsion efficiency.

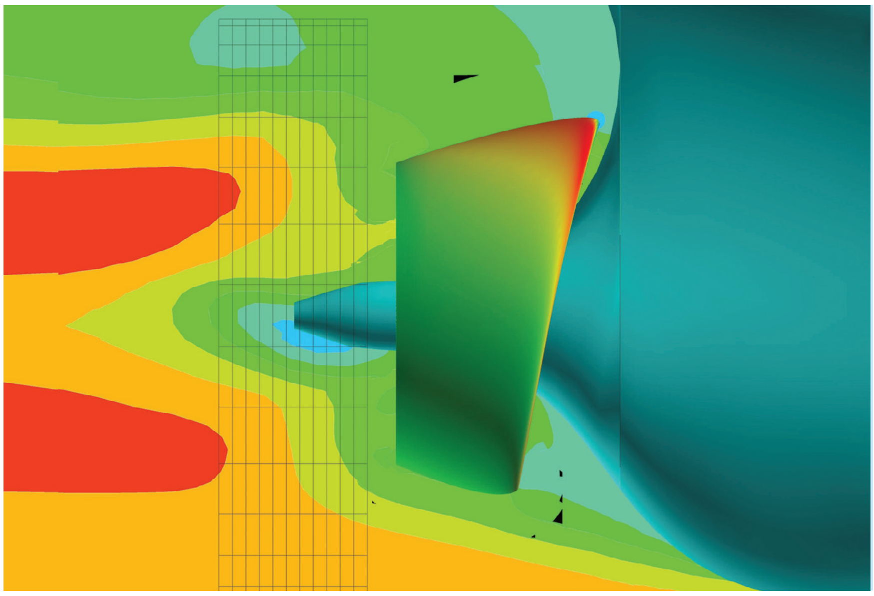


Figure 3: Self-propulsion simulation. Propeller grid, velocity contours in a longitudinal plane, dynamic pressure coefficient on the duct surface.

A well optimised PSS shows gains of more than 5% in performance, reducing both emissions and fuel costs. SHIPFLOW validation to towing tank results agree with measurements proving SHIPFLOWs potential in optimising complex appendages in self-propulsion mode. An additional advantage of the system is that many designs and unusual configurations can be evaluated with ease with no risk of costly model tests. *NA*