Improved hull optimisation using PARNASSOS Explorer

MARIN's in-house RANS optimisation tool PARNASSOS Explorer is helping the industry discover more about the optimal hull form in order to improve performance and save energy.

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Today, CFD-based optimisation procedures are used more and more in practical ship design projects. For many years potential flow solvers have been used routinely to optimise the front part of ships in order to minimise wave resistance for example. For the aft ship, however, where the flow is often dominated by viscous effects, viscous flow solvers have to be used.

Nowadays, it is not unusual in ship design to analyse the results of a limited number of computations, and derive recommendations on hull form changes from that. However, more quantifiable improvements can be obtained by automatic optimisation procedures based on a series of CFD computations with different hull forms. This makes it possible to study any trends that are present. This is one reason MARIN decided to develop the in-house RANS optimisation tool PARNASSOS Explorer (Van der Ploeg and Raven (2010)). Multi-objective optimisation at full-scale Reynolds numbers can be performed, in which the required power to sustain a given ship speed is minimised and the quality of the inflow to the propeller is optimised by minimising the variation of the angle of attack on the propeller. The GMS-Merge tool is used, which varies hull forms by a special interpolation between some predefined basis hull form variants. And here MARIN's decades of experience is a big advantage because it can add new basis hull forms into the process.

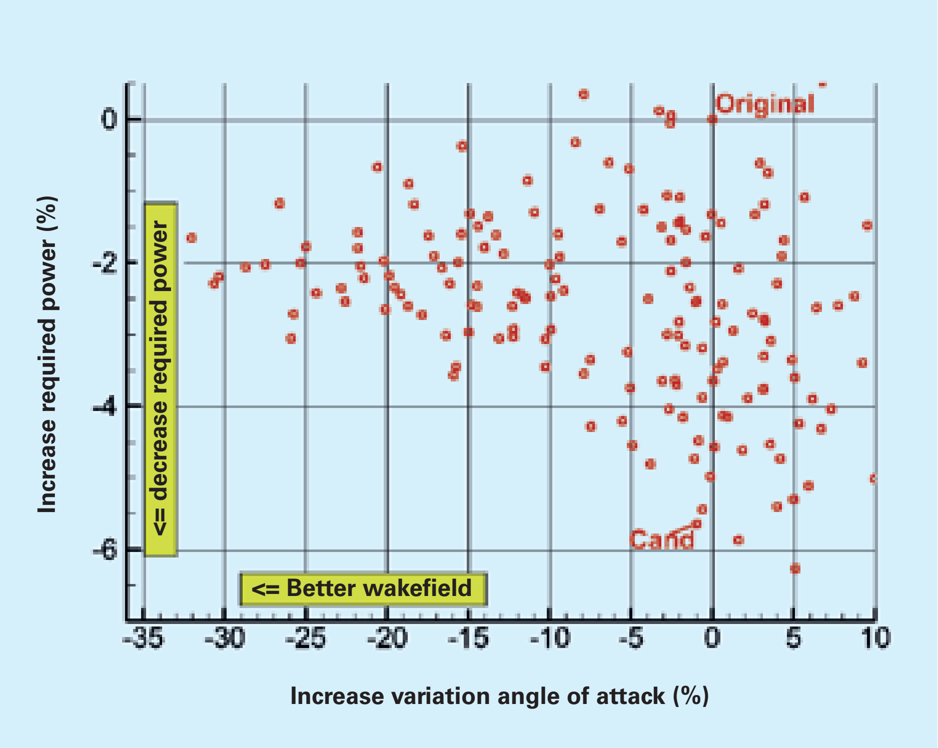

Figure 1. Pareto front obtained with full-scale RANS/FS computations

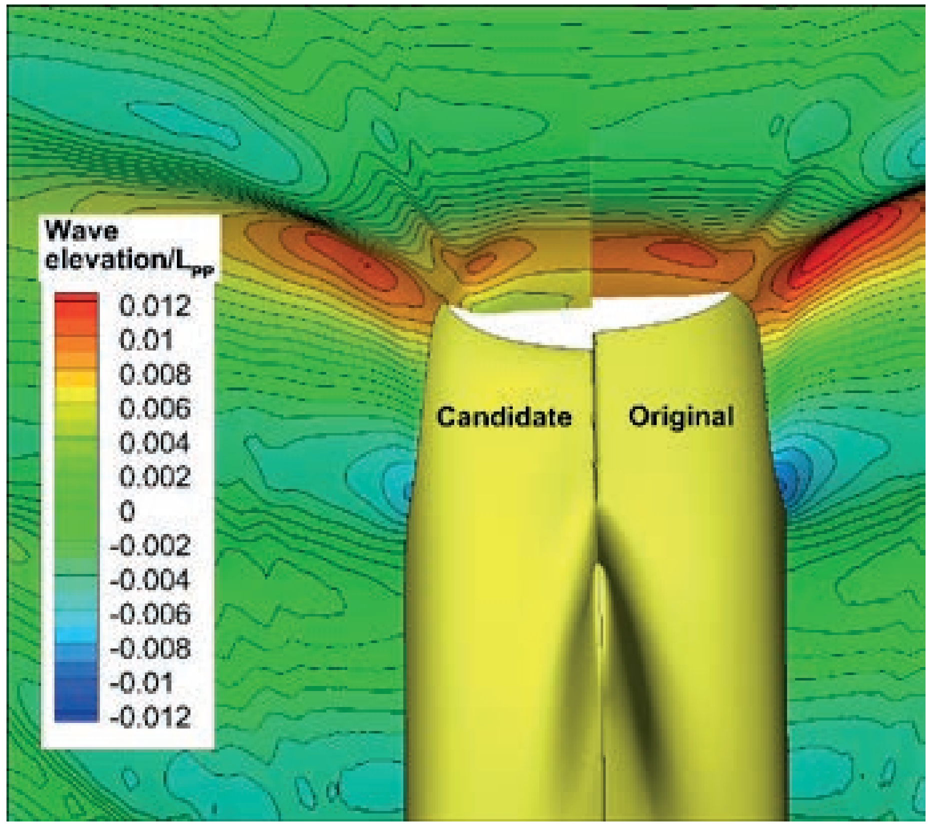

Figure 2. Stern wave systems of the candidate and original vessel

Bare hull In essence, PARNASSOS calculates the viscous flow around the bare hull. The estimate of the required power requires not only the nominal resistance, but also the thrust deduction fraction and the achievable performance of the propeller. It is essential to estimate the latter, as this may vary significantly between design variations. Propulsive performance could be evaluated by a coupling with a propeller code or by incorporating the propeller in the RANS computation. In these cases only one propeller design would be used in order to minimise the parameter space and computational effort. This would mean the hull form is optimised for this particular propeller only, instead of optimising the combination of the optimum hull with the optimum propeller design. In order to improve the estimate of the achievable performance, the open water efficiency obtained from the optimum B-series propeller selection for a given resistance and corrected for thrust deduction is used. The thrust deduction fraction and thrust T required for self-propulsion can be estimated from the resistances computed without propeller thrust and with a fixed imposed thrust T_0, which is reasonably near T at self propulsion.

Techniques extended Recently, PARNASSOS Explorer techniques have been extended with the possibility of taking the ship's wave making into account. This shows how modifications of the hull form near the water line influence wave resistance, propeller inflow and required power. MARIN demonstrated this in a first systematic variation of the aft part of a single screw chemical tanker, which is one of the test cases used in the 7th Framework EU project STREAMLINE. The design space was set up with six distinct hull shapes verifying the gondola, frame or V-type frames, transom width and buttocks slope. Figure 1 shows the required power relative to the initial hull form on the vertical axis and the quality of the wake on the horizontal axis. Each point gives the computed values for one hull form variation. There is an envelope, a 'Pareto front', indicating the best that can be achieved. A compromise between both objectives is clearly required. The candidate hull form has a deeper transom immersion, a reduced waterline curvature near the transom and a more slender gondola. The reduced waterline curvature and higher transom immersion result in a less pronounced stern wave system (Figure 2).
These results show that even a first systematic variation with only a limited number of hull-form evaluations already results in a significant decrease in required power (5.8%), without a decrease in the quality of the inflow to the propeller. Based on the insight obtained, the design space can be extended, leading to a sharper Pareto front and more detailed knowledge about the optimal hull-propeller combination. ¬

References

Ploeg A. van der and Raven H.C. (2010), "CFD-based Optimization for Minimal Power and Wake Field Quality", Proceedings 11th International Symposium on Practical Design of Ships and other Floating Structures, Rio de Janeiro, pp. 92-101.