

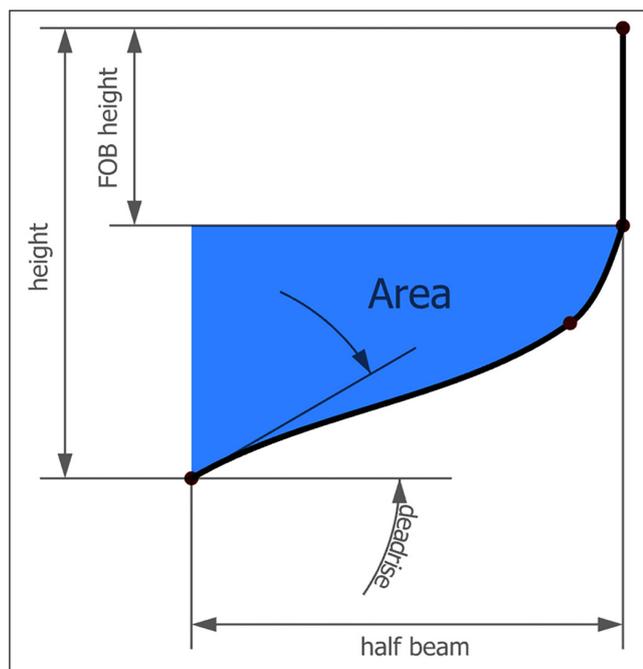
Application of CAESES and NavCad for optimisation of ship hulls

HydroComp and Friendship Systems have recently presented a hull design workflow that includes their respective tools, NavCad and CAESES

The advantage of pairing NavCad and CAESES in a design workflow lies in the ability to rapidly optimise the geometrical properties of the vessel in question, based on the performance feedback provided by NavCad, especially in early stages of the overall design process.

Within this performance-driven design process, CAESES fulfils two roles: generating geometry variants based on selected parameter combinations, and providing the necessary functionality for process automation. The former includes different strategies for the efficient and, most importantly, robust variation of complex, free-formed geometries as they are encountered in ship hulls. The latter comprises systematic variation and optimisation algorithms, coupling to and execution of external tools, as well as management and assessment of the large amount of data that is typically generated in such an automated design study. In cases where the time for setting up the study is limited, morphing techniques can be applied to an existing, imported hull shape. While this approach is very fast, it allows for somewhat less direct control over the hull's properties and constraints.

The alternative approach is to set up a fully parameterised model of the hull from scratch in CAESES. CAESES' powerful surface parameterisation technology – where a parameterised cross-section, e.g., a frame or waterline, is swept in a specified direction either longitudinally or vertically, and function curves control how the cross-section parameters, such as waterline beam, deadrise angle or sectional area, change during the sweep – allows for a highly flexible, yet very efficient, parametric description of the hull lines. The number of free variables is kept low, especially in comparison to control point based modelling approaches, which is advantageous for a speedy optimisation. Obviously, in comparison to the previous, this approach requires more time, but brings along the advantage that properties of the hull form can be addressed in a very direct and precise



Example of parametric variation

way, and that constraints, such as hydrostatic properties or internal arrangements, are easy to fulfil by the generated hull variants.

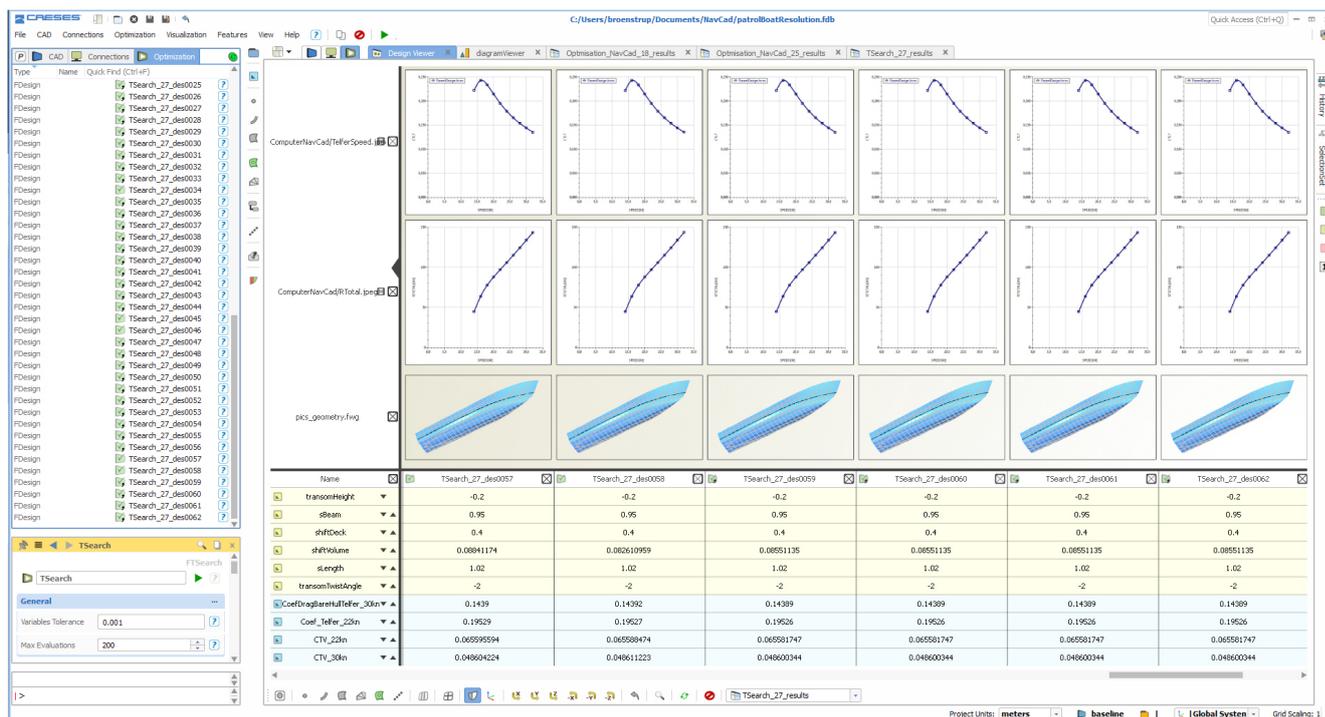
NavCad's role in the design process is to provide a performance feedback for each CAESES design iteration, by performing an operational hydrodynamic and propulsion system simulation. A physics-based framework for the Hull-Propulsor-Drive-Engine system is the foundation of the simulation. NavCad offers a variety of 1D and 2D component prediction models that connect to the system for a broad range of hulls and propulsors. It is the 2D ADVN hull resistance method in NavCad Premium that is employed for this study, which will be coupled to a waterjet propulsor model for a complete system simulation.

Workflow in practice

This workflow shall be demonstrated here on the example of a waterjet-driven patrol boat, which had failed to reach the target speed of 26knots promised in the tender (an initial speed prediction by the designer

indicated barely 23knots.) The vessel has a round-bilge hull with an immersed transom stern. Length overall is 29m and beam overall 6.8m. The design targets that were set going into the process were to find the best hull form with regard to resistance, find the best hull-waterjet-engine configuration and, finally, reach the target speed of 26knots.

Since a parent hull form already existed, a morphing approach on the imported hull form was used. Several different morphings or transformations were set up to allow changing of the length, beam, transom immersion, transom deadrise, deck and waterline shape, as well as the volume distribution in a longitudinal direction. While the geometry for each variant can be exported in several generic formats (like IGES, STEP, or STL), a special input script is used for NavCad that contains the computation settings and the geometric particulars of the vessel. Apart from the main dimensions, this comprises values for waterline beam, sectional area, and sectional area centroid at a certain amount of longitudinal positions.



Example of CAESSES workspace for evaluation of optimised variants

To seamlessly transfer this input to NavCad, a custom export was written in CAESSES that automatically extracts all necessary values from a given geometry and generates the script file. Finally, NavCad is tightly-coupled in the automated process workflow through the interface available in CAESSES for the connection of external tools. This interface allows a user to specify and prepare all the necessary input for the external tool, as well as the results that are loaded into CAESSES after the computation for the evaluation of the variant.

Prior to initiating the optimisation session, it is typically necessary to setup a NavCad project to define static data (such as appendages or environmental data), as well as analysis and prediction settings. This was prepared within the NavCad Premium GUI using its recommended standard settings, but could include user-defined custom options. Data for the parent hull from the study was entered into NavCad to allow its “Method Expert” utility to evaluate the suitability of the selected component models for the proposed speed and principal hull characteristics.

The optimisation process

The six aforementioned design variables with suitable bounds defined the design space for the optimisation process. The objectives were

the resistance values at 22 and 30knots and constraints were put on the displacement and the center of buoyancy, allowing only small changes for these properties. Various approaches can be taken within CAESSES to drive formal optimisation processes. For the patrol boat a combination of Design-of-Experiments (DoE) and a deterministic search strategy was selected. Firstly, a DoE with 500 designs was undertaken to explore the design space and to identify favorable parameter combinations. Secondly, several local optimisations using a deterministic pattern search were run to fine-tune the hull form further.

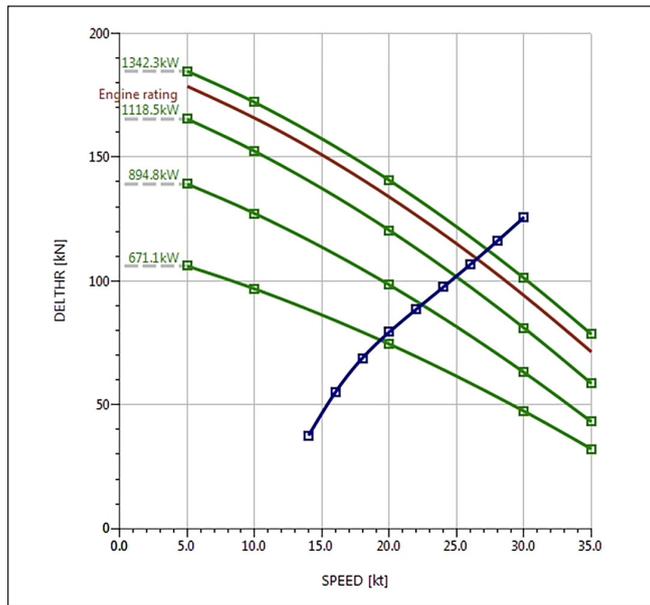
The results of the preliminary design space exploration helped to recognise the sensitivity of the objectives to the individual design parameters. While some of them showed a strong influence on the resistance, like the transom immersion and deadrise, some only had a negligible influence, such as the shape of the deck and design waterline. The final optimisation results recommended a new hull geometry with a slightly more slender hull, LCB shifted aft, greater immersed transom area, and a narrower entrance angle. Evaluation of the resistance over the complete speed range showed a tangible reduction throughout and a first indication that the

modified hull shape would be able to meet the speed objective.

Following this step, a study was run in NavCad to select a suitable waterjet for the vessel. The waterjet component model in NavCad has the ability to accept manufacturer product-model performance data, and to utilize this in novel ways. It integrates the nozzle-inlet Speed-Thrust-Power data with impeller Power-RPM data to predict proper speed-power-RPM relationships for engine load, as well as to expose propulsor efficiency from the data. This is particularly important for successful product selection, as a waterjet’s propulsor efficiency across the speed range is generally embedded in the data and not expressly published.

Significant savings

The CAESSES-NavCad optimised hull form with a proper waterjet increased the operational speed from approximately 23.0knots to 26.5knots – meeting the design objectives without installation of a larger engine. The original parent hull with its specified high-speed waterjet would have needed an engine of some 10% to 15% more power to meet the design speed. Of course, this translates into a comparable increase in fuel consumption – without further



NavCad's presentation of equilibrium-thrust waterjet component performance

of \$100,000, can be scaled proportionally to a cost of approximately \$120,000. So, for the pair of engines needed the client receives a saving of capital expenses of at least \$40,000. Operational expenses are even larger. The fuel consumption predicted in the NavCad analyses for a mean cruising speed of 20knots is 252 l/h per engine for the parent hull and 185 for the proposed hull. Given a representative operating demand of 500 hours-per-year for a patrol craft at an average cost of marine diesel fuel of ~\$1.05 per litre, an estimate of the savings of operating cost with the proposed hull and waterjet will be \$72,000 per year.

Ultimately, this study demonstrates how a highly automated and tightly-coupled pairing of CAESES and NavCad can provide a very cost-effective and time-efficient solution for any naval architectural office. This pairing is a powerful instrument for finding improvements in hull form and propulsion components at any stage in a design. **NA**

considering the heavier displacement due to a larger engine. Naturally, the initial capital expense would also be greater with a

larger engine. The original expectation by the client was to install an engine some 20% larger, which, assuming an initial engine cost

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In general there is a growing need in the maritime world for ship performance analysis on full scale. This has several reasons related to either cost saving, legislation and environmental concerns.

With the introduction of the IMO Energy Efficiency Design Index (EEDI) the need for ship full scale performance measurement and verifications has grown in importance. There are now new ISO standards for initial ship trials to verify the EEDI calculations. ISO 19030 standard consolidates the latest academic and industry knowledge regarding a standardised method to measure the performance of a vessel through the water. IMO and EU require vessels to monitor their efficiency in terms of fuel consumption and distance travelled (EU MRV starts 1st January and the IMO system 1st January 2019). It is expected that the data collected will help inform future EEDI regulations.

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