Democratising propeller design

A new propeller design tool aims to be more inclusive of naval architects, empowering them with greater investigative capabilities

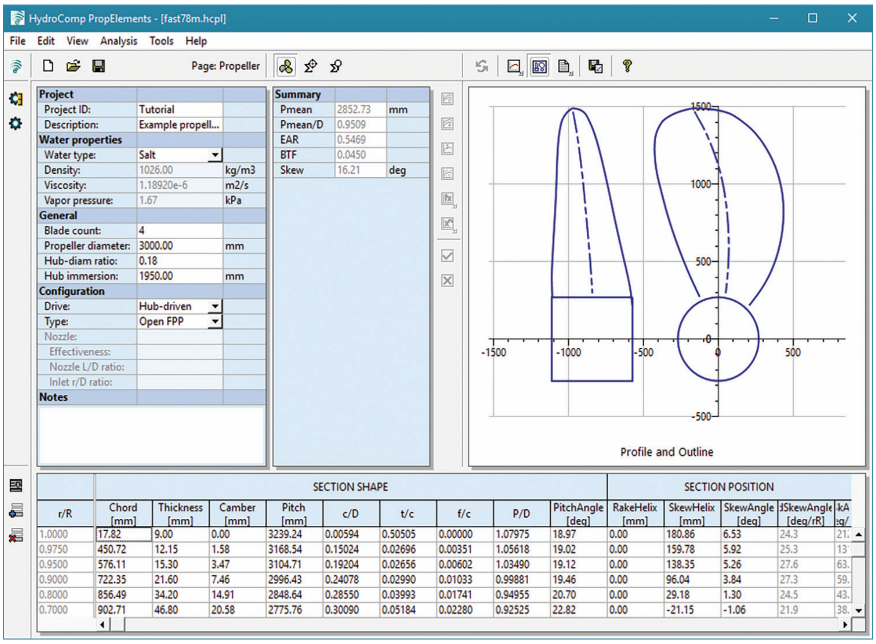
HydroComp, a US-based company specialising in predictive software for naval architects and shipbuilders, has substantially re-tooled its PropElements software to make it easier for naval architects and specialists alike to investigate propeller iterations at later design stages.

PropElements is used for wake-adapted propeller design and possesses a unique, distributed blade foil code with empirical connections at its core for viscous and full-scalable analyses. Donald MacPherson, technical director at HydroComp explains that the latest major update is a response to the identification of two issues: a disconnect in the design process and demand for a predictive tool that can handle custom and semi-custom propeller analysis.

Naval architects have historically dissociated themselves from propeller design, says MacPherson, allowing specialists and manufacturers to take the reins following the identification of principal propeller parameters (diameter, pitch, blade area, number of blades etc.) and the occasional assessment of certain performance details, such as hydroacoustics. This can be quite limiting for naval architects, he continues, as it distances them from a crucial part of the ship system, i.e. the propeller as a component piece of a wider hydro-efficient system. By improving the investigative tools available to naval architects, they will be able to explore more iterations that are also a better fit for each vessel's operational profile.

PropElements 2017 aims to do just this, providing a means to discover system improvements over component improvements. "A basic propeller doesn't necessarily improve by more than few percent", points out MacPherson, but big gains can be found with improvements in the system as a whole. Naval architects rely on an accurate system perspective, MacPherson emphasises, and this tool will aid them to assess "what am I giving up [with each iteration] and does this proposal make sense from the noise and vibration issue?"

Crucially, "naval architects can become a meaningful participant in the design and analysis of these contemporary propellers at later design stages," according to the software company. "For example, they can employ PropElements to conduct studies of alternatives prior to development of the final design, as well as to confirm and check these designs."



A propeller outline in PropElements

MacPherson says the rising popularity of custom or semi-custom propellers is necessitating a more intricate analysis of wake-adapted propellers by naval architects, as these kinds of propellers are designed using contemporary foil geometries and are optimised and fitted to individual vessels. The traditional propeller models and studies, methods naval architects have relied on for some time, are consequently less than ideal for predicting how these unique propellers will perform. However, it must be said that there is still some preoccupation with the risk involved in computational methods, similarly in respect of modelling new propeller types.

How it works

In wake-adapted propeller design, a custom propeller is optimally matched to the unique inflow properties of the vessel or its wake field. PropElements is able to consider axial and tangential inflow properties, and to ascertain optimised distributions of pitch and camber for prescribed foil characteristics. The design process takes blade strength, tip and hub loading, and cavitation into account, and calculation pages include propeller, performance and strength; supplemental calculations are available for the creation of KT-KQ curves.

PropElements can also be used for analysis and the forensic investigation of blade failure. The ability to investigate radial values of foil lift and cavitation number can help to identify potential sources of root cavitation or blade impulse excitation, while the ability to evaluate tip loading can be used to understand hydroacoustics – a topic of increased interest as shown by the Port Of Vancouver's move to provide discounts to validated 'quiet ships' in port.

To clarify, these capabilities are already available to those who need them, i.e. specialists and manufacturers, explains MacPherson, but this update can cater to a different audience that hasn't known it can be invested in the later stages of wake-adapted propeller designs.

In order to bring this audience onboard, the company has taken an interesting approach that sits between simple and advanced computations. To put this in perspective, MacPherson describes where the new approach lies in relation to three categories: 1D, 2D and 3D.

A 3D approach is the most advanced, using real geometry that has empirically based 3D analysis from a towing tank or higher order CFD to observe the full 3D geometry of a ship propulsor system. The drawback is that both 3D approaches are time consuming and expensive.

Compare this to a 1D approach, which can be achieved using HydroComp's NavCad software (a tool for the prediction and analysis of vessel speed and power performance). It involves representing a ship by parameters and using statistical methods to predict performance. Obviously this is very quick and immediately accessible – the technique principally being used to date – but it also has limitations. For example, modelling propellers and hulls in this way lacks detail, which ultimately means that the models presented are not really characteristic of the shapes involved.

PropElements' 2D approach, on the other hand, is positioned in a flexible relationship with 1D and 3D approaches, explains MacPherson. It offers an intermediate level of analysis of propellers, with a more detailed definition of the propeller than a 1D approach. This means "it is not limited to the standard propeller types found in 1D calculations and [instead] allows for better definition of the radial nature of the hull-propulsor interaction," says MacPherson.

Speed is a further benefit. "A calculation in PropElements using a standard business-grade computer is on the order of 1/100-th of the calculation time of a comparable CFD calculation on a high-performance cluster," says MacPherson. "This allows for rapid initial convergence of an analysis when conducted with PropElements' 'reduced order' calculations, making the application of CFD much more effective because you are closer to the final answer when you 'flip the switch' on CFD."

The tool can also be used to set the table for CFD calculations in a 3D approach, creating a benchmark to ensure the right CFD studies are being investigated. According to MacPherson, 100s of options can be investigated by PropElements, which helps to map out the design space for a more refined CFD search if necessary. "In short, it can evaluate a propeller or walk a design much closer to 3D CFD with the cost and user requirements of a 1D calculation," says Macpherson. "In many cases, the PropElements 2D solution provides enough fidelity that a 3D CFD calculation may be unnecessary for anything other than a single validation run (and even this may not be needed)."

Conclusion

Users have the capability to understand velocities, blade loads, cavitation levels and hydroacoustic levels with the 2D approach. Once complete, the PropElements 2D component calculations can be reconnected with NavCad's system analysis, which provides a higher fidelity model of the propeller's performance for NavCad's "whole ship" calculations.

MacPherson concludes: "Once you run CFD or conduct model testing, many of the important decisions are already locked in. By incorporating a 2D propeller calculation at the system design level, naval architects can take control of their own destiny and achieve better and more cost-effective outcomes." *NA*