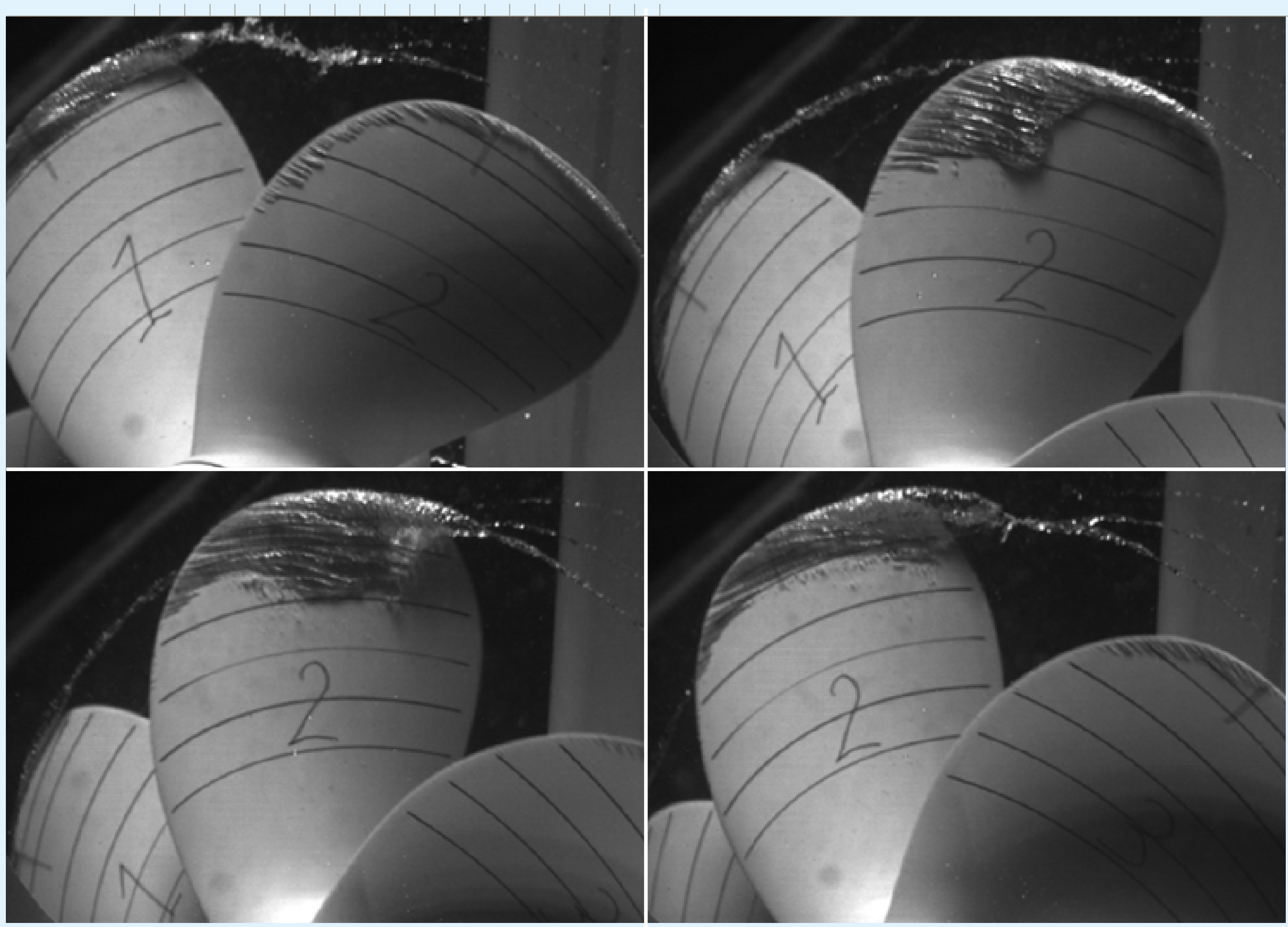

High-speed video footage of propeller cavitation

MARIN assists in the design of naval propellers

Independent evaluation of the hydrodynamic performance of ship propellers is a very popular MARIN service. With essential feedback from customers like the Royal Netherlands Navy, steady advances are being made in model testing techniques and computational methods that predict key characteristics of naval propellers. Multi-objective optimisation techniques allow propeller designers to define design trade-off studies and in turn, end-users can sharpen their design specifications.

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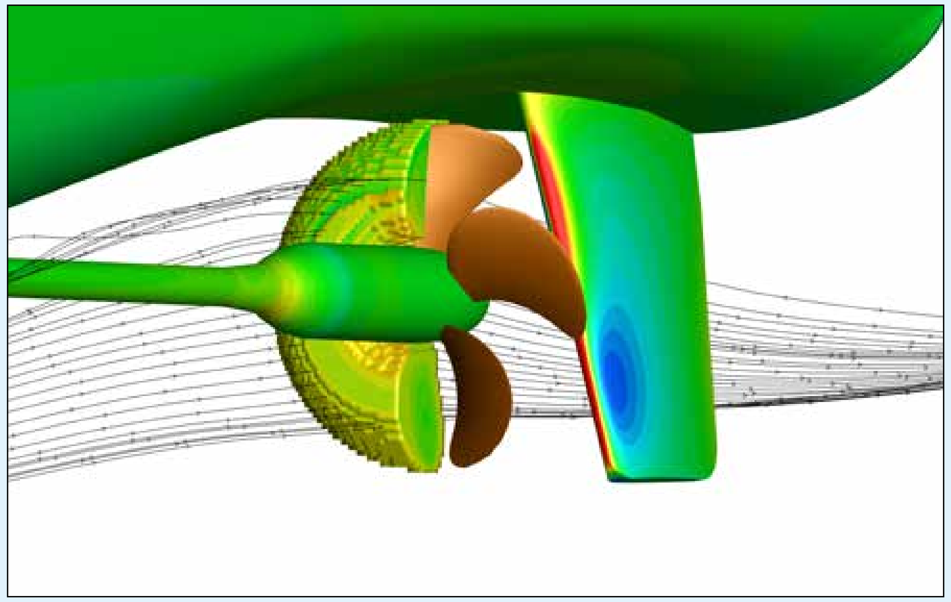
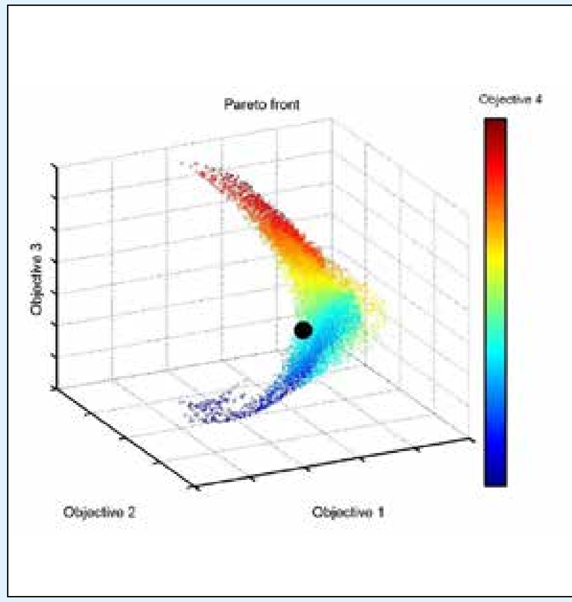


RANS-BEM coupling with propeller modelled by body forces



4D Pareto front of optimum propeller designs with arbitrary objectives

Propeller design is about making the right compromises. Many qualities and circumstances define a successful propeller design. Obviously, propellers should work well in combination with the ship's engine and stay intact during operations. Good fuel economy and the absence of cavitation related vibration and erosion issues are the key conflicting objectives that are considered in propeller designs. For naval ships, but also for other ship types such as research vessels, the limitation of underwater noise in operational conditions can be an important objective.

MARIN assists with independent propeller design evaluations and explores design trade-offs that allow naval customers to improve their design specifications. A key focus is the continuous improvement of the required numerical as well as experimental tools and methods.

Experimental evaluation Cavitation tests on naval propellers are typically carried out in the Depressurised Wave Basin (DWB). Cavitation inception characteristics and the underwater radiated noise of cavitating propellers are typical subjects of investigation. Today, high-speed cameras are the standard instrument used to record propeller cavitation. The dynamic behaviour of different types of cavitation can be followed closely and assessed for erosion risk. The DWB is also equipped with a state-of-the-art, silent towing carriage built for very low background noise levels.

Computational evaluation For its day-to-day propeller designs and evaluations, MARIN employs Boundary Element Method (BEM) code PROCAL, which was developed by the Cooperative Research Ships (CRS) consortium. Practical methods like the Empirical cavitating Tip Vortex (ETV) method are used to predict broadband hull pressure fluctuations and underwater radiated noise due to cavitating tip vortices. Additionally, the hybrid combination of PROCAL and CFD code ReFRESCO is often used to compute the full-scale effective wake fields of ships.

Optimisation and trade-offs Questions are often raised about how much the design requirements have impacted the propeller design. For instance, how much efficiency has been sacrificed to achieve acceptable noise and vibration levels? Things get very complicated for designers when an optimum propeller has to be designed and a large number of objectives and constraints have to be taken into account. A low level of the pressure fluctuations or underwater noise levels can be specified for a range of operational conditions, perhaps with challenging limits to the weight of the propeller, its strength etc. An optimisation of the propeller design defined by tens or even hundreds of parameters with regards to multiple objectives and constraints potentially requires an enormous amount of numerical design evaluations.

With the advent of distributed computing and cluster computers, however, it becomes possible to significantly increase the number of design evaluations. Then it becomes attractive to exploit the possibilities of advanced optimisation algorithms.

A very useful way to present ranges of propeller designs is the so-called Pareto front representation. For each design on the Pareto front no further improvement of an objective is possible without another objective being negatively affected. In a multi-objective optimisation problem the Pareto front defines all solutions from which the designer can select the most appropriate design solution for the specified objectives. Simultaneously it provides information to quantify the trade-off between the conflicting objectives and the influence of the constraints. An example of a 4D Pareto front for four design objectives is shown.

With these techniques, the traditional experience-based design process, with many manual design iterations, can be assisted by automated parameter explorations. They provide designers with a clear overview and highlight possible design trade-offs to clients in and outside the naval domain.