University of Genoa

Department of Electrical, Electronic, Telecommunications Engineering and Naval Architecture

Design by Optimization of a Controllable Pitch Marine Propeller

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Ship oriented Innovative soLutions to rEduce Noise and Vibrations

SILENV

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Background

The propeller design is an activity which nowadays presents ever increasing challenges to the designer, involving not only the usual mechanical characteristics fulfillment (with maximum efficiency) and cavitation erosion avoidance, but also other cavitation side effects, such as radiated noise and/or pressure pulses. This is evident with the ever increasing demand for improvement of comfort onboard and concerns about radiated noise problems, especially in proximity of protected areas or for Navy ships. Moreover, in some cases propeller characteristics have to be optimized in correspondence to multiple very different functioning points (i.e. different ship speeds, propeller pitches...) including considerably off-design conditions, hardly captured by conventional design methods, still widely based on lifting line/surface approaches. Such designs, with a traditional approach, would have been addressed in an intermediate condition, leading to a geometry which is not optimal for any of the required settings.

In this work, a «design by optimization», based on the coupling between a multiobjective optimization algorithm and a panel code (certainly more accurate and reliable with respect to traditional design tools but inherently not directly applicable for the design itself), is applied for the design of a Controllable Pitch (CP) propeller at different pitch settings, with the aim of reducing the cavitating phenomena and, consequently, the resultant radiated noise. Only through optimization, as a matter of fact, it is possible to take advantage of the panel method features in an «automated and iterative» procedure and to look for a final design that correctly balance the performances at the different working conditions on the basis of the objectives and of the constraints required for the design itself.

Particular attention has been devoted to the slow speed (low pitch) condition, obtained at constant RPM, and characterized by considerable radiated noise and vibrations related to face cavitation. Numerical results are validated by means of an experimental campaign, testing both the original and the optimized geometry in terms of propeller performances (delivered thrust and efficiency), cavitation extent and radiated noise. Experimental results confirm the numerical predictions, proving the capability of the method to assess the propeller functioning characteristics and the effectiveness of the proposed design procedure in correspondence of challenging problems.

Objectives

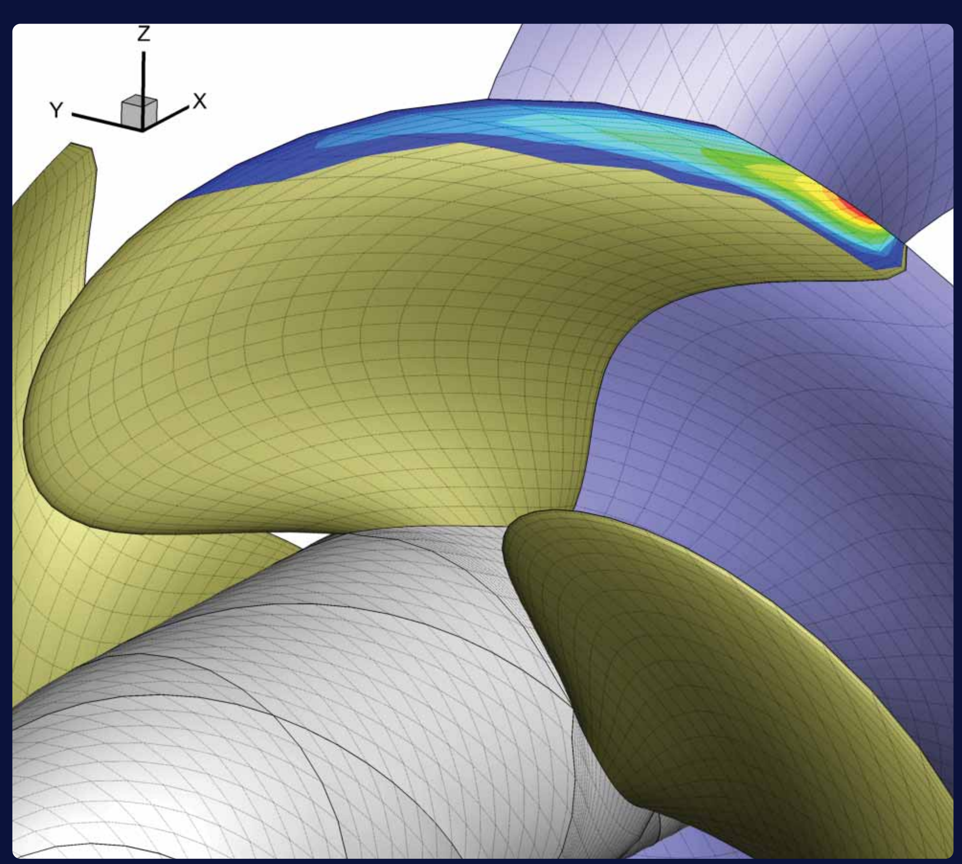
Design a propeller that delivers the same thrust (both at the design and at the reduced pitch working points) in order to:

1. Reduce back cavitation at the design pitch,
2. Reduce face cavitation at the reduced pitch,
3. Avoid back cavitation at the reduced pitch,
4. Avoid face cavitation at the design pitch,
5. Increase the efficiency (both pitches).

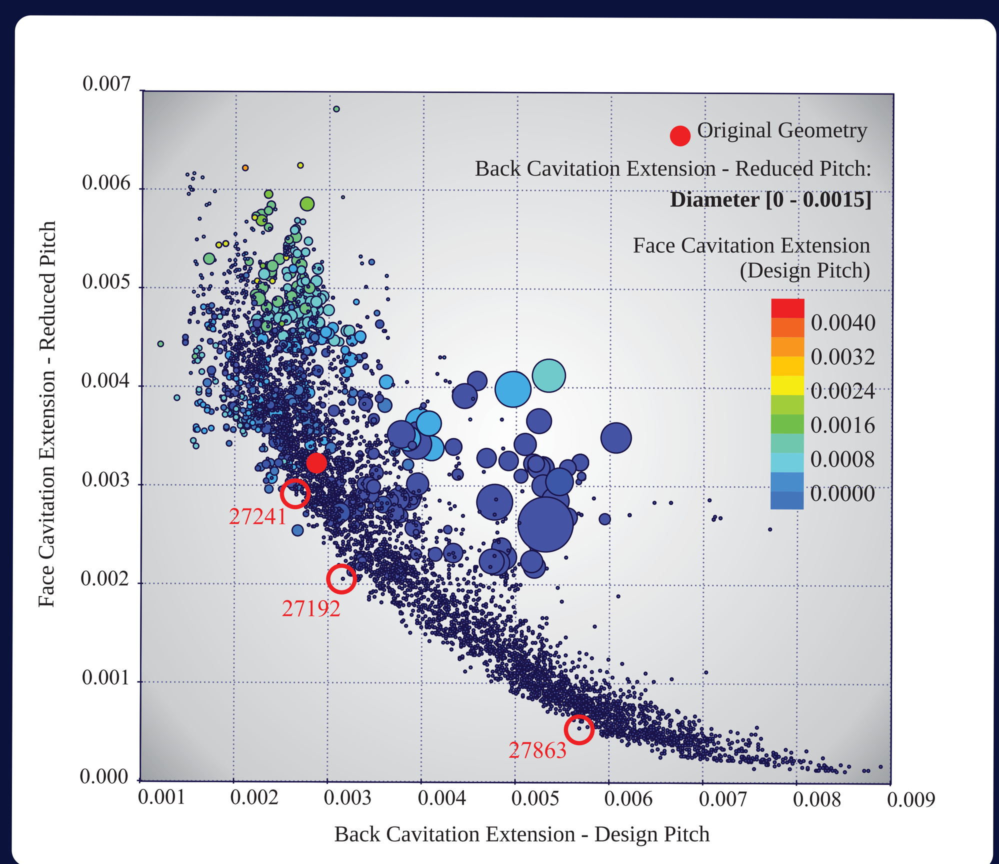
Tools

1. MatLAB for the parametric description of the propeller geometry,
2. A Potential Panel Method, developed at the University of Genoa, to efficiently compute propeller performances and steady/unsteady sheet cavitation,
3. ModeFRONTIER, as a link between the parametric description of the geometry and the panel method solver, to drive the optimization through a multiobjective genetic algorithm (MOGA II) for a total of 30.000 different geometries tested,
4. StarCCM+ to further check the perforances of the original and of the pareto geometries,
5. The Cavitation Tunnel of the University of Genoa to finally validate the results of the design by optimization through a dedicated experimental campaign.

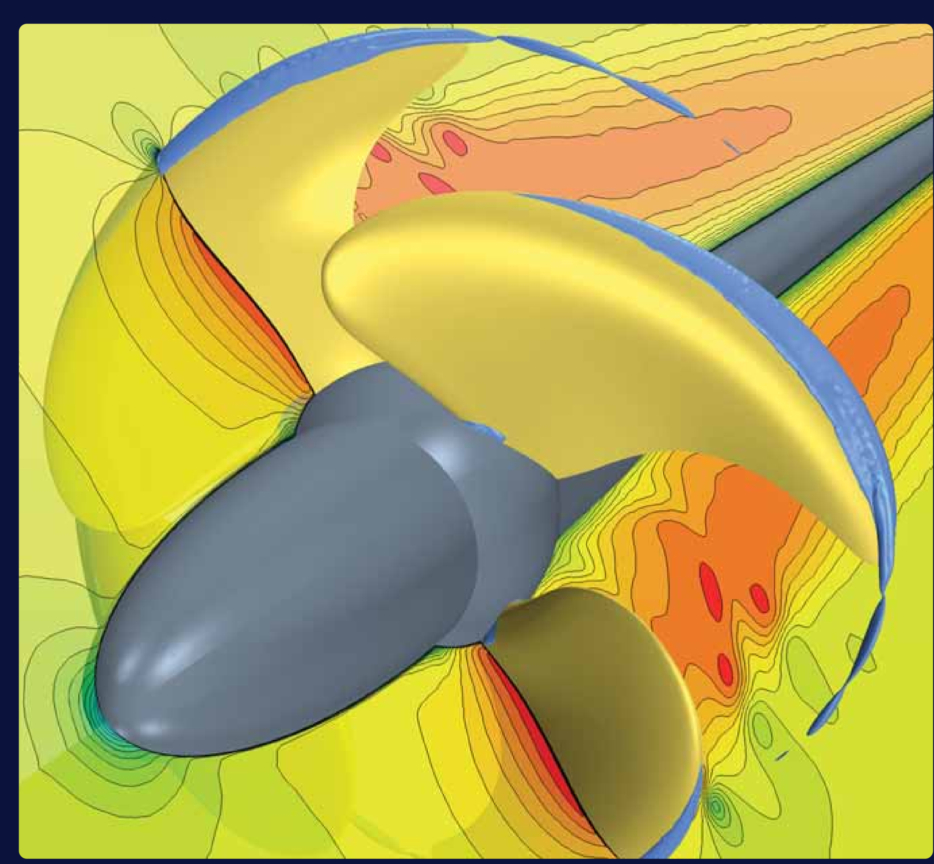
Application & Results



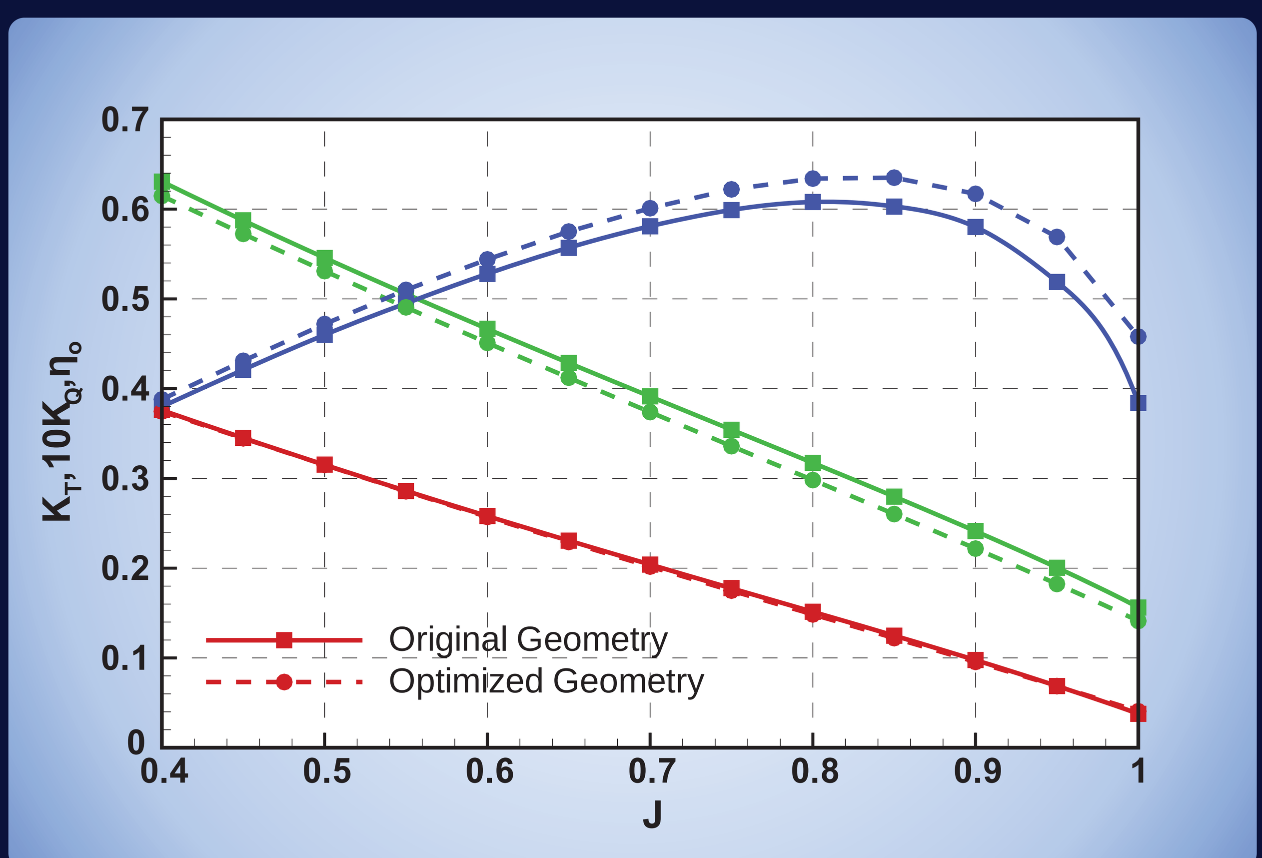
Prediction of the sheet cavity extension and of the propeller thrust and torque by a computationally efficient Panel Method.



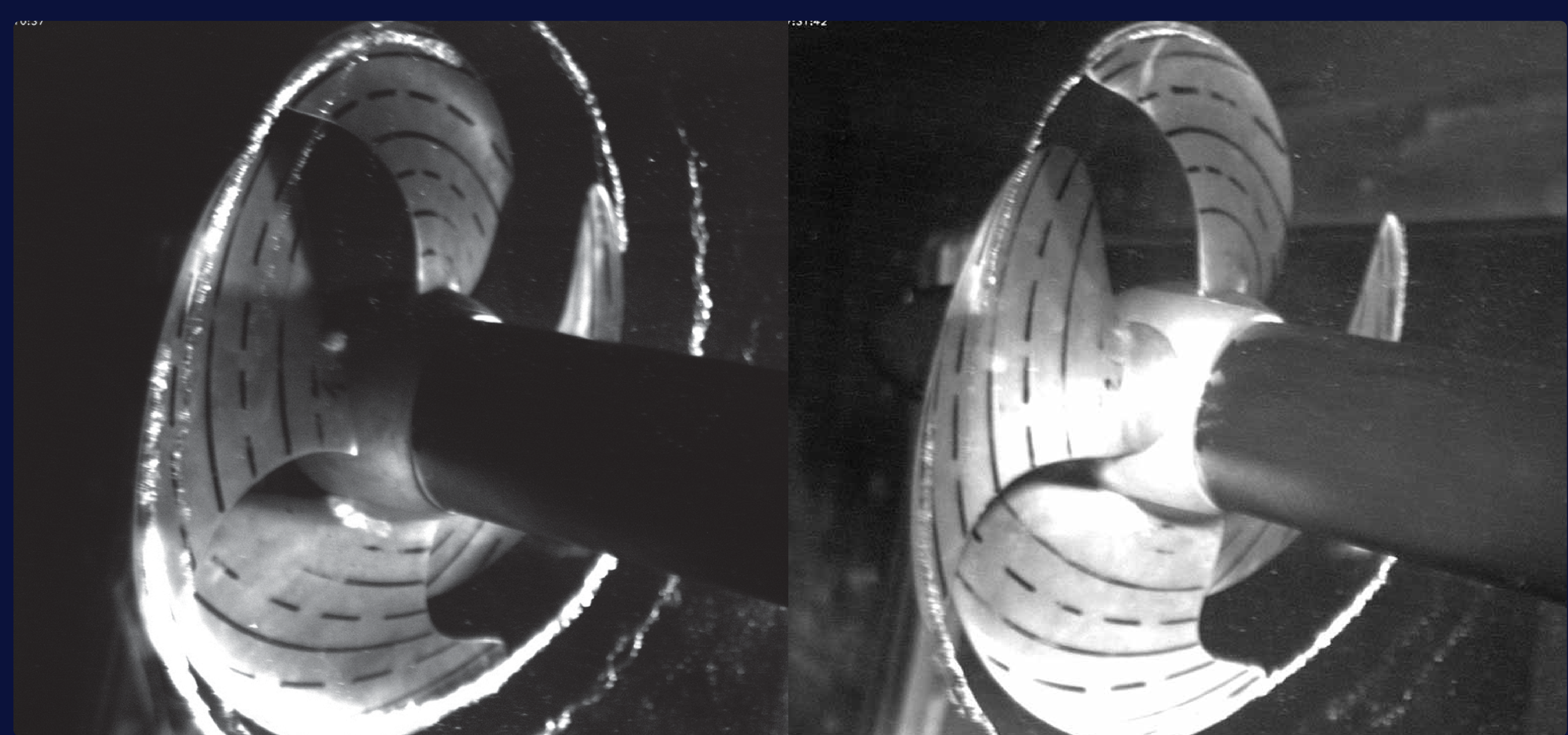
The Pareto Frontier representation of the multi-objective optimization carried out with ModeFRONTIER.



Flow field and cavity extension prediction for the Pareto cases by a RANS multiphase solver for the selection of the optimal geometry.



Thrust (K_T), torque (K_Q) and efficiency (η_o) at the design pitch setting for the original and the optimal propellers - Measurements at University of Genoa Cavitation Tunnel.



Observed pressure side cavity extension for the original (left) and for the optimal (right) propeller at the reduced pitch setting for the evaluation of the radiated noise - Validation of the design at the University of Genoa Cavitation Tunnel.

Bertetta, D., Brizzolara, S., Gaggero, S., Savio, L. and Viviani, M. - CPP propeller cavitation and noise optimization at different pitches with panel code and validation by cavitation tunnel measurements. **Ocean Engineering** 53 (2012), 177 - 195