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Simulation-base Optimization of a Propeller for a Navy Ship

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ABSTRACT

The optimal propeller design represents a balance between competing performance aspects, including efficiency, noise and vibration levels, and structural durability. Designing propeller blades is a time-intensive process that requires several evaluations at each design iteration. Manually exploring the design space for a high-performance propeller can take weeks, even for an experienced designer. This makes automated optimization a potentially essential tool for creating superior propellers while reducing the time and resources needed.

In this work, the design process of a navy propeller is carried out using a simulation-based optimization approach, which incorporates simplified RANSE analyses and synthetic wakes created via body force distributions through the commercial RANSE solver Simcenter STAR-CCM+. The primary geometric features, such as diameter and blade number, along with the radial distributions of pitch, chord, and camber, are managed using a parametric geometric description in the Rhinoceros-Grasshopper environment. A genetic algorithm (driven by the open-source software DAKOTA) is employed to steer the design towards Pareto-optimal solutions by maximizing propulsive efficiency while minimizing the cavitation inception index under different constraints related to structural characteristics and blade rotation capability.

After the optimal propeller is designed, it undergoes detailed unsteady RANSE analyses to evaluate its dynamic performance (thrust and torque) under behind-ship conditions, including the cavitation patterns and the pressure pulses induced on the ship's stern.

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