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CFD Prediction of Tip Vortex Cavitation Inception on a Hydrofoil

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ABSTRACT

It is important to predict and delay the inception of tip vortex cavitation (TVC), that is, often the first cavitation type shown at the lowest inception speed on marine hydrofoils, propulsors and appendages because the levels of pressure pulses and underwater noise can be increased by more than an order of magnitude after the cavitation inception (Shin et al. 2021).

TVC on a symmetric planform hydrofoil with a NACA16-020 cross-section is predicted by CFD simulations. The computational domain and condition are prepared by following the setup of the cavitation tunnel test conducted in CNU-CT (Nagarathinam et al. 2022). A discretized computational model is refined in process of validation against the experimental results of TVC trajectory, sheet cavitation variation and pressure pulses in conditions showing fully developed cavitation. CFD is carried out with an Eulerian multiphase flow model and a cavitation model based on the asymptotic Rayleigh-Plesset equation. Different CFD solvers such as LES and RANS with isotropic and anisotropic turbulence models are adopted for evaluating the suitability of numerical methods in terms of computational effort and accuracy as a practical tool in marine appendage design.

The criterion for determining cavitation inception is established through an iterative process by adjusting the threshold value of cavity volume. The cavity volume within a certain wall distance is excluded due to discretization error. Diagrams for the inception cavitation number with respect to the incident angle are prepared for comparison with the experimental measurement. The effect of the seed density is investigated as a crucial factor calibrating cavitation inception.

The high-fidelity CFD approach has advantage in reproducing dynamic behaviours of unsteady cavitation and predicting inception speeds of detached TVC. RANS with an isotropic turbulence model can be a practical approach as a computationally efficient method in predicting inception speeds of attached TVC in spite of underprediction of detached cavitation.

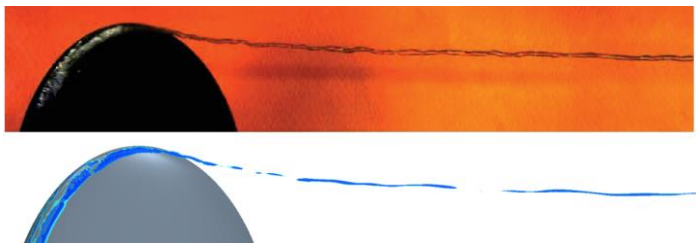

Figure 1. Cavitation on the NACA16-020 planform hydrofoil:
(a) Cavitation tunnel test (Shin et al. 2021), (b) LES

References

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