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Aerodynamic Analysis of Full- and Model-Scale Wingsails with Cambered Profiles

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ABSTRACT

Wingsails with cambered profiles represent one of the promising solutions for wind-assisted ship propulsion (WASP), offering enhanced aerodynamic performance through increased lift and drag generation. However, these wingsails are prone to strong flow separation, resulting in oscillatory aerodynamic loads that can induce structural flutter and vibration, posing challenges for both practical implementation and numerical simulation. Additionally, model-scale effects complicate experimental validation, necessitating a comprehensive evaluation framework.

This study employs high-fidelity numerical methods, including unsteady Reynolds-averaged Navier-Stokes (URANS) and improved delayed detached eddy simulation (IDDES), to analyse the aerodynamic behaviour of cambered wingsails. Model-scale wind tunnel tests are conducted to validate the computational results, addressing scale-related discrepancies and ensuring reliable force predictions.

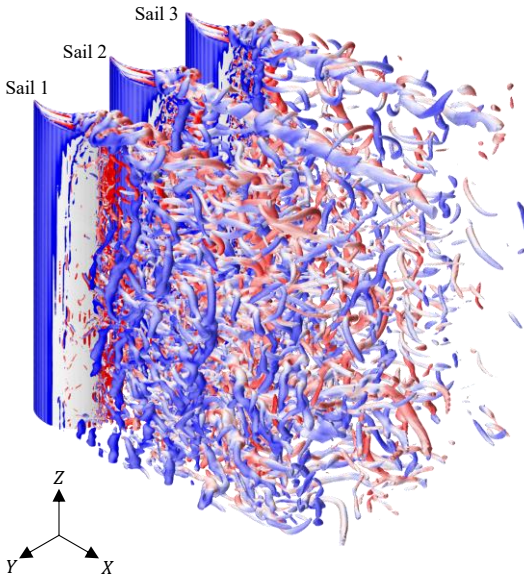

Figure 1: Vortex structures induced by a three-wingsail system.

Results reveal that although cambered wingsails generate high thrust, strong unsteady aerodynamic effects caused by flow separation are observed, highlighting the need for careful aerodynamic and structural design. Besides, model-scale effects, such as Reynolds number sensitivity due to laminar-turbulent transition, affect aerodynamic performance predictions through model-scale experiments. These findings contribute to the development of efficient cambered wingsail systems, advancing sustainable wind propulsion technologies in the maritime industry.

References

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