Examining Rotor Sail Performance Using Empirically Corrected Potential Flow Modelling

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The maritime shipping industry faces increasing pressure to reduce greenhouse gas emissions under the International Maritime Organization's 2030 regulations. Wind Assisted Ship Propulsion (WASP) technologies, particularly rotor sails, offer a promising solution by harnessing the Magnus effect to generate high lift-to-drag ratios and improve fuel efficiency. Rotor sails, often installed on large cargo ships, operate at Reynolds numbers exceeding 10^6, making experimental and numerical modeling challenging. Existing studies primarily rely on low Reynolds number data, leading to uncertainty in full-scale aerodynamic predictions. Recent experimental results at high Reynolds numbers have found strong dependencies on velocity ratio and endplate configurations for lift generation. Understanding these mechanisms is crucial for optimizing rotor sail designs and ensuring their widespread adoption. In this work, potential flow theory is used to model the lift and drag forces of a two-dimensional rotating cylinder under different operating conditions. The model is evaluated using experimental data from recent tests within the Queen's research group, and from canonical studies in literature. Initial model results are examined for flow over a static cylinder, which successfully replicate well known drag characteristics by incorporating empirical corrections. Moving to results of a rotating cylinder, differences between the theoretical model and experimental data are examined and highlight the important effects of both the velocity ratio and the induced drag. Additional simulations of rotating cylinders will provide a foundation to understand the role of tip vortices on lift force generation for three-dimensional cases. It is expected that the model results will highlight the sensitivity of aerodynamic performance to velocity ratio and endplate size, contributing to the broader understanding of rotor sail optimization.

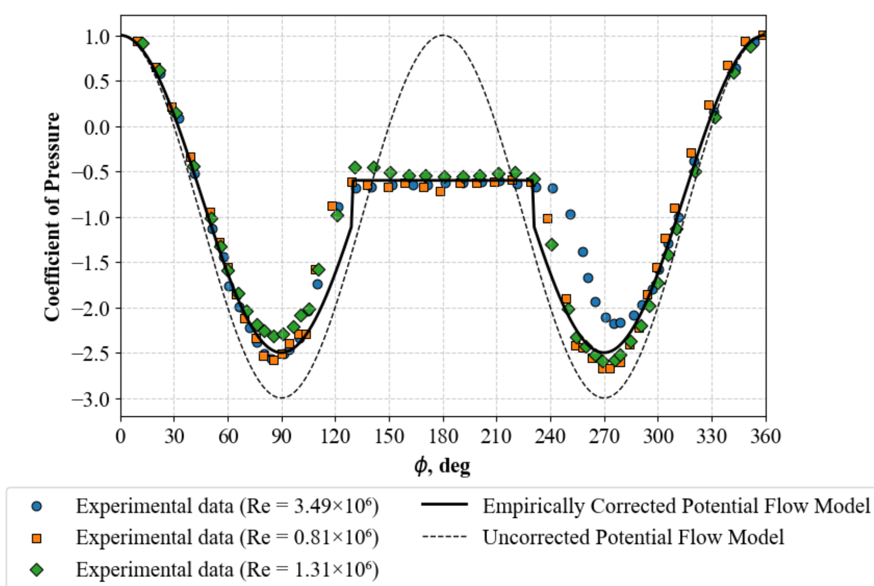

Figure 1: Pressure coefficient distribution on the static cylinder over the angle ϕ (clockwise direction with 0° located at the stagnation point). Experimental data is from Jones et al. ("Aerodynamic Forces on a Stationary and Oscillating Circular Cylinder at High Reynolds Numbers," 1969).

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