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Numerical and Experimental Comparison of Surface Pressures around a Scaled Ship Wind-Assisted Propulsion System

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Abstract : Significant legislative changes are set to revolutionise the commercial shipping industry. Upcoming emissions restrictions will force operators to look at technologies that can improve the efficiency of their vessels -reducing fuel consumption and emissions. A device which may help in this challenge is the Ship Wind-Assisted Propulsion system (SWAP), an actively controlled aerofoil mounted vertically on the deck of a ship. The device functions in a similar manner to a sail on a yacht, whereby the aerodynamic forces generated by the sail reach an equilibrium with the hydrodynamic forces on the hull and a forward velocity results. Numerical and experimental testing of the SWAP device is presented in this study. Circulation control takes the form of a co-flow jet aerofoil, utilising both blowing from the leading edge and suction from the trailing edge. A jet at the leading edge uses the Coanda effect to energise the boundary layer in order to delay flow separation and create high lift with low drag. The SWAP concept has been originated by the research and development team at SMAR Azure Ltd. The device will be retrofitted to existing ships so that a component of the aerodynamic forces acts forward and partially reduces the reliance on existing propulsion systems. Wind tunnel tests have been carried out at the de Havilland wind tunnel at the University of Glasgow on a 1:20 scale model of this system. The tests aim to understand the airflow characteristics around the aerofoil and investigate the approximate lift and drag coefficients that an early iteration of the SWAP device may produce. The data exhibits clear trends of increasing lift as injection momentum increases, with critical flow attachment points being identified at specific combinations of jet momentum coefficient, Cµ, and angle of attack, AOA. Various combinations of flow conditions were tested, with the jet momentum coefficient ranging from 0 to 0.7 and the AOA ranging from 0° to 35°. The Reynolds number across the tested conditions ranged from 80,000 to 240,000. Comparisons between 2D computational fluid dynamics (CFD) simulations and the experimental data are presented for multiple Reynolds-Averaged Navier-Stokes (RANS) turbulence models in the form of normalised surface pressure comparisons. These show good agreement for most of the tested cases. However, certain simulation conditions exhibited a well-documented shortcoming of RANS-based turbulence models for circulation control flows and over-predicted surface pressures and lift coefficient for fully attached flow cases. Work must be continued in finding an all-encompassing modelling approach which predicts surface pressures well for all combinations of jet injection momentum and AOA.

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