High-Order Large Eddy Simulation and Low-Order Unsteady Reynolds Averaged Navier-Stokes Simulations of a Ducted Wind Turbine

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In this work, the accuracies of an in-house high-order code's Large Eddy Simulation (LES) model and a commercial software Simerics' Unsteady Reynolds-Averaged Navier-Stokes (URANS) model are validated by studying turbulent flow past a DTMB 4119 marine propeller. Experimental data are used to validate both LES and URANS results. An advance ratio of 0.833 with a Reynolds number of 0.56 million was used for the propeller. The URANS thrust and torque coefficients are found to be within 5% of that from experimental data. The LES thrust and torque coefficients are more accurate and have less than 3% discrepancies from the experimental data.

Subsequently, both LES and URANS models are applied to simulate turbulent flows around a ducted wind turbine designed and built at Clarkson University. The ducted wind turbine has a tip speed ratio of 3.93 and a Reynolds number of 1.25 Million. The LES and URANS predictions have less than 10% differences in thrust and torque coefficients for the ducted wind turbine.

Furthermore, the URANS model is used to study the effect of varying tip speed ratio on the output of the turbine. It is found that for turbine studied, the optimal tip speed ratio is very close to the design value of 3.93. This corresponded to a thrust coefficient of approximately 8/9. Increasing the tip speed ratio beyond the optimal design value generates a vastly different flow structure downwind of the turbine and drastically reduced the power output.

This joint LES and URANS study justifies that the high-order LES model is suitable for exploring detailed flow physics for ducted wind turbines and marine propellers at moderate Reynolds numbers. The URANS model from Simerics however is sufficiently accurate for exploring design optimizations.