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Validation of Virtual Blade Model in CODA for Efficient Modelling of Aircraft Propellers and Wind Turbine Blades

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1 Introduction

The computational-fluid-dynamics (CFD) software CODA is being developed as part of a collaboration between the French Aerospace Lab (ONERA), the German Aerospace Center (DLR), and Airbus (Tschüter *et al.*, 2022). The CFD suite is modularly integrated as a plugin into the FlowSimulator high-performance-computing (HPC) ecosystem for multiphysics simulations and includes second-order finite-volume and higher-order discontinuous-Galerkin solvers along with various capabilities for different types of flows and configurations. In this study, the solver is validated for an aircraft propeller and a wind turbine blade, where rotors are modelled using a virtual-blade-model (VBM) plugin.

The VBM used in this investigation is based on the original formulation by Zori & Rajagopalan (1995), and a tip loss model by Glauert (1963) is added to the model. Derived from the blade element theory, the VBM utilises a local angle of attack and Mach number at each section of the wing to obtain the load from 2D airfoil lift and drag lookup tables, and the load is converted to the momentum source. This modelling approach allows fast and cost-efficient computations of the rotor performance with reasonable accuracy. Hence, the VBM is targeted to analyse and optimise the performance of complex systems like wind farms or aircraft with distributed propulsion, for which a geometric resolution of the involved rotors quickly becomes prohibitive.

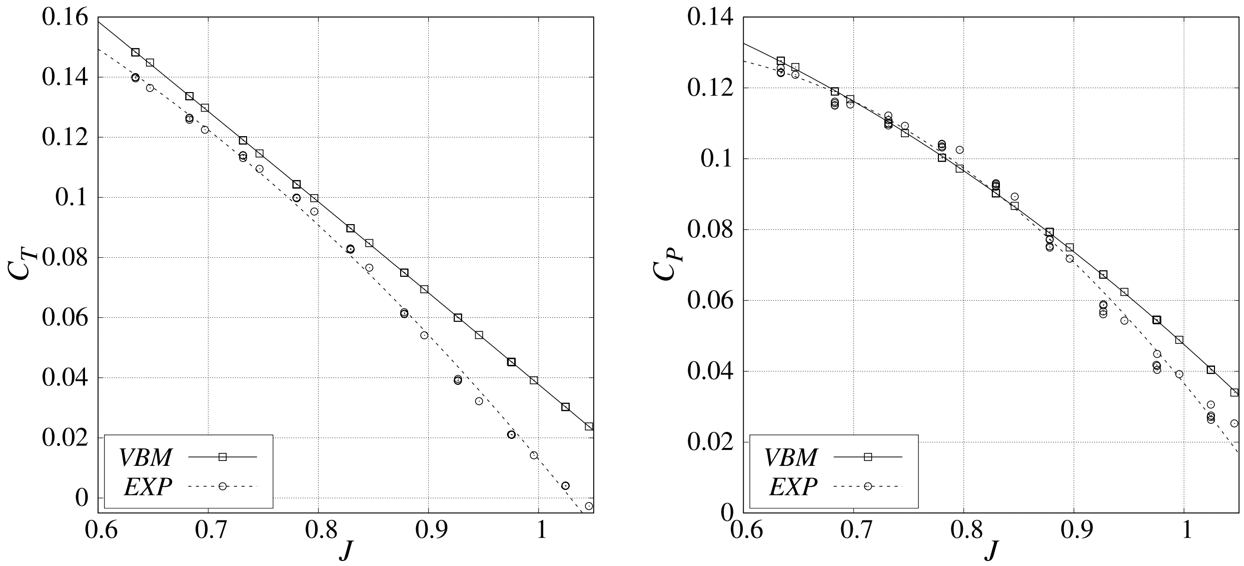
In this extended abstract, an aircraft propeller-nacelle test case from Sinnige *et al.* (2019) is presented. Various advance ratios are simulated, and the performance data are measured and compared to the experimental data. A wind turbine case presenting Enercon E115 3.2MW wind turbine will be discussed in the accompanying presentation.

2 Results and Discussion

Figure 1 presents the performance polars of the propeller, while Figure 2 provides a close-up of the CFD grid and the propeller wake from the simulations. The CFD grid consists of approximately 35 million elements, and the momentum source term calculated from the VBM is applied to the coloured region in Figure 2(a). 45 test conditions were run, and most of them reached convergence around 200 iterations. Thrust and power in Figure 1 show a slight discrepancy in the trend compared to the experimental data. This may be improved by inflow correction approaches utilising sampled values in the upstream of the rotor.

3 Conclusions

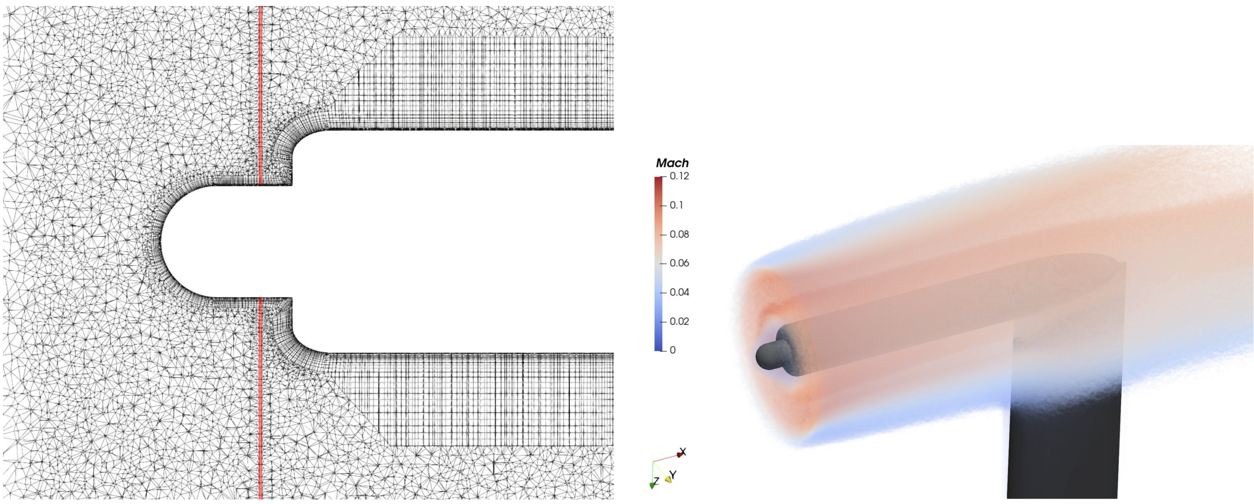
The VBM in CODA is validated for the aircraft propeller-nacelle case and demonstrated a reasonable level of accuracy compared to the experimental data for a cost-efficient, simplified rotor modelling approach. This approach is deemed to have a huge potential for multi-rotor analyses such as a wind farm, in which more than 30 wind turbines are often involved. Future work includes enabling large-scale, gradient-based analyses and optimisation of wind parks.



(a) Thrust coefficient

(b) Power coefficient

Figure 1. Performance polars of the aircraft propeller. EXP: expriment from Sinnige *et al.* (2019).



(a) A close-up of the CFD grid (source region is coloured red)

(b) Volume rendering of the propeller wake

Figure 2. Visualisations from the simulations.

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