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CFD validated technique for prediction of aerodynamic characteristics on horizontal axis wind energy turbines

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Introduction

The wind energy is considered as one of the most feasible renewable energy and its associated sector has rapidly expanded in the last years. Parallel to the growth in wind energy sector, wind turbines has continued to grow in size and complexity, being required a deeper knowledge in both structural and aerodynamic wind turbine behavior for providing the most adequate technologies and strategies for a high performance and reliability turbines [1].

Objectives

Aerodynamic study of the flow around a wind turbine rotor, in order to :

- Provide a set of validated numerical tools enable to predict the wind turbines performance in different working conditions.
- Provide the basis for a posterior flow control study by the use of rod vortex generators [2].

Methods

The NREL UAE Phase VI experiment [3] was selected for validation of the numerical tools and approach. The rotor blade was modeled and a fully structured 8.9 million volume cells per blade grid generated. A cell centered, block-structured, parallel CFD solver was used. All the simulations were performed with the CFD-RANS (Spalart-Allmaras and SST-kω) approach.

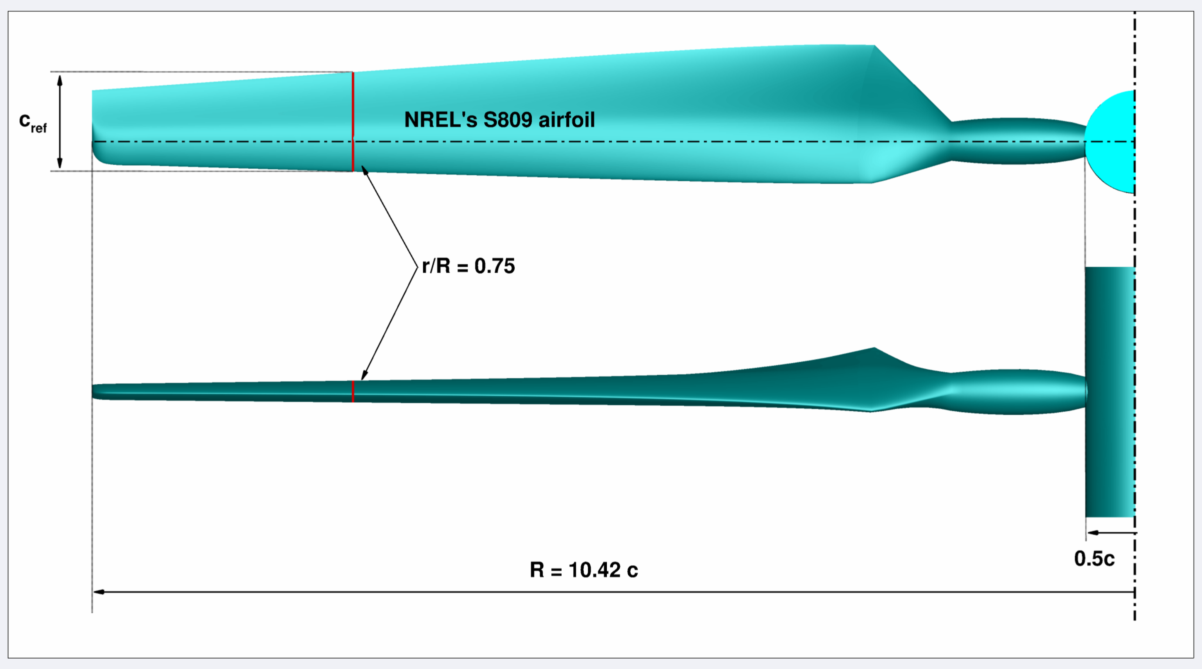

Figure 1: NREL Phase VI rotor model dimensions.

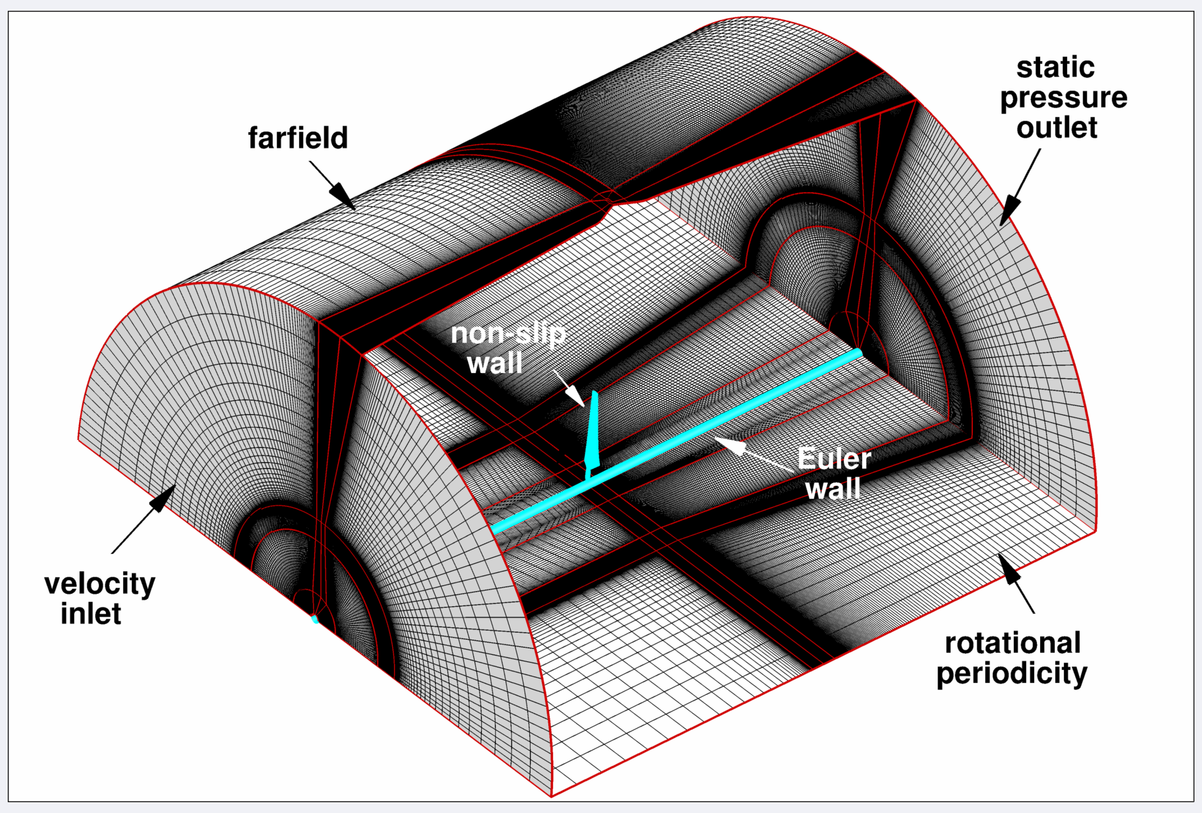

Figure 2: Computational domain, boundary conditions and grid.

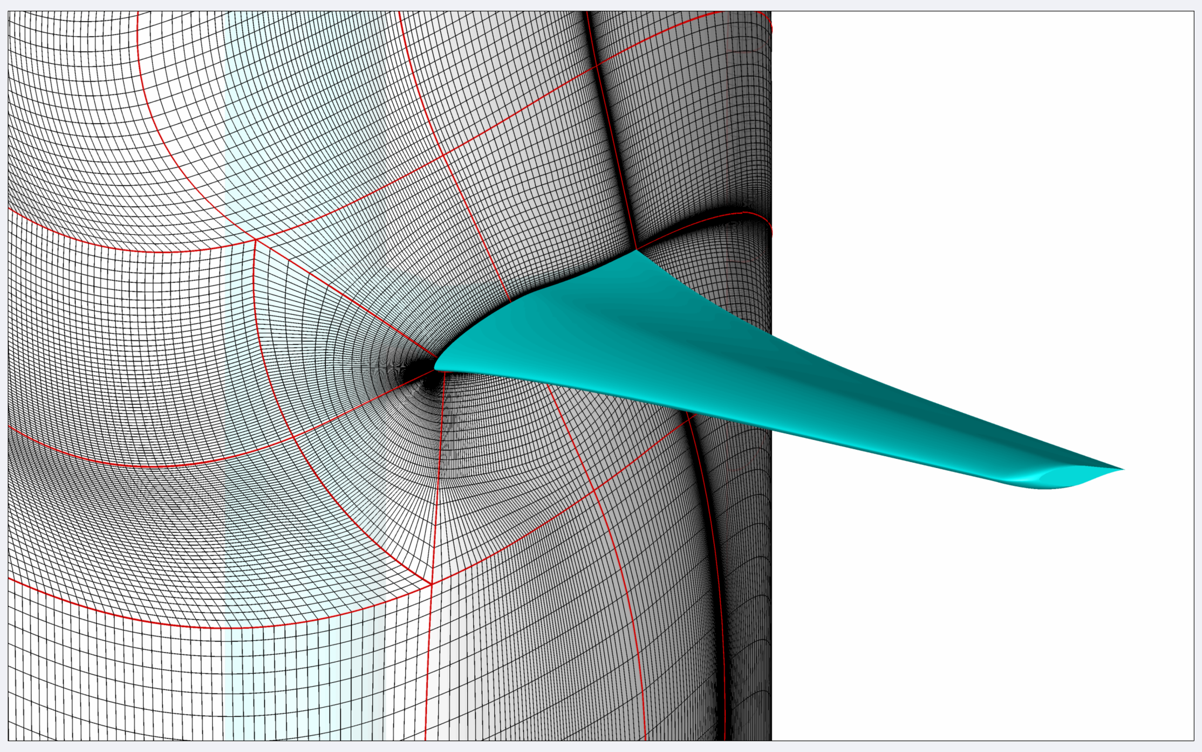

Figure 3: Grid details around blade root cross section.

Results

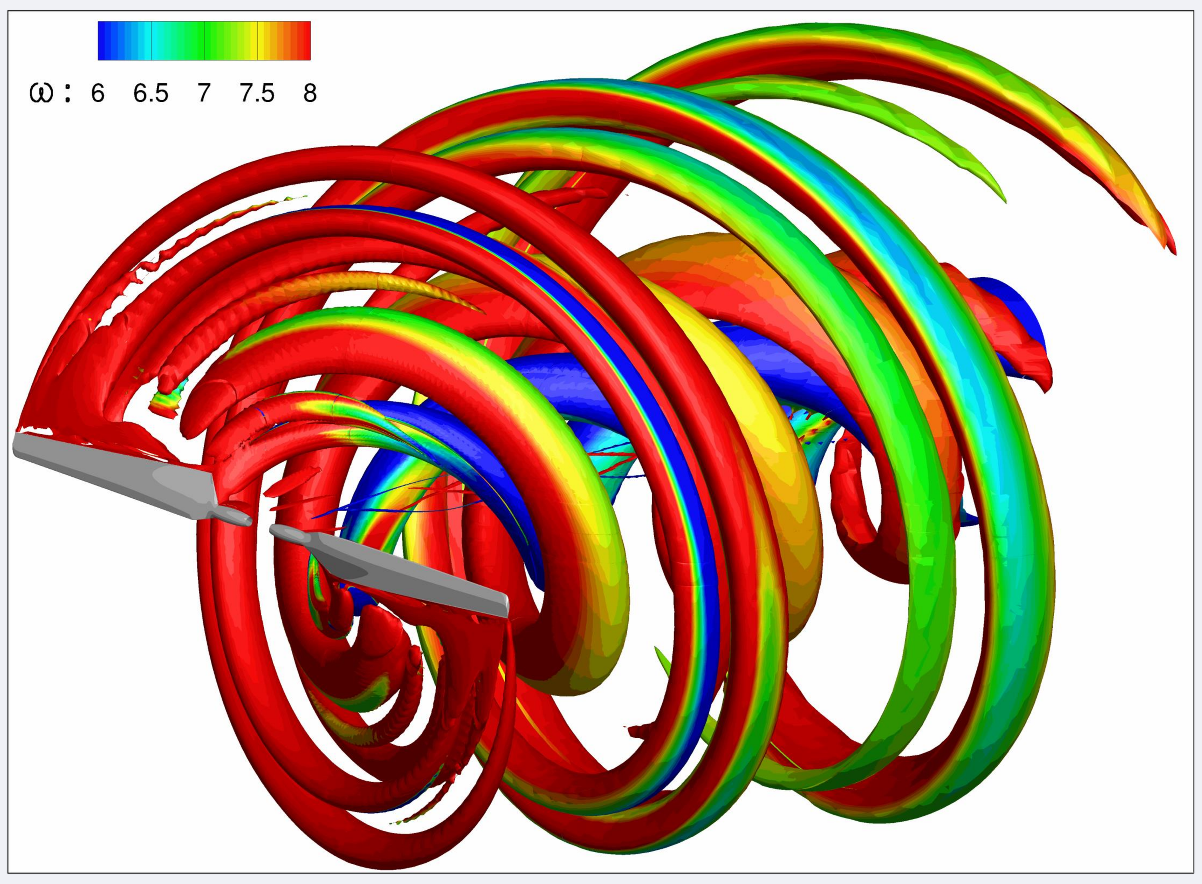

Figure 4: Aerodynamic wake for a 13 m/s wind inflow.

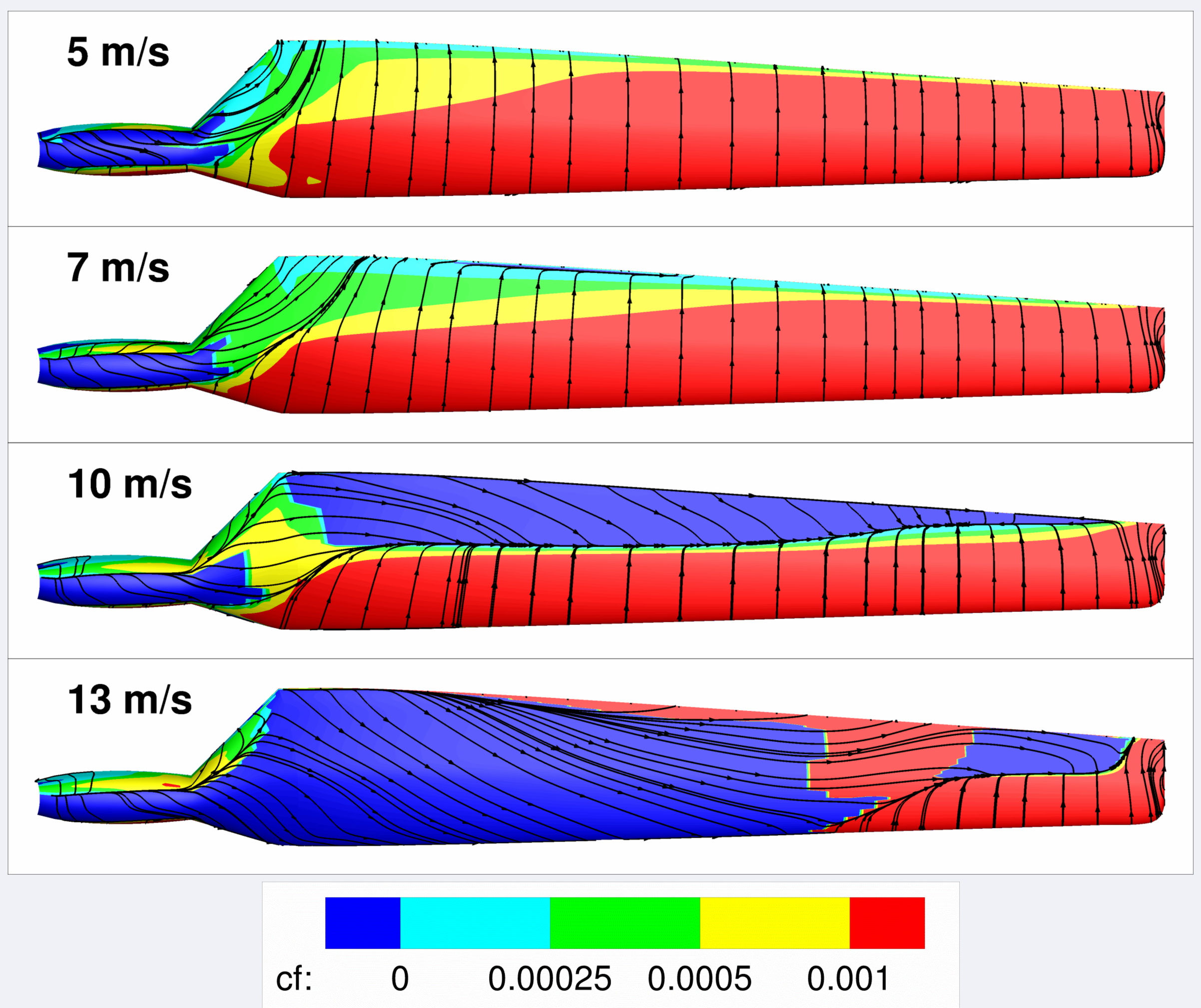

Figure 5: Friction coefficient distribution and streamlines on a NREL Phase VI rotor blade upper surface .

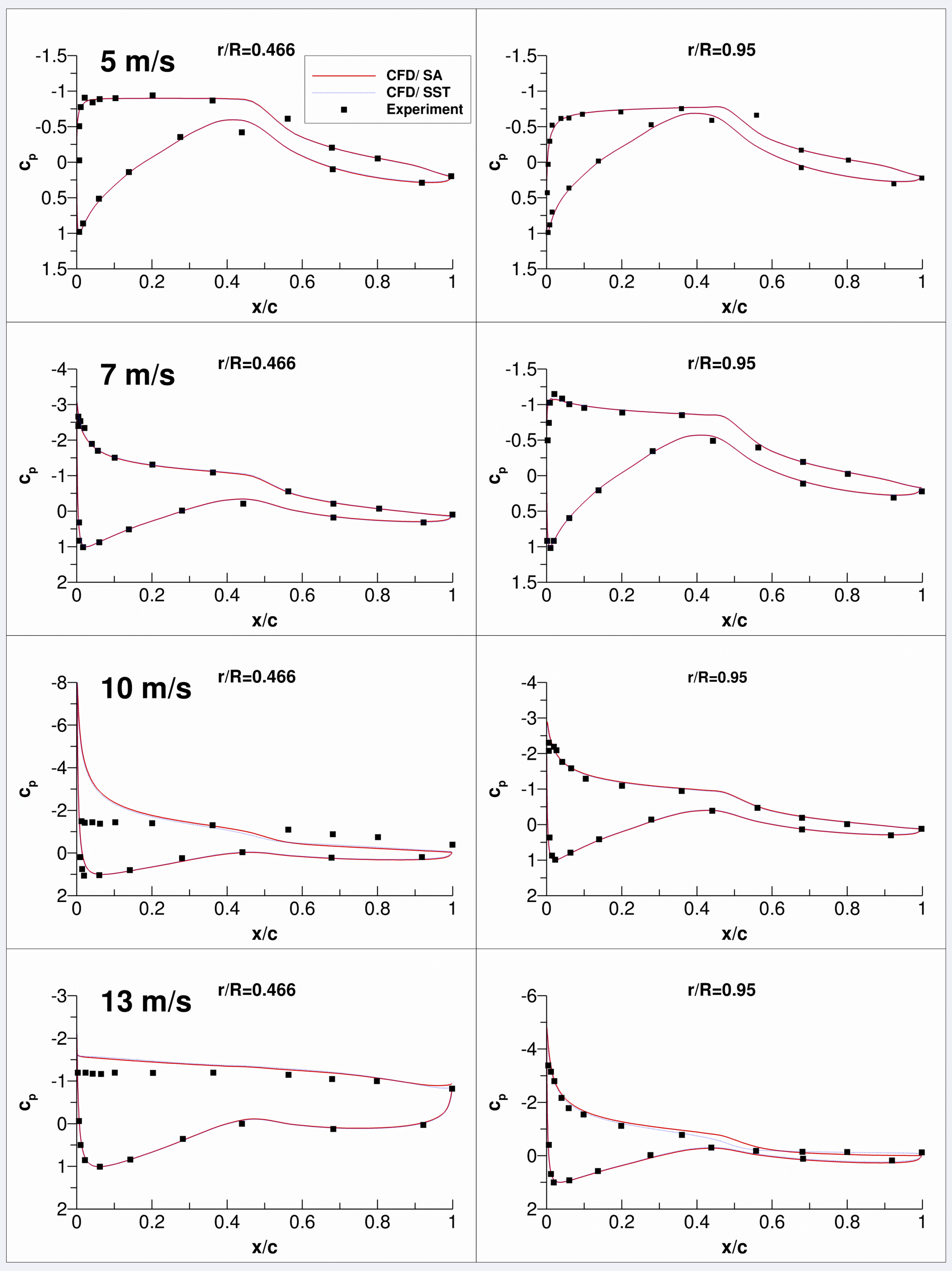

Figure 6: Comparison of numerical predictions and experimental data for the pressure coefficient distribution on two blade cross sections.

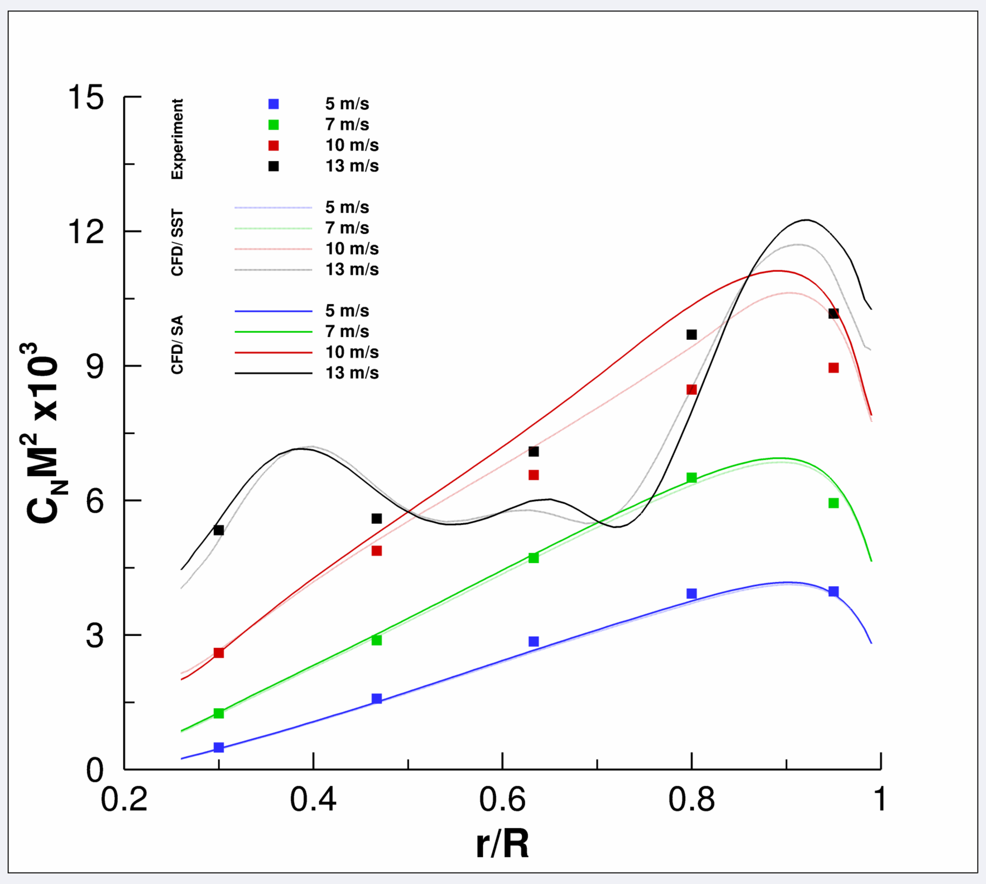

Figure 7: Blade sectional normal force coefficient multiply by the wind speed inflow mach.

Observations

- The shape of the 19.8 kw, S809 aerofoil based [4], stall-regulated NREL Phase VI turbine blade was accurately modelled and all its dimensions scaled to section taken as reference (75 % radius) [figure 1]
- A structured, 76 blocks, high quality, 8.9 million volumes cells per blade, wake refined grid was generated [figure 2]
- The properly capture of the aerodynamic wake is of notable importance to determine the interaction with the following blade at 180º and ,possibly, with other subsequent wind turbines. Besides, the wake strength and path is related to the energy extracted from the wind. The adopted grid clustering downstream the wind turbine rotor has shown to provide adequate resolution to capture the aerodynamic rotor wake, including the strong flow separation rotor working conditions [figures 4 and 5].
- Being the optimum TSR close to 5.4 (wind speed 7m/s), as the wind speed increases from the optimum, so does the flow separation on the blade, affecting to the rotor performance and to the solver prediction accuracy [figures 5, 6 and 7].
- The stall initialization occurring with the increasing in wind speed flow from 7 m/s to 10 m/s is more likely to happen than the strong stall situation for higher speed in modern wind turbine rotors, being selected as the range for flow control technology application.

Conclusions

- The proposed numerical tools and methodology were validated against the UAE Phase VI experiment, showing reasonable good agreement.
- The rotor working conditions susceptible of performance improvement by rod vortex generator technology implementation were identified.

References

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