Validation of vortex code viscous models using lidar wake measurements and CFD

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Validation of vortex code viscous models using lidar wake measurements and CFD
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Abstract
The newly implemented vortex code Omnivor [8], coupled to the aero-servo-elastic tool hawc2 [7], is presented. Vortex wake improvements by the implementation of viscous effects are considered.

Description of the vortex code and viscous models
• Convection/Strain/Diffusion as separate steps [5]
• Elements: segments, particles, panels and misc.: theoretical elements (rings, cylinders, helices), Lagrangian markers. See Figs. 1 and 2.
• Lifting (line, surface, panels) and non-lifting (source) bodies. Viscous boundary condition for non lifting bodies (beta version)
• Wake viscous models tested: grid-based, random-walk, core-spreading
(to do: particle-strength-exchange)
• Strong/Soft coupling with hawc2
• Acceleration: clusters or GPU

Turbulent inflow: Lidar measurements, Vortex Code and CFD
Figure 1: Vortex-based aeroelastic simulation of the DeepWind vertical axis wind turbine in the wake of a horizontal axis turbine. Nacelle and tower modeled with source panels. Conversion from vortex segments to particles. The frame represents the hybrid-wake grid [6] that will be used to record the influence of the far-wake.

Laminar inflow – Viscous models
Figure 5: Comparison between CFD (top) and vortex code (bottom) axial velocity contours normalized with free-stream velocity. The vortex wake do not sustain the deficit as far downstream as the CFD simulation.

Figure 6: 10min-average wake deficits for two viscosity values. Comparison of CFD and vortex code, and two vortex code viscous models. Strong correlation in the near wake. Trend captured: wake deficit reduced for increased vorticity. Differences in the far-wake may be due to wake distortion (no resampling).

Conclusions
• A new vortex-based aerodynamic library implemented.
• The library was successfully coupled to the aero-servo-elastic tool hawc2.
• For turbulent and laminar inflow, CFD and vortex code showed consistent results up to 3 diameters downstream
• External turbulence and shear appeared sufficient to obtain agreement with lidar measurement and CFD. Potential-flow implementations would be preferred.
• Viscous effects down to Re₉₋₁ₓ = 2x10⁴ are negligible in the near wake. The modeling of the nacelle is important.
• Consistent results between grid-based viscous diffusion and random-walk
• Core-spreading to be used with care (tuning required)
• Further work: further viscous validations (at low Re), more advanced body-viscosity model, improved far-wake modeling

References

Figure 3: Vortex-based aeroelastic simulation of the Nordtank turbine with vortex segments are converted to particles. Figure 4: One-hour wake deficits behind the Nordtank turbine. Comparisons between lidar measurements, CFD and vortex code. Preliminary nacelle modeling shows slight improvement but a better modeling of the nacelle and its wake is required for both the CFD-ADAL and the vortex code to capture the near-wake.