11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

COUPLED CFD/CSD METHOD - VALIDATION FOR WIND TURBINES

Marina Carrion[1], Rene Steijl[2], George N. Barakos[3], Sugoi Gomez-Iradi[4] and Xabier Munduate[5]

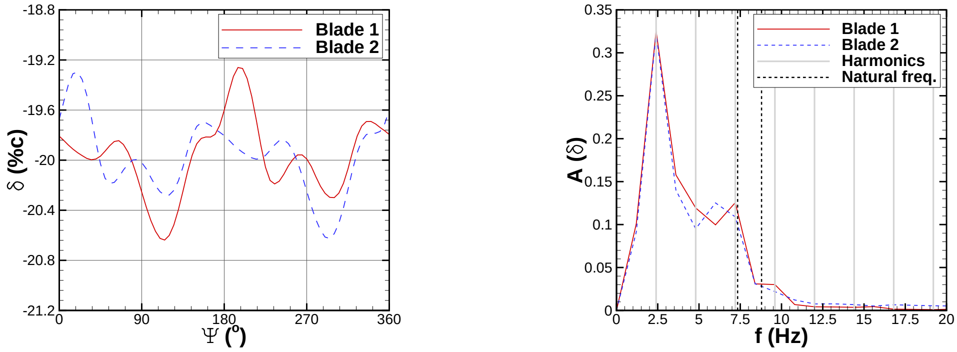
[1] PhD student, University of Liverpool, m.carrion@liverpool.ac.uk
[2] Lecturer, University of Liverpool, r.steijl@liverpool.ac.uk
[3] Professor (corresponding author), University of Liverpool, g.barakos@liverpool.ac.uk
[4] National Renewable Energy Centre of Spain, CENER. Email: sgomez@cener.com
[5] National Renewable Energy Centre of Spain, CENER. Email: xmunduate@cener.com

Key words: *Aeroelasticity, CFD-CSD coupling, NREL Phase VI wind turbine.*

The purpose of this work is to present a validation of a tightly coupled CFD/Aeroelastic method for wind turbine analysis, using as test case the 2-bladed NREL Annex XX wind turbine [1]. For this, the Helicopter Multi-Block (HMB2) solver [2] developed at Liverpool University is used, which is coupled with an aeroelastic method [3] to account for the blade deformations. In the analysis, a structural model for the blade was built and the natural frequencies and blade modes were extracted with NASTRAN, which were used as input for HMB2. In the solver, the blade shape (ϕ) is expressed as a sum of eigenvectors (ϕ_i), multiplied by amplitudes α_i for each mode. At each solution update, in addition to solving the Navier-Stokes equations, the modal amplitudes are calculated based on the computed aerodynamic loads, the CFD grid is deformed and the flow field is updated again. This process is performed until the end of the computation. The method presented in Ref. [3] is used for the grid deformation, where the blade is firstly deformed using the Constant Volume Tetrahedron (CVT) method, the block vertex positions are updated via spring analogy (SAM) and the re-generation of the grid is done via Transfinite Interpolation (TFI).

The test case used for the NREL Annex XX project [1] was selected to exercise this method. Axial flow conditions were assumed, wind speed of 7m/s with a rate of rotation of 72rpm ($\lambda = 5.4$). To account for the rotation of the rotor while keeping the nacelle and tower fixed, the sliding plane technique was employed. In the computations, the first four modes were considered, corresponing to the first two flapping and edgewise modes. Due to the properties of the studied blade, the main deformations were observed in flapping and edgewise modes, with negligible torsion. A mean flapping deflection of 0.26%R towards the tower was obtained, with amplitude oscillations of $+/-$ 5% over a revolution. The maximum amplitudes were present after the blades had passed in front of the tower ($\Psi = 0^o$ and $\Psi = 180^o$ for blades 2 and 1, respectively), with 20 degrees of delay. Likewise, the behaviour of the 2 blades was symmetric and with 180 degrees of off-set, as Figure 1 (a) shows. FFTs of the flapping signal presented in Figure 1 (b) revealed a main frequency of 2.4Hz, which is the blade-passing frequency, and a second peak at 7.34Hz, corresponding to the first natural frequency (flapping mode). The effect of these deformations on the loads was found to be small, obtaining a difference of 2% and 5% in the averaged thrust and torque, respectively, between the rigid and elastic blades.

A case with higher wind speed (20m/s), where the flow all over the blade was stalled, was also found of interest. In this case, the loading on the blades is higher and with more frequency content, which can trigger the blade aeroelastic response. The computed cases showed good performance and the aeroelastic method proved to be useful for wind turbine applications. A detailed description of the method and analysis of the results are presented in the full paper.



(a) Flapping motion at the blades tip. **(b) FFTs of flapping motion.**

Figure 1: Flapping motion at the tip of the blades over one rotor revolution. Harmonics: $f_n = nf_1$ (f_1 =2.4Hz). Natural frequencies: $f_{n_1} = 7.34$ (flap), $f_{n_2} = 8.79$ (edge).

REFERENCES

[1] Hand, M. M., Simms, D. A., Fingersh, L. J., Jager, D.W., Cotrell, J. R., Schreck, S., and S.M. Larwood, *Unsteady aerodynamics experiment phase VI: wind tunnel test configurations and available data campaigns*. Technical report TP-500-29955, NREL, December 2001.

[2] S. Gomez-Iradi, R. Steijl and G.N. Barakos, *Development and Validation of a CFD Technique for the Aerodynamic Analysis of HAWT*, Journal of Solar Energy Engineering-Transactions of the ASME, 131(3):031009, 2009. DOI: 10.1115/1.3139144.

[3] F. Dehaeze and G.N. Barakos, *Hovering Rotor Computations Using an Aeroelastic Blade Model*, Aeronautical Journal, Vol. 116, Issue 1180, pp. 621-649, June 2012.