FSI for wind turbine blades

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Design of efficient and reliable wind turbines requires a thorough understanding of the interactions between the structural components of the turbines and the surrounding turbulent airflow they operate in. Wind tunnel experiments have improved the understanding of such interactions but the issues related to the scaling of the results applicable to full-scale turbine has remained unresolved. Fortunately, numerical simulation tools are addressing the issue and offering a comparatively cheaper and quicker alternative. Such tools attain even more significance in an offshore context where the turbines are significantly larger than their onshore counterparts and effects of marine atmospheric boundary layers can only be understood through numerical experiments. The frequently extreme atmospheric conditions prevalent there introduce nonlinear and three-dimensional effects not captured by state of the art models. To assess the power production potential and structural integrity of the wind turbines, computational models need to take these effects into account.

Significant progress toward this end, using an isogeometric, ALE, partitioned framework, has been made in the recent past [1, 2]. In the current work we build upon the framework by discussing different flow solvers and their ability to reproduce relevant turbulent statistics, cf. e.g. [4] Emphasis is placed on the NREL 5MW reference turbine [3]. The more recent Variational Multiscale and the more established Spalart-Allmaras turbulence models are compared. Also, important numerical considerations, such as mesh quality and efficient preconditioners, are visited.

References

[1] Y. Bazilevs, M.-C. Hsu, J. Kiendl, R. Wüchner, and K.-U. Bletzinger. 3D simulation of wind turbine rotors at full scale. part II: Fluid-structure interaction modeling with composite blades. *International Journal for Numerical Methods in Fluids*, 65:265–253, 2011.

[2] M.-C. Hsu, I. Akkerman, and Y. Bazilevs. Finite element simulation of wind turbine aerodynamics: validation study using NREL phase VI experiment. *Wind Energy*, 17:461–481, 2014.

[3] J. Jonkman, S. Butterfield, W. Musial, and G. Scott. Definition of a 5-MW reference wind turbine for offshore system development. Technical report, National Renewable Energy Laboratory, 2009.

[4] K. Nordanger, R. Holdahl, A. Kvarving, A. Rasheed, and T. Kvamsdal. Implementation and comparison of three isogeometric Navier-Stokes solvers applied to simulation of flow past a fixed 2D NACA0012 airfoil at high Reynolds number. *Computer Methods in Applied Mechanics and Engineering*, Accepted, 2014.