Combined pseudo-spectral / actuator line model for wind turbine applications

This work contains a development of a new large eddy simulation (LES) tool for wind farm computations. One of the main goals of the development part has been to produce a scalable and efficient flow solver using pseudo-spectral discretization. In the first part of the thesis, details of the developed code is presented and verifications are carried out. In the second part, by using the new LES code, a comprehensive investigation is made for the well-known actuator line model (ALM), which is cost-efficient for investigation of the loading estimations on wind turbine blades. In ALM, the body forces are first distributed on a line to represent a blade and then projected to the CFD domain by a smearing function to avoid oscillations in the solver. As a result of the smearing application, the vorticity from the airfoil sections become distributed in 3D space which then causes over estimations of the blade tip loadings. To avoid the effect, researchers either use Prandtl’s tip correction, which is conceptually wrong under ALM framework, or employ extremely fine grid resolutions which result in excessive computational load. In this thesis detailed investigation of the issue is made and a correction procedure is introduced to avoid the effect. First an investigation is held for a simple planar wing that is represented with ALM in the CFD domain and the correction is presented in detail. Furthermore, NREL 5MW and Phase VI rotors are used for rotor applications and it is concluded by various validation cases that the new tip correction greatly improves the loading distributions on the blades. Additionally, it is found that by using grid resolutions as coarse as 10 grid points per blade, comparable results can be obtained.

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