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Computation of effective velocity to couple RANS and Vortex Particles Methods through an intermediate lifting line

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Nowadays, several methods are used to perform simulations of wind turbines. Even if each one has advantages, there is not an ideal one. With a 3D rotor, the *Reynolds Average Navier-Stokes* (RANS) method is accurate but expensive in time and the *Large Eddy Simulation* (LES) one is even more, in both. The rotor may be modeled using different theories to decrease the computation cost with these methods. The *Blade Element Momentum* (BEM) theory, based on airfoil polar, is cost-effective. Still, a lot of physic is lost due to the beam discretization of the blade. The same argument stands for the *Actuator Disk* and *Actuator Line* (AD/AL) theory. Nevertheless, these two models can be efficient and accurate for studying wind turbine wakes. Finally, the *Vortex Particle* (VP) method is powerful when dealing only with the wake (when coupled with a lifting-line theory, typically). However, the management of particles along solid boundaries (of the blade) is difficult and computationally expensive.

To get advantages from RANS and VP without their disadvantages, it seems interesting to couple these methods as follows: use the RANS 3D model in an "*Eulerian Domain*" near the blade and around its aerodynamic center. Outside this first domain, the flow is solved inside the "*Lagrangian Domain*" with a VP method. The present work is included in a Ph.D. whose aim is to develop a coupling between RANS and VP methods suitable for wind turbines.

A first method to couple both domains were developed by Cottet [1]. It involves computing the vorticity inside the mesh's cells (in the Eulerian domain) to generate particles. A variant consists in creating particles only in a buffer [2]. This area is overlapping the last row of cells of the Eulerian domain. In another method developed by Ploumhans [3], particles are created from vortex sheets on the solid boundary. In both cases, the number of emitted particles depends on the cell's size and so could be important.

Limiting the number of emitted particles is possible by means of the intermediary of a lifting-line from a 3D blade. Particles are created at some points of the line and emitted on the blade's trailing edge.

Lifting-Line theory is founded on the modification of the flow around a profile due to the circulation (Kutta-Joukowski Theorem). Thus, the *far-field velocity* (U_∞, far from all obstacle) is different from the *effective* one (U_{eff}) which is the flow velocity arriving on the airfoil.

The effective velocity may be computed from the field's value on the cells around the blade to get the circulation. The influence of these cells' selection on the effective velocity is the present work's point of interest.

The *Stanford University Unstructured* (SU2) software with the RANS method and incompressible Navier-Stokes solver is used to perform computations.

A Line-Average (LineAve) based method [4] is used here to compute the effective velocity as the mean velocity on the perimeter of a shape around a section of the blade. The theory doesn't impose a specific form even if circles are often used [5, 6].

An ellipse is used in this work. The influence of parameters (semi-major and semi-minor axis) on the effective velocity will be presented in the first part. The results will be compared to the "3-Points method" [7] in the second part. This method involves computing the average velocity between 3 points above the blade's section and as much below. Finally, the velocity at the leading edge will be compared to the LineAve results using a circle.

References

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