CFD simulations of a wind turbine wake for rapid recovery of velocity deficits

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 Abstract
In a large wind farm (arrays of wind turbines), wind turbine wake can cause power deficits or/and additional
fatigue in turbine stands in wake region. In this study, several wake simulations were performed to obtain the
characteristics of wind profiles in wind turbine wakes. These information can be used for design of wind farm.
In this year, we focused on the effect of rotational speeds and yaw angles on recovery processes of velocity
deficits. In addition, simulations of multiple rotor are performed to investigate wake interferences in actual wind
farms.

 Reasons for using JSS2
In wind turbine wake simulations, computational domain should cover about 10 rotor diameters downwind
because of its large impact range. On the other hand, to resolve the fluctuations from rotational blades, grid scales
need to be the order of chord length of blade tips. As a result, it is necessary to put large computational grid which
has high grid resolution. Thanks to JSS2, such simulations of high computational cost can be performed.

 Achievements of the Year
Our numerical study focuses on the effects of tip speed ratio (TSR) and yaw angle on the recovery of velocity
deficits. All simulations are performed by using rFlow3D. Fig. 1 shows vorticity contours in the near-wake region.
When increasing TSR, distances between vortices becomes narrows and vortex pairing occurs more easily.
Consequently, it accelerates momentum exchanges between wake region and outer flow.

Fig. 2 depicts a wake structures in active yawed condition, in which yaw angles change periodically. Dynamic
meandering caused by an active yaw condition can be confirmed in the picture and it has strong mixing effects of
wake as shown in Fig. 3. Deficits of averaged wind speed in wake region quickly recover when the wake meanders
dynamically.
Fig. 4 shows isosurfaces of vorticity in a case of multiple rotors assuming large wind power plants. A problem of much computational time was solved by applying MPI techniques to multiple rotors. This simulations can evaluate rotor torques and velocity fields in various conditions of wake interferences at the same time.

Fig. 1: contours of vorticity around the blade tip in the near-wake region

Fig. 2: iso-surfaces of vorticity in a case of active yawed condition

Fig. 3: Transition of rotor averaged wind speeds in wake region
Publications
- Peer-reviewed papers

- Oral Presentations
Usage of JSS2

Computational Information

<table>
<thead>
<tr>
<th>Process Parallelization Methods</th>
<th>MPI</th>
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<tr>
<td>Thread Parallelization Methods</td>
<td>OpenMP</td>
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<tr>
<td>Number of Processes</td>
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<tr>
<td>Elapsed Time per Case</td>
<td>300 Hour (s)</td>
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Resources Used

Fraction of Usage in Total Resources*:1 (%) : 0.68

Details

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<th>Computational Resources</th>
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<th>Fraction of Usage*:2 (%)</th>
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<td>SORA-PP</td>
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<td>SORA-TPP</td>
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<td>/ltmp</td>
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<table>
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<th>Storage Used (TiB)</th>
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<tr>
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*:1 Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*:2 Fraction of Usage: Percentage of usage relative to each resource used in one year.