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FLOW CONTROL USING A DBD PLASMA ACTUATOR FOR HORIZONTAL-AXIS WIND TURBINE BLADES OF SIMPLE EXPERIMENTAL MODEL

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Aerodynamics of three-dimensional wind turbine blade with dielectric-barrier-discharge(DBD) plasma actuator flow control[1] is investigated by large-eddy simulations base on a high-order accurate and resolution computational method[2]. Large-scale parallel computations have been conduced using message passing interfaces and 1,201 nodes (9,608 cores) of the K computer which is based on a distributed memory architecture with over 80,000 nodes[3]. A horizontal-axis wind turbine experimental model[4] is considered whereas a nacelle and a pole are not included in current simulations (see Fig.1). A geometrical angle of attack is set to be 80 degrees with respect to the rotational plane and the blade rotates with a constant angular frequency. A position of the blade is represented by the azimuthal angle Φ and $\Phi = 0$ and 90 degrees correspond to the blade with 12 and 9 o'clock direction from the view point of upstream. A chord-and-freestream-based Reynolds number of $133,333$, a non-dimensional angular frequency of 0.058, and Mach number of 0.07 is considered based on experiments[4]. A tip-speed ratio is approximately 2. A freestream is inclined at an angle of 40 degrees with respect to the rotational axis. An aspect ratio of the blade is 5 and a cross-sectional shape is NACA0012 (see Fig.1). A DBD plasma actuator is installed at the leading edge and modeled as the body force distribution. An overset grid method is employed to treat the small area of body force and to deal with the overlapping region of multiple wind turbine blades. Totally 0.2 billion grid points are used as a baseline case. The minimum grid spacing is 0.00014 chord length. Moreover, a computation with a finer grid (about total 1 billion grid points) is also on-going and a comparison of experimental and computational torque will be presented in the final paper.

Figure 2 shows a comparison of time history of torque for uncontrolled and controlled cases. The DBD plasma actuator is switched on from 2^{nd} rotation of the blade (i.e. from $\Phi = 360$ degrees shown in Fig.2). It is demonstrated that an increase in torque generation is attained by the flow control. Timing of peak is slightly changed due to the

DBD plasma actuator. Instantaneous flow structure and surface pressure distribution at $\Phi = 480$ degrees are shown in Figs. 3 and 4. Flow over all blades separates and tip vortices are generated. Suppression of separation from the root to the middle span by the DBD plasma actuator is observed in the surface pressure distribution (see Fig.4). This leads to the increase in torque generation at $\Phi = 480$ degrees. (see Fig.2). Further analyses of instantaneous three-dimensional flow structures around each blade will be conducted and discussed in the final paper.

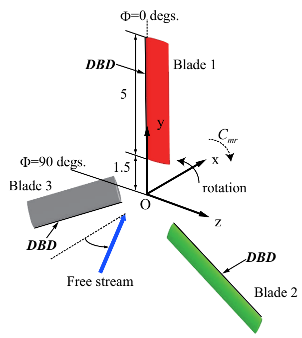

Figure 1: Configuration of a horizontal-axis wind turbine blade model.

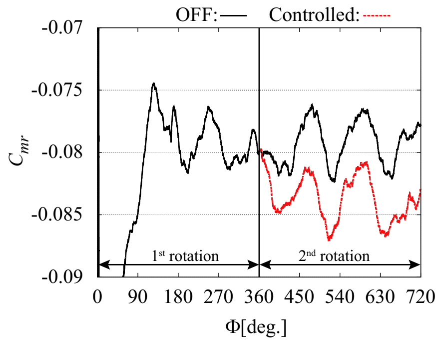

Figure 2: Time history of total torque (C_{mr}) generated by blades.

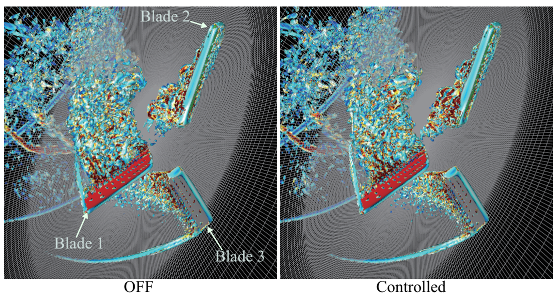

Figure 3: Instantaneous iso-surface of second invariant tensor of velocity gradient tensor around the turbine blades at Φ=480 [degs.]. Color of iso-surface indicates vorticity magnitude and its range is from 0 to 0.05. Every two point is used for flow visualization.

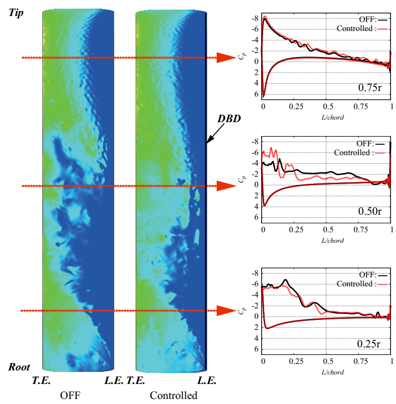

Figure 4: Instantaneous surface pressure distribution on the suction side of the blade 1 at Φ=480 [degs.]. L.E. and T.E. indicate the leading and trailing edge.

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