Effect of surface curvature on a wall jet induced by a multi-DBD actuator

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In the goal of load fluctuation alleviation for wind turbine airfoils, we investigated innovative active flow control devices implemented at the trailing-edge of the airfoils in order to achieve circulation control [1]. Circulation control strategy can be in particular performed by using blowing devices along a rounded trailing edge [2] in order to manipulate the separation point of the boundary layer. This leads to the modification of the circulation around the aerodynamic airfoil, and so, of the lift force. As depicted in Fig.1, a multi-DBD setup was implemented along a rounded trailing-edge of a wind turbine airfoil for this flow control application [1]. The ionic wind produced by this actuator was characterized in quiescent air conditions using a PIV system. The results discussed in this work present the topology of the wall jet induced over the curved trailing-edge by comparing it to the one induced by its plane equivalent DBD configuration and to a conventional plane [3] and curved [4] fluidic wall jet. This analysis may be particularly helpful for the implementation of numerical models that would reproduce the flow control actuation on wind turbine blades and for a better understanding of the curvature effect on the ionic wind topology.

Figure 2 shows the time averaged velocity field deduced from PIV measurement. It is assumed that the flow induced by the DBD actuator behaves like a two-dimensional wall jet. The induced jet does follow the curved surface. All along the actuator, the velocity increase is visible. As observed for a plane DBD configuration, the three main zones, aspiration, acceleration and diffusion, are highlighted. In order to study the evolution of specific variables describing the wall jet and to compare it to a fluidic wall jet, it is necessary to define a specific coordinate system related to the curved jet, as well as a virtual slot width, as shown in Fig. 3. Then, it is possible to study the jet characteristics in terms of dominant length and velocity scales, spread rate and self-similarity of velocity profiles. An example is shown in Fig. 4. As discussed in [4], for the curved wall jet, the dominant lengthscale is the radius R of curvature and the velocity scale is the square root of the kinematic jet momentum divided by R. A local Reynolds number based on these variables can be defined [4]. In Fig. 4, the evolution of this local Reynolds number Re_{x^*} with x^* shows an effect of the surface curvature on the jet development. The overall Re_{x^*} level of the curved jet is greater than the one of the plane jet. After the virtual origin x_0, because the spread rate is more important for the curved wall jet due to the curvature, the Reynolds number increase is faster damped than the one of the plane wall jet.

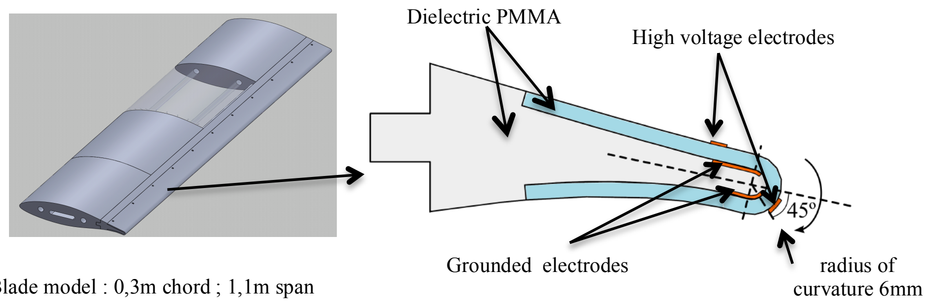


Figure 1: Sketch of the airfoil model with the specific trailing-edge and electrode's position around the trailing edge

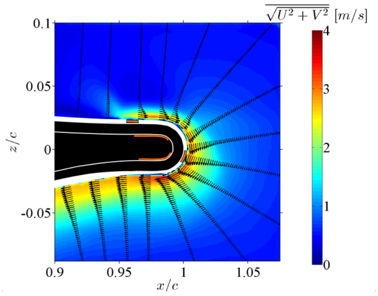
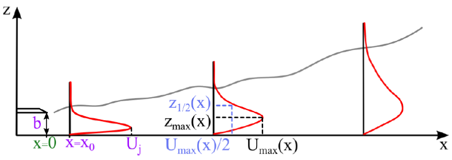
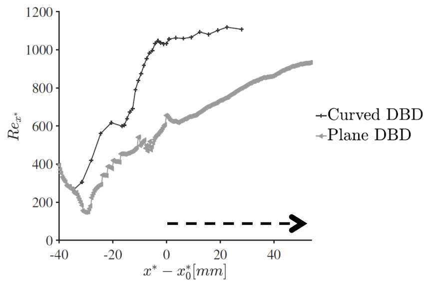


Figure 2: Time averaged velocity fields in quiescent air conditions in a wind-related coordinate system (sinusoidal high voltage 18kV, 1kHz, 80 W/m)





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