Aeroacoustics of ice-accreted NACA0012 airfoil

Sogand Okhovatian[1] & Philippe Lavoie[1] & Stephane Moreau[2]
1 Institute for Aerospace Studies, University of Toronto, Toronto, Ontario, Canada
2 Department of Mechanical Engineering, University of Sherbrooke, Sherbrooke, Quebec, Canada

Ice accretion on wind turbine rotor blades in cold climates modifies the airfoil shape and surface roughness. This significantly reduces power output by decreasing the airfoil lift and increasing surface friction drag. Precipitation ice, or glaze ice, forms at warmer temperatures and is a common contributor to power losses in wind energy applications. Glaze ice typically generates a leading-edge horn which induces a separation bubble, degrades aerodynamic performance, and increases noise. Although leading edge flow separation or ice-roughness contributes to the generated noise, turbulent boundary layer trailing edge (TBL-TE) noise remains the dominant noise source. The ice modifies the boundary layer transition and the scattering of turbulent boundary layer pressure fluctuations, consequently altering the TBL-TE noise. To date, very few studies have discussed the aeroacoustics of ice-accreted airfoils or the possibility of detecting icing through acoustic signatures, resulting in little insight on the modification of the underlying noise generation mechanisms. This study aims to fill this gap by characterizing the aeroacoustic signatures of a clean and a glaze-iced airfoil through investigations of the flow mechanisms and the TBL-TE, leading-edge, and roughness noise sources.

This presentation will compare the aerodynamics of a clean and glaze-iced NACA 0012 airfoil at an angle of attack of $\alpha = 4^\circ$ using two-dimensional Reynolds-Averaged Navier-Stokes (RANS) simulations. Velocity contours will showcase the suction and pressure side flow separation and reattachment. Mean surface pressures, coefficient of friction, and boundary layer profiles of the two cases will be compared. Furthermore, the TBL-TE noise will be predicted using analytical noise models. To predict this, boundary layer parameters extracted from the RANS solution near the trailing edge are used as input to Amiet's analytical trailing edge noise model, coupled with empirical wall-pressure spectra and spanwise coherence models.

The RANS framework has been validated against existing experimental and computational literature data, showing good agreement in surface pressure distributions and boundary layer velocity profiles near the iced leading edge. The results confirm that the glaze-ice horn induces a separation bubble on both the suction and pressure sides and produces a thicker turbulent boundary layer at the trailing edge. Boundary layer characteristics are modified, with an increased displacement and momentum thickness and a stronger adverse pressure gradient, all of which alter the wall-pressure fluctuations near the trailing edge and consequently the radiated noise. The far-field noise spectra predictions between the clean and iced airfoil will be presented and compared. These preliminary findings will be complemented by high-fidelity Large Eddy Simulations and upcoming wind tunnel measurements as part of this broader project to provide a comprehensive aeroacoustic characterization of ice-accreted airfoils.

Email address for correspondence: *sogand.okhovatian@mail.utoronto.ca*