LOW ALTITUDE ICE ACCRETION PHYSICS ON SMALL UNMANNED AIRCRAFT

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1. INTRODUCTION

The main focus of this study is the ice accretion geometry under atmospheric conditions that may be encountered by low altitude unmanned aircraft, or UAS. Aircraft icing is a significant hazard for manned aircraft. Between 1998 and 2009, more than 510 icing accidents were reported. As unmanned aircraft begin to fill the roles for many flight needs, the impact of icing on unmanned aircraft (UA) needs to be explored. Small UAS may be required to fly in hazardous SLD icing regions for research purposes. Small unmanned aircraft are usually incapable of supporting anti-aircraft systems, thus it is especially important for investigation.

NASA's LEWICE program will be run under low Reynolds number flows and NCAR's CM1 program will be used to estimate the atmospheric conditions under which an icing UAS would fly. In order to gage an expectation for icing accumulation under low Reynolds numbers, a number of past studies will be reexamined with varied velocities and airfoil size.

2. GLAZE ICE ACCUMULATION

NASA has undergone extensive studies for ice accretion with the Lewis Icing Research Tunnel, including studies simulating icing on a general aviation aircraft (Berkowitz, 1991). The conditions run for this general aviation study are approaching the type of glaze icing conditions anticipated for UAS icing.

The aerodynamic impact can show distinctive patterns and trends in the physics behind the ice shape. Viewing trends in airfoil pressure distribution with icing will give an initial basis for flow as the icing conditions approach UAS icing conditions. In order to gain a greater understanding of accretion behavior simulated with LEWICE, it is compared with tunnel experiments under set conditions. Figure 1 shows the results of the simulation at full accretion time compared to the icing tunnel experimental results. Table 1 outlines the conditions set for the icing tunnel and used in the LEWICE simulation.

Table 1: General Aviation Experimental Icing Conditions

Static Temperature	268K
Velocity	66.9 m/s
Angle of Attack	0.3 deg
LWC	0.54 g/m3
MVD	20 micrometers
Spray time	22.5 min
Chord	90 cm

With only a small amount of ice accretion on the airfoil, LEWICE shows significant changes in the surface pressure. Figure 2 shows the accretion after 3.3minutes pulled directly from LEWICE output. The black line is the airfoil without any icing and the red line shows the outer icing line and changed pressure. The accretion shape is relatively minor at this step and the geometry could be characterized as streamwise icing or roughness icing. The aerodynamic effect, therefore, should be relatively small without a separation bubble. The geometry was run in XFOIL in order to compare pressure distributions between the two software. Figure 3 shows the XFOIL pressure coefficient result compared to the Cp values directly from LEWICE. The XFOIL pressure result is in blue. Since the aerodynamic effect is shown to be significant with both software, the icing is closer to moderate roughness icing rather than streamwise icing. However, the XFOIL results in that case are less reliable due to likely leading edge separation.

Figure 4 has both the results from the 40s accretion and after 11.5 minutes. This is shown by the green line and has extreme negative pressure spikes pushing back to 0.1 of the chord. At this later time step, the ice accretion has developed into the horn shape. The resultant separation bubble explains the extreme behavior seen in the pressure coefficients.

3. RIME ICE ACCUMULATION

The NASA study for the general aviation conditions does not have an experimental result for pressure coefficients. The NASA rime ice study conducted at Ohio State University (Bragg, 1982) will be examined to gain insight into pressure coefficients with ice accretion.

The experimental results of the pressure distribution can support the validity of the Cp behavior predicted in LEWICE. For the experimental tests, NASA used the NACA 65A413 airfoil; for the LEWICE simulations, the similar NACA 64215 airfoil was used. Table 2 shows the simulation parameters with the results that best match the experimental ice shape. Figure 5 shows the leading edge of both airfoils with tunnel ice shape and the LEWICE shape. There are some discrepancies between the two, but they both fall into the streamwise icing category as is expected in rime icing. The thickness of the ice geometry is large enough that a separation bubble may occur, though not as significant a bubble as would occur in horn icing.

The pressure distribution shows changes in Cp for both surfaces after the initial trend from the leading edge. This is shown in Figure 6 in the LEWICE simulation. The pressure behavior matches the experimental results well enough to support the pressure results from LEWICE, at least under streamwise conditions.

Table 2. Rime Study LEWICE Icing Conditions

Static Temperature	257K
Velocity	127.4 m/s
Angle of Attack	1 deg
LWC	0.25 g/m3
MVD	15 micrometers
Chord	54.3 cm

The next stage of the study will consist of matching the LEWICE simulation conditions with weather patterns generated with CM1. The program will generate idealized models of atmospheric systems. The atmospheric conditions along given flight paths will then be matched with parameters in the LEWICE simulations. These results will be invaluable for planning icing flight tests.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Berkowitx, B., Potapczuk, M., Namdar, B., Langhals, T., 1991, "Experimental Ice Shape and Performance Characteristics for a Multi-Element Airfoil in the NASA Lewis Icing Research Tunnel," NASA Technical Memorandum 105380

Bragg, M., 1982, "Rime Ice Accretion and Its Eect on Airfoil Performance," NASA Contractor Report 165599

6. FIGURES

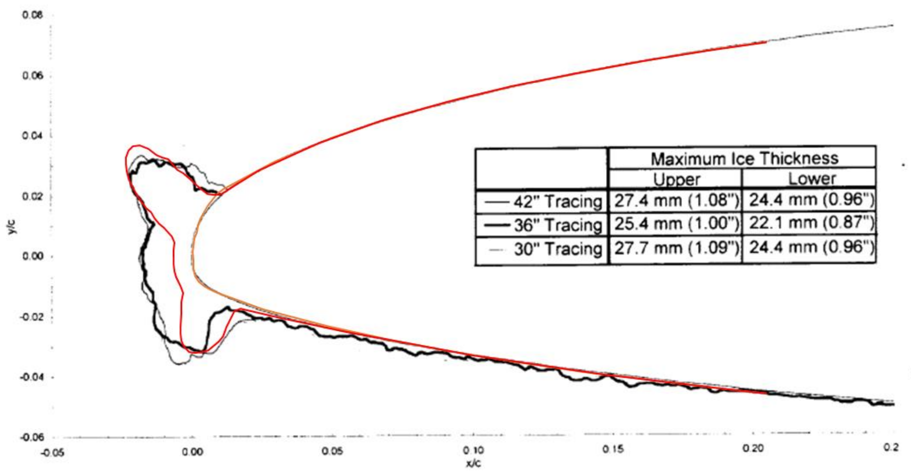

Figure 1: LEWICE icing simulation for a general aviation aircraft compared to past experimental study in an icing tunnel. Red line represents final ice accretion.

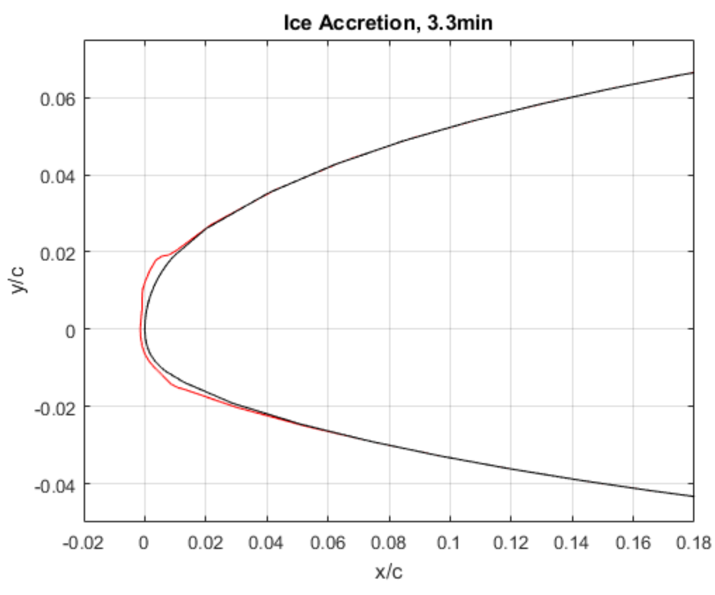

Figure 2: LEWICE simulation with ice accretion and Cp plot for a general aviation aircraft after 3.3 minutes.

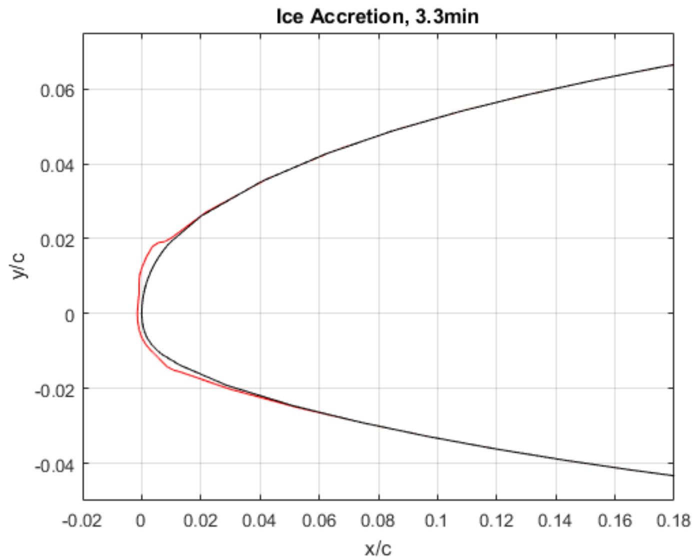

Figure 3: LEWICE ice accretion pressure distribution compared to the pressure distribution result from

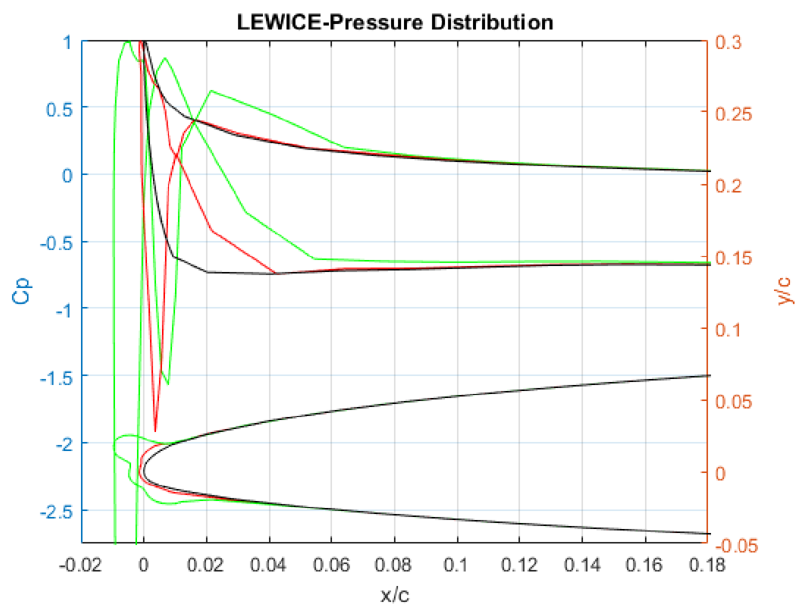

Figure 4: LEWICE icing simulation for a general aviation after 11.5 minutes.

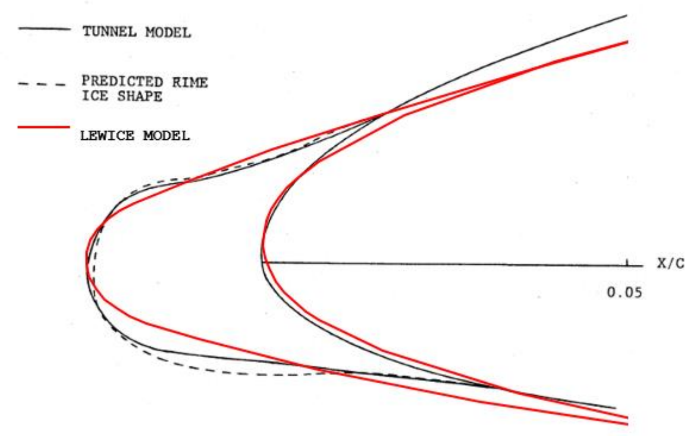

Figure 5: LEWICE icing simulation overlaid with the experimental airfoil and simulated ice shape.

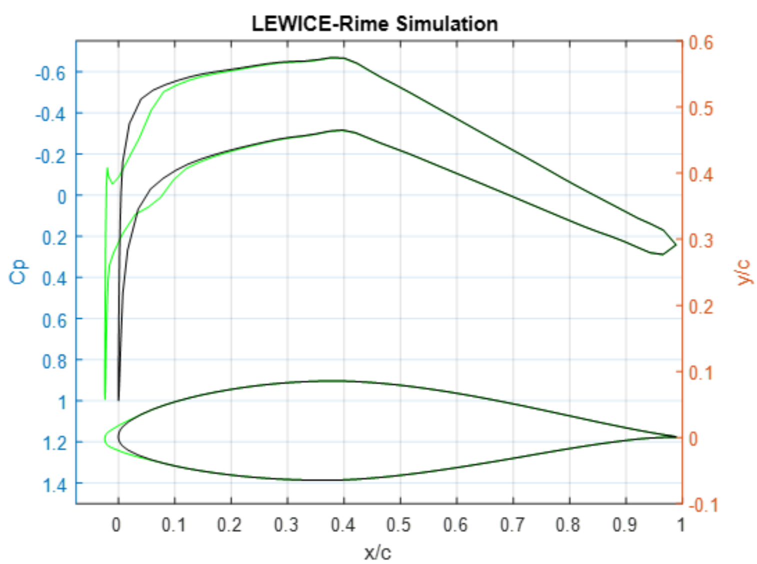

Figure 6: LEWICE results for coefficient of pressure and the simulated added ice shape.