De-icing System for Composite Leading Edges

by Team

CryoSAMP

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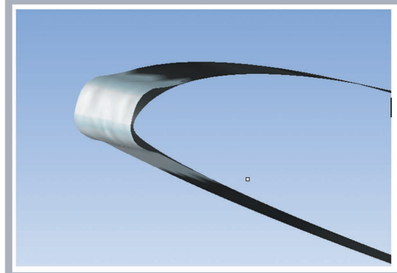
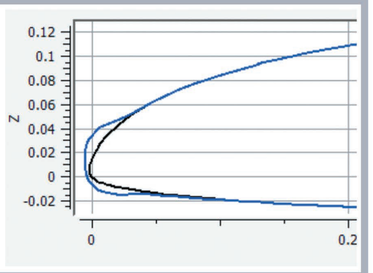
Problem Statement & Solution

Ice-formation on the leading edges of aircraft wings is an issue that negatively affects the aerospace industry. Recently, there has been an increased usage of composite structures, but the thermal limits of these materials are much lower relative to more traditional aluminum structures. Therefore, a reliable means for removing ice formation is needed. This system includes heating wires embedded in the composite layers with the addition of expanded graphite to the epoxy matrix in order to increase its thermal conductivity.

Icing

-Ice itself starts to form at sub-zero temperatures or under the presence of supercooled water droplets.
-Past 25,000 ft there is no moisture = no ice formation.
-Presence of “light” to “moderate” icing : -22°C to -9°C
-FENSAP-ICE was used to simulate ice accretion.
-Largest mass of ice formed at 6,000 ft and -10°C, with less severe icing occurring at higher altitudes/lower temps.
-Average droplet size ranged from 15µm to 40 µm.
-25 µm aaverage droplet size caused the most severe icing.





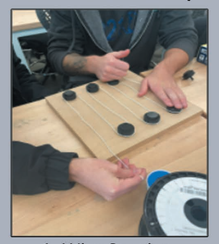
Ice accretion with a wing angle of attack of +3°

Targets

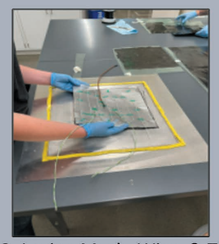
-Melting connection layer between composite and ice
-Operation altitude of 0-60,000 ft.
-Critical operation altitude of 6,000-25,000 ft.
-Operation at true air speed of 150-500 kts.
-De-icing time after 10 minutes exposure of “light” to “moderate” icing of 5 minutes or less.
-Compliance with various military handbooks and airworthiness manuals.
-Operation in most weather conditions (including during presence of lightning).

Prototyping

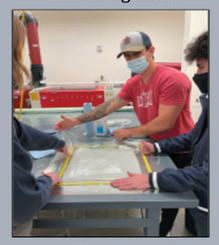
-Prototyped with 12-layer 12”x12” carbon fiber plates.
-Each prototype assembly is comprised of:
•Thermocouple: Measures temperature of plate surface.
•Lightning protection mesh: In case of discharge.
•Embedded Nichrome wire with PTFE Insulation: Its high resistivity (0.831 Ω/ft) allows for a temperature rise which fuels the de-icing process when current is applied.
•GS-3807 Expanded Graphite Powder: Added to resin mixture during manufacturing to increase thermal conductivity of carbon fiber composite.


1. Wire Spacing

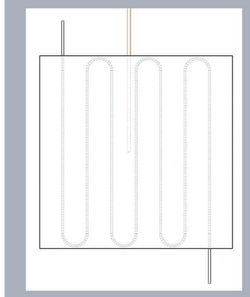

2. Waxing Mold

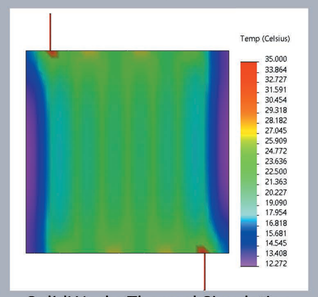

3. Laying Mesh, Wire, & TC


4. Final Carbon Fiber Layers

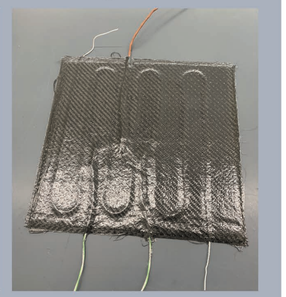

5. Sealing Assembly

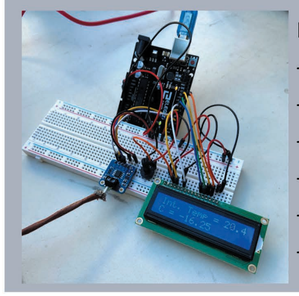

6. Vacuuming Excess Resin


SolidWorks Model



SolidWorks Thermal Simulation at -20°C environmental temp.

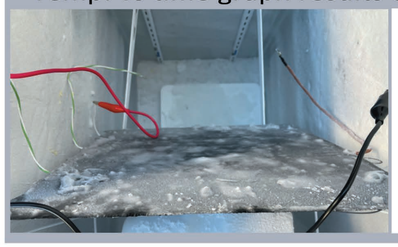

Final Prototype

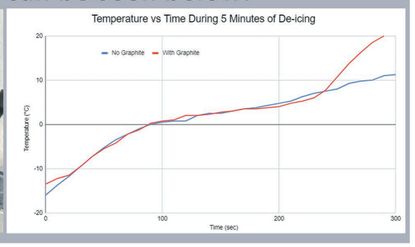


Electronics Package:
-Arduino Uno R3: Data acquisition.
-LCD display: Displays temperature.
-MAX31855: Thermocouple amplifier.
-K-Type Thermocouple: Temp. sensor.
-Potentiometer: Controls LCD contrast.
-32V DC Power Supply: Current for wires.

Testing

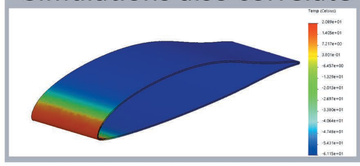
-Prototype testing was done inside of a freezer with added dry ice in order to simulate -22°C environmental temp.
-A total of 28V, 4.6A, and 128.8W of power were applied.
-Testing was successful with ~98% of the ice formation melting. Results did closely correlate with the simulations.
-Temp. vs time graph results can be seen below:





Final Design

-Final design will use main prototype components.
-Will be upscaled for use with NASA-LRN 1015 airfoils.
-Adaptable to other airfoil shapes as well.
-Since ice formation shape is thicker on middle of leading edge, wire spacing is closer together in those areas.
-Simulations also correlate with plate testing results.



Meet the Team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