Fiber optic based ice detector
to discriminate between App O and App C condition

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Contents

- Physical principle of INTA Fiber optic Detector (FOD)
- From individual sensor data to icing data
- IWT and Flight tests
- Summary
Basic Physical Principle
INTA Ice detection: FOD

Basic physical principle:

- Fiber optic Bragg grating sensors (FBGS) - Energy release due to liquid/solid transformation

Graph showing temperature changes over time with labels for ice and liquid phases.

Thermographic video

NACA0012 in IWT
Differentiate between App C and O

Aeronautic profile: NACA0012

INTA IWT
Differentiate between App C and O

New FOD detectors during IWT tests

FOD Sensor head design
8 FBGS the along chord

LWC=0.9g/m3
MVD=70 micron
-10°C, 1min

LWC=0.3g/m3
MVD=20 micron
-10°C, 1min
INTA Ice detection: tests performed

<table>
<thead>
<tr>
<th>Icing conditions tested at INTA-IWT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>App C</strong></td>
</tr>
<tr>
<td>Tubes_C1</td>
</tr>
<tr>
<td>Tubes_C2</td>
</tr>
<tr>
<td>Tubes_C3</td>
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<tr>
<td>NGPDA_C4</td>
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<td>NACA0012_C4</td>
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<tr>
<td><strong>App O</strong></td>
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<td>NGPDA_O1</td>
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<td>NGPDA_O2</td>
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<td>NACA0012_O1</td>
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<tr>
<td>NACA0012_O2</td>
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</tbody>
</table>
Example: IWT test

Stage 1

- IWT running at 70m/s and -14°C
- No water spray
Example: IWT test

Stage 2

- Spray is on. Ice forms at sensor 7 close to leading edge, and sensor 6 and 5.
- Rime ice
- App O
- No run-back water.

T = -14°C
LWC = 0.3
MVD = 40 μ
V = 70 m/s

Video

Sensors

Spray

Graph: Logarithmic Ice Growth Rate vs. Ambient Temperature
Stage 3

- Spray for 1 minute
- Ice is also forming and detected on S6 and S5.
From individual sensor data to icing data
From individual sensor data to icing data

**Sensor data**

Raw output of each sensor

**Icing data**

\[
LWC = f(\Delta T_{Sp}) \\
ACC = f(\Delta T_{Sp}) \\
MVD = f(\Delta T_{Sp}, \Delta T_{S7} \ldots \Delta T_{S2}) \\
ACC_O = f(\Delta T_{S7} \ldots \Delta T_{S2}) \\
ACC_{THK} = \frac{LWC \times e_b \times TAS \times t}{\rho_{ice}} \\
ACC_{RATE} = \frac{LWC \times e_b \times TAS}{\rho_{ice}}
\]
From individual sensor data to icing data

\[ \text{LWC} = f(\Delta T_{Sp}) \neq f(\text{MVD}) \]

<table>
<thead>
<tr>
<th>LWC [g/m³]</th>
<th>MVD [micron]</th>
<th>S8</th>
<th>S7</th>
<th>S6</th>
<th>S5</th>
<th>S4</th>
<th>S3</th>
<th>S2</th>
<th>S1</th>
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<table>
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<tr>
<th>GLAZE P3.5 ΔT [°C]</th>
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<tbody>
<tr>
<td>LWC [g/m³]</td>
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<td>0.95</td>
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Fligh tests
INTA FOD performed flight tests

Optional second sensor probe

First sensor probe (SENS4ICE configuration)

Spacer to lift the probe into the free air flow

Sensor configuration from flight tests at INTA in C212 aircraft

Al Sensor probe in IWT Heater (optional)

Fiber optic Interrogator Si155 from Micron Optics 3kg/30W

Actual sensor position
Specific topics

- Pairing: NRC AIWT
- Pairing: EMBRAER Phenom 300

Impingement/free air flow definition to evaluate extension length
Summary
Summary

- Fiber optic sensor FOD has a high potential for ice detection in A/C
  - Light weight, robust
  - Low consume
  - Electro Magnetic Interference (EMI) safe

- First App C and App O detection has been shown in INTA IWT tests

- Possibility for evaluation of:
  - MVD
  - LWC
  - Ice thickness/ accretion

- Very good detection in RIME, more complicated in GLAZE

- Future development
  - Characterization in critical App O condition (NRC IWT tests) with low LWC
  - Optimization of the evaluation software
  - Optimization of the sensor head development
  - Demonstration in flight tests
Thank you for your attention

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Visit our website: www.sens4ice-project.eu