Indirect ice detection for the hybrid ice detection system

SAE symposium

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In Aviation

шей Icing is a relevant issue for aviation
  - Safety of flight
  - Turnaround time
  - Costs and resources

шей Factors increasing likelihood to encounter icing:
  - High speed relative to ice or fluid particles
  - Wide range of temperatures during one single flight
  - All kinds of atmospheric disturbances and weather phenomena
  - Long ranges passing different climate zones
Dangers of Icing in Flight

**Vertical Tail Plane**
- Control degradation
- Drag increase

**Elevator Gap**
- Control degradation

**Stabilizer**
- Control degradation
- Drag increase

**Engines**
- Danger of flameout or damage due to contaminants

**Aileron Gap**
- Control degradation

**Wing**
- Performance loss
- Control degradation

**Fuselage**
- Drag increase
- Collected contaminant ice layer

**Sensors**
- Malfunction
- Blockage

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Means to Identify Icing

- Visual cues
- Change in powersetting
- Weather forecast / radar
- Pilot experience

[Links and images related to aviation and icing]
Situational Awareness

- Cues for the flight crew are given but not 100% reliable.

- Today’s situation:
  - Ice detection by performance monitoring is commonly established in commercial aviation
  - Pilot experience and procedures play a significant role in counteracting icing
  - Room for interpretation – room for false or missed decisions
Indirect Ice Detection within the Hybrid Ice Detection System

Direct Sensors focus on the surrounding environment
- Atmospheric icing conditions detectors
- Median volume diameter (MVD)
- Liquid water content (LWC)
- Air temperature
- Ice accretion rate (IAR)
- ...

Indirect System regards the aircraft itself
- Engine parameters
- Aero parameters
- Inertial data
- Aircraft configuration
- ...

The mix of internal and external information creates additional value
- Reliability
- Accuracy
Indirect System Design

- **Engine Data**
  - N1
  - Torque
  - NPropeller

- **Inertial Data**
  - Rates
  - Accelerations
  - Speeds
  - Mass/Inertia

- **Aerodynamic Data**
  - Airspeed
  - Angle of Attack
  - Angle of Sideslip

- **Control Data**
  - Control Surface Position
  - Configuration

Performance Calculations

\[ \dot{E}_{total} = \sum_{k=0}^{n} \ldots \ldots \]

Reference Model

- \( \dot{E}_{total,ref} \)

Comparison

- \( \Delta \dot{E} \)

Alert

Detection

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System Performance

Conflicting demands

Detection time

- Early detection information
- Enable early countermeasures
- Faster than any hazardous effects could occur

Trade-Off

Detection accuracy/reliability

- Prevent false alarms
- Increase reliability of detection information
- Increase situational awareness
- Basis for automatic system response

System is based on ice accretion effects on performance (continuous change, no significant step)

→ Determine a threshold that represents the necessary compromise
Detection Performance I

Reference Aircraft
No Ice

Calculated Aircraft
Iced

Lift coefficient

Drag coefficient

0.5 Quantile
0.9 Quantile
0.99 Quantile
0.9999 Quantile
1 Quantile
best fit
Detection Performance II

Necessary:

- Good aerodynamic database / model
- Good engine database / model
- Sufficient sensor quality and quantity
- Sufficient computing power

<table>
<thead>
<tr>
<th></th>
<th>EMB Phenom 300</th>
<th>ATR 42</th>
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<tbody>
<tr>
<td>Data available</td>
<td>2.3 million flight data samples</td>
<td>80000 flight data samples</td>
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<tr>
<td>Parameter of S4I flight test configuration</td>
<td>Flight tests with clean aircraft before icing flight's for parameter adjustment</td>
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Detection Threshold

- Threshold determination depends on several factors
  - Aircraft type
    - Features of the specific A/C type
    - Critical ice accretion
    - Corresponding change of flight characteristics
  - Expectable ice accretion rate
    - Flight speed and trimming
    - Collection efficiency
  - Accuracy of calculations depend on quality of
    - Used reference (thrust models, aerodynamic database, flight test database)
    - Flight data (sample times, delays, synchronization, sensor quality)

- Poor data quality causes miscalculations
  - Filtering necessary to prevent multiple false alarms
  - Time delay before reliable detection alert
  - Higher threshold value to prevent false alarms
Indirect System in S4I Flight Test

- Basic Indirect Ice Detection System design is generic
- Switches and different datasets (configuration and reference) foreseen for two flight test campaigns

**American Campaign**
- EMB Phenom 300
- Direct Sensors
- Aircraft Bus System
- ATR FDAU + Safire Measurement Installation

**European Campaign**
- ATR 42 SAFIRE
- Direct Sensors

HIDS = Hybrid Ice Detection System

- Input Conversion and selection
- IIDS = Indirect Ice Detection System
- Performance Calculation
- Reference Calculation
- Comparison and Alert
- Evaluation & Arbitration

- Choice of A/C,
- A/C parameters,
- …
Outlook

(SENS4ICE aims for flight tests of the indirect ice detection system in the frame of the hybrid ice detection system)

- It will be tested on a jet as well as a turboprop aircraft

- All flight data gathered will be used for tuning of the current system and for future system design changes (offline and post flight)
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Visit our website www.sens4ice-project.eu and Linkedin #sens4iceproject