Aircraft Icing Research Alliance

3-D Ice Accretion Codes Workshop

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3-D Icing Codes Workshop

- Issues for acceptance of 3-D ice accretion codes by regulatory authorities for aircraft icing certification
- Status and needs for standards, guidance, and acceptable practices for 3-D codes
- Validation plans for a publicly available swept wing ice shape and aero-performance database for code verification and performance studies
- Approach for 3-D ice accretion code working group to help identify paths to improve tools
- Forum for establishing a working group to continue developing the principles of this workshop

FAA Motivation

- Many new Part 25 and Part 23 that are ice-protected have modern airfoil designs with swept wings and other compound-geometry, 3D surfaces.
- The suite of icing engineering tools used for aircraft design and certification include computational fluid dynamics (CFD) analysis methods.
- New rulemaking for SLD icing conditions will increase the use of computational tools as a means of compliance

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FAA Motivation

- 2D ice accretion codes have a well documented history of use with substantial verification and validation data.
- However, use of 3D ice accretion codes is not well understood outside of the developers and a few expert-level users.
  - 3D ice accretion code routines for analysis of swept wing airfoil designs are complex and not easily understood.
  - There is very little public experimental data for both verification and validation of 3D icing codes.

FAA Motivation

- During an aircraft certification effort, the FAA Aircraft Certification Offices are often challenged to:
  - Determine how well the engineering tools operate and if they are being used appropriately,
  - Determine how to assign a confidence level to the resulting analysis.
- There is very little experimental data and no historically acceptable public, benchmark database the codes can be compared to

3-D Ice Accretion Code Use for Certification

- **Limited information for guidance is available**
  - AC 20-73A “*Aircraft Ice Protection*”
    - Appendix I Droplet Impingement and Water Catch
      - Page I-2: *…“You should provide experimental confirmation in the form of wind tunnel, natural icing, or tanker data to support the calculated flow field and drop impingement.”*

        … “You should consider SAE ARP5903 when judging the acceptability of drop impingement analyses performed using computer codes.”

3-D Ice Accretion Code Use for Certification

- **Limited information for guidance is available**
  - AC 20-73A "*Aircraft Ice Protection*"
    - Appendix K Ice and Icing Conditions Detection
      - Page K-4: …*"Some impingement computer codes calculate the quantity of runback icing. They do not address the runback ice characteristics nor water mass loss because of drop splashing or shedding. Also, the runback results of these codes have not been validated using wind tunnel or flight tests. Therefore, you should use icing wind tunnel tests to examine the splashing, shedding, and runback characteristics of the ice detector."*

3-D Ice Accretion Code Use for Certification

- **Limited information for guidance is available**
  - AC 20-73A "*Aircraft Ice Protection*"
    - Appendix R Ice Shapes
      - Page R-13: … *"Computer codes may be unable to estimate the characteristics of the runback water or the resultant ice shapes. Some codes may be able to estimate the mass of the runback ice. Until computer codes are developed and accepted, determine runback ice empirically by natural icing tests, icing tanker tests, or icing wind tunnel tests."*
      - Page R-37: … "Ice accretion codes with 3D flow field and drop trajectory abilities, coupled to a 2D ice accretion calculation, have been developed to predict 3D ice shapes. The experimental ice shape data available for verifying these pseudo 3D ice accretion codes is limited. Therefore, confidence in these ice accretion codes is limited."

3-D Ice Accretion Code Use for Certification

- **Limited information for standards and guidance are available**
  - SAE ARP 5903 *"Droplet Impingement and Ice Accretion Computer Codes"*
    - Page 9, Section 3.2: …*"It is not the intent of this document to evaluate experimental data to assess the performance of any of the codes listed, nor is this document intended to provide guidance as to whether a particular code is acceptable or has been validated."*

Swept Wing – Validation Studies are Needed

- There are no experimental aero-performance and flowfield data on the effect of ice on swept wing aerodynamics at high-Reynolds number in the public domain.
- There are no full-scale, high-Reynolds number research quality ice accretion data on complex 3-D geometries in the public domain.
- There are some good low-Reynolds number aerodynamic data by Papadakis, Ratvasky, Lee, Bragg, and others.
- We have a basic understanding of swept wing ice accretion from IRT experiments, but at small scale.

Slide courtesy of NASA

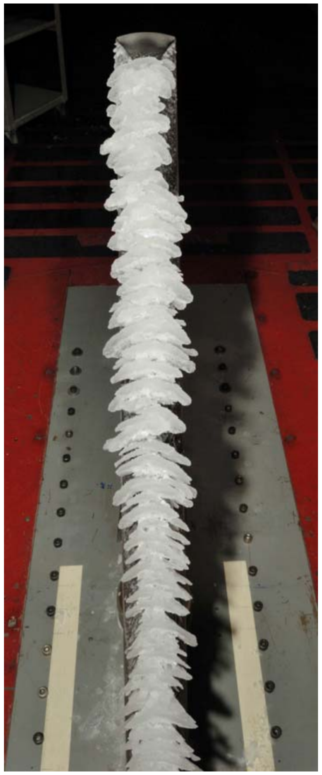
FAA – Support for Swept Wing Database

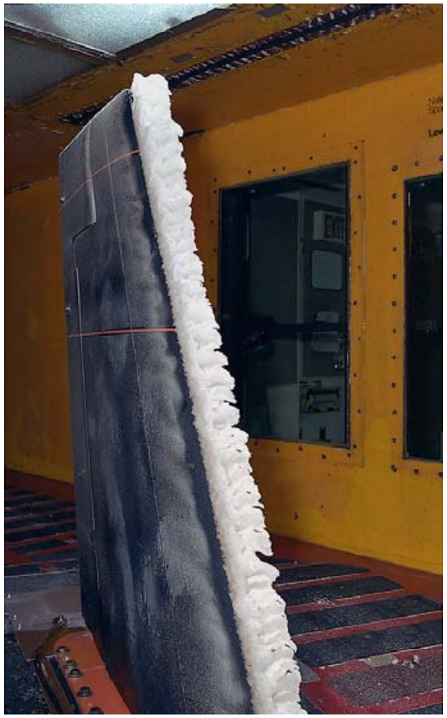
- Swept wing experimental studies are needed to
  - Build a publicly available ice shape database that can support validation for 3-D ice features and ice accretion prediction codes.
  - Improve the knowledge of iced aerodynamic phenomena to support a basic understanding of airflow effects due to ice contamination and for use of aero analysis methods.

The operational benefit for 3-D ice accretion and aerodynamic effects studies is directly related to current and upcoming certification guidance material needed by the FAA to support the acceptability for use of 3-D icing codes for aircraft icing certification.

3-D Aerodynamic Icing Simulation

- 3-D icing codes are being developed for swept-wing ice accretions but the validation data are limited
- An understanding of icing effects on swept-wing aerodynamics is critical to evaluating the accuracy to which ice accretions must be predicted by computational tools or simulated in aerodynamic testing.
- An understanding of scale effects including Reynolds and Mach number is needed to develop/validate lower cost aerodynamic test techniques for iced swept wings.
- Aerodynamic data are needed for validation of computational flow simulation (CFD) codes for iced-wing configurations.





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3-D Aerodynamic Icing Simulation

Discussions have started between NASA, ONERA, FAA, and UIUC to develop a 3-D swept wing experimental project

Overall Goal

- Improve the fidelity of simulation methods, both experimental and computational, for swept-wing ice accretion formation and resulting aerodynamic effect.

Objectives

- Measure 3-D ice accretion geometry for icing code development/validation and for follow-on aerodynamic testing.
- Develop a systematic understanding of the aerodynamic effect of icing on swept-wings including: Reynolds and Mach number effects, important flowfield physics and fundamental differences from 2-D.
- Determine the level of geometric fidelity required for accurate aerodynamic simulation of swept-wing icing effects.

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Next Steps

- Continue plans to develop a publicly available 3-D aerodynamic icing database
- Use past experience with NATO/RTO working group on icing simulation tool evaluation for 2-D ice accretion codes as a model for code evaluation strategy for 3-D
  - WG has code developers, users, and regulatory authorities
  - WG uses existing and TBD ice shape cases in similar format to RTO working group 2-D evaluation
  - WG identify areas of research needed to support improvements in physical models for heat transfer and roughness, water film transport, ice accretion, and flow field phenomena
- Consider AIRA as a forum for a WG