National Aeronautics and Space Administration

Airframe Icing Research Gaps
NASA Perspective

Airframe Icing Workshop
NASA Glenn Research Center

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Current Airframe Icing Technology Gaps (1/2)

Computational Methods

- Development of a full 3D ice accretion simulation model
- Development of an improved simulation model for SLD conditions
- CFD modeling of stall behavior for ice-contaminated wings/tails
- Computational methods for simulation of stability and control parameters
- Analysis of thermal ice protection system performance

Experimental Methods

- Quantification of 3D ice shape geometric characteristics
- Development of accurate ground-based simulation of SLD conditions
- Development of scaling methods for SLD conditions
- Development of advanced diagnostic techniques for assessment of tunnel cloud conditions
- Identification of critical ice shapes for aerodynamic performance degradation
- Aerodynamic scaling issues associated with testing scale model ice shape geometries
- Development of altitude scaling methods for thermal ice protections systems

Current Airframe Icing Technology Gaps (2/2)

Flight Dynamics

- Development of accurate parameter identification methods
- Measurement of stability and control parameters for an ice-contaminated swept wing aircraft
- Creation of control law modifications to prevent loss of control during icing encounters

Experimental Databases

- 3D ice shape geometries
- Collection efficiency data for ice shape geometries
- SLD ice shape data, in-flight and ground-based, for simulation verification
- Aerodynamic performance data for 3D geometries and various icing conditions
- Stability and control parameter data for iced aircraft configurations
- Thermal ice protection system data for simulation validation

Airframe Icing Research
Aviation Community Areas of Interest

Fixed Wing Airframe Icing

- Ice Accretion Simulation
  - Ground based facilities
  - Computational methods

- Development of SLD 'Means of Compliance'
  - SLD Icing physics
  - SLD scaling methods
  - Modify ground based facilities
  - Modify computational methods

- Iced Aircraft Performance Evaluation
  - Ground based facilities
  - Computational methods
  - Flight Simulation
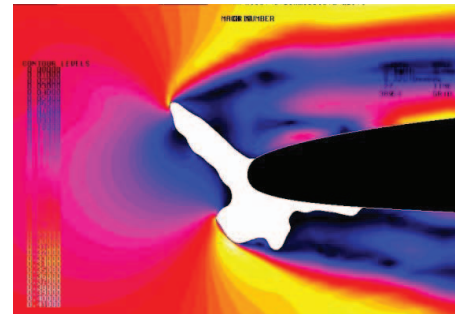
Fixed Wing Airframe Icing

Ice Accretion Simulation

Issue: Methods are needed to simulate, experimentally and computationally, the process of ice growth on aircraft surfaces to reduce flight test cost and to improve safety. These methods are used for design, analysis, and certification efforts performed by industry and government.

Gaps: Our ability to model ice growth on swept wings, future generation aircraft configurations (e.g. blended wing body), and for Supercooled Large Droplet (SLD) (i.e. freezing drizzle and rain) conditions are limited and lack a comprehensive database for validation. Ice accretion physics, such as, water film dynamics on ice substrates and heat transfer augmentation on complex rough ice surfaces are not well understood and require further research. Also, ice accretion scaling methods need to be extended and validated for large scale configurations envisioned for next-generation aircraft.

Current NASA effort: Ice growth on subscale swept wings is being investigated in understanding intelligent controls response to an icing encounter.

Potential NASA Role to Fill Gaps: Full scale swept wing and SLD ice accretion simulation research.

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Fixed Wing Airframe Icing

Development of SLD 'Means of Compliance'

Issue: Methods are needed to simulate, experimentally and computationally, the process of Super-cooled Large Droplet (SLD) ice growth on aircraft surfaces to reduce flight test cost and to improve safety. These methods are needed for industry to have a 'means of compliance' with proposed regulations for flight in SLD conditions.

Gaps: Modifications to the Icing Research Tunnel (IRT) and associated instrumentations are needed to simulate SLD environments. Deficiencies in knowledge of droplet dynamics (i.e. droplet breakup, impingement, and splashing) and feather formation for SLD conditions still exist. Computational modeling is largely based upon empirical information and correlations. Current means of compliance does not cover the full range of SLD conditions. Scaling methods are not adequately validated for SLD environments. Note: These gaps are in addition to those in "ice accretion simulation."

Current NASA Effort: Testing at a limited set of SLD conditions is currently performed as part of the existing icing physics programs.

Potential NASA Role to Fill Gaps: Expansion of limited IRT SLD capabilities; improve and validate scaling methods for SLD; more comprehensive SLD physics studies performed at icing physics flow lab; improve and validate ice accretion models

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Fixed Wing Airframe Icing

Iced Aircraft Performance Evaluation

Issue: Methods are needed to simulate, experimentally and computationally, the degradation in performance of an aircraft exposed to in-flight icing conditions. These methods are used for design, analysis, and certification efforts performed by industry and government. Information from this research is used to provide input to controls-based remediation efforts.

Gaps: Limited capability with either experimental or computational methods to determine performance changes (lift, drag, stability and control) for iced aircraft. This is related to limited understanding of Reynolds number and ice accretion geometry scaling for swept wing and full aircraft configuration. Applications of computational methods (e.g. turbulence, roughness, grid generation) to iced surface has not been adequately validated.

Current NASA Effort: Use Generic Transport Model (GTM) for examination of controls response to ice build-up. Note: Experimental effort is subscale and computational effort is both full- and subscale. Development of a CFD approach to calculate influence of ice build-up on aircraft aerodynamics and resulting control system behavior.

Potential NASA Role to Fill Gaps: Full scale, high Re number iced modern aircraft (e.g. swept wing) aerodynamic research and validation database development

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Discussion of Airframe Icing Technology Gaps

It is our desire to compare the technology gaps identified in this presentation with those deemed of importance to industry and other government organizations and come to some consensus on what research areas should be pursued if appropriate resources become available.