Current CFD Capabilities for SLD Modeling
A Gulfstream Perspective

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CFD Icing Tool Use at Gulfstream

Primary Use: Part 25 Certification

Majority of use (80-90%)

- 3D use on non-lifting surfaces

- Safety of flight eval with unprotected surfaces

- Need for ice protection

Occasional use (10-20%, but still very important!)

- Ice protection system design/analysis

CFD Icing Tool Use at Gulfstream

Tools in Use at Gulfstream

Lewice 2D

- **Preliminary WAI design studies for bleed heated wings**

Fluent

- **Internal leading edge and piccolo tube flows for bleed-heated WAI design and analysis**

Current Use of CFD tools for Icing

LEWI3DGR

Gulfstream's primary MOC for 25.1419 cert-by-analysis.

- **3D collection efficiency distributions for WAI design.**
- **Ice shape generation for wind tunnel performance effects testing.**
- **Simulated ice shapes for certification dry air testing.**
- **Workhorse analysis tool for aircraft external mod certification.**
  - **Antennas**
  - **Radomes**
  - **Fairings**
  - **Probes**
  - **Drain masts**
  - **Cameras**
  - **Auxiliary Inlets**
  - **Etc.**
- **Majority of use is NOT airfoil icing.**

Current Use of CFD tools for Icing

Example: Special Mission Airplane Modifications

LEWI3DGR used for

- **Ice Protection Requirements**
- **Ice Detector Location**
- **Ice Drag**
- **Ice Buffet & Vibe Assessments**
- **Simulated Shapes for Flight Test**
- **Shapes for Ingestion and Impact Analysis**
- **Ice Effects on Air Data System**

Need for SLD Icing Tools

SLD icing tools are needed at Gulfstream to satisfy regulations. Safety of flight has not been an issue.

- **The icing atmosphere is the same as it always has been.**
- **Exceedence of Appendix C envelopes is rare, even in flights dedicated to finding SLD conditions.**
- **Gulfstream business jets have been operating worldwide in this atmosphere safely for 40 years.**
- **There is no issue with safety of flight of Gulfstream aircraft in icing conditions. We need tools strictly to show compliance to regulations aimed at a separate, lower performing class of airplanes.**

Readiness of SLD CFD tools

Developers know better than industry the capabilities of the latest models in their icing tools.

"Readiness" means to Gulfstream "Ready to be used in certification efforts"

- **Cold truth: No icing tool is considered validated by FAA, but some are grudgingly accepted due to valiant efforts of the icing community and FAA icing experts.**

- **Readiness will entail satisfying regulatory bodies that the tools satisfactorily model currently identified large droplet phenomena:**

  - **Aerodynamic deformation**
  - **Splashing**
  - **Breakup**
  - **Bouncing**
  - **Reimpingement**

Readiness of SLD CFD tools

A *beta* version of an SLD tool is of little use for certification.

A *released* version of an SLD tool requires a substantial base of validation data, obtained from flight or from SLD-accurate icing tunnels, with associated validation test cases, to satisfy authorities.

Readiness of SLD CFD tools

Readiness Summary

- **The FAA is not going to step forth and bless any SLD tool as "ready" or valid.**

- **Only a history of code use, certification experience, and accumulation of certified aircraft fleet hours will earn grudging acceptance.**

- **For Gulfstream's purposes, where SLD icing is not a safety concern, SLD tool developers should target efforts to produce released versions of their codes, with substantial validation cases, to coincide with codification and enforcement of proposed rules.**

Strengths/Weaknesses of Current Tools

These comments are primarily regarding Lewice 2D and 3D

Strengths:

Gold standard, NASA codes with excellent reputations built on the technical expertise of top icing researchers and laboratories.

Continuous improvement efforts with openness to industry suggestions for improvements.

Excellent support.

Droplet trajectory, impingement and accretion modeling are very good.

Allows use of any flow solver.

Possible to employ for certification credit, with appropriate care and established relationship with FAA.

Free in the good old USA.

Strengths/Weaknesses of Current Tools

These comments are primarily regarding Lewice 2D and 3D

Weaknesses:

Limited capabilities compared to some of the newer technology codes available.

Validation always an issue, although Lewice 2D is probably the closest thing to being a validated code in USA.

Integration of impingement and heat transfer models with ice protection system design is limited to 2D.

Assembly and analysis tools for 3D ice shapes almost nonexistent.

Recommendations for Further SLD Research

Current focus

- **Understanding SLD impingement physics and creating initial modeling algorithms, primarily on 2D airfoils.**

Future needs

- **3D, non-lifting surface SLD analysis tools.**
- **Ice accretion in SLD / mixed conditions validated against SLD tunnel database.**
- **Ice protection design and analysis in SLD conditions.**

Prioritization of Efforts

- **Integrate SLD capabilities into existing Appendix C tools**
- **Assemble SLD validation database**
- **Prepare and document validation cases**
- **Develop ice protection design and analysis capability**
- **Prepare release version of tools**
- **Establish training in new capabilities**


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