3-D Ice Accretion Code Workshop – BCA Perspective

Ben Paul
Cris Bosetti
Adam Malone
Aerodynamics Engineering
Boeing Commercial Airplanes
August 4th, 2010

Introduction

Topics to be covered in the presentation

- Current use of 3-D ice accretion codes
- Issues for acceptance by the regulatory authorities
- Validation experiences from icing or dry-air tunnel testing required to support code acceptance
- Interest in supporting and approaches for validation data and inter-code comparisons studies
- Interest in supporting future AIRA working groups to continue developing the principles of this workshop

Introduction – Current Use of Ice Prediction Codes

- **A substantial portion of the flight-in-icing certification flight testing is performed with artificial ice shapes.**
- **Analysis tools, such as LEWICE3D, in combination with icing-tunnel data, are used to determine ice shapes for the flight-in-icing scenarios required for certification.**
- **Aerodynamics is responsible for determining icing effects on aerodynamic performance and handling characteristics.**
  - **Design and Product Development:**
    - **dry-air wind-tunnel tests**
    - **piloted simulator sessions**
  - **Certification: Natural and artificial ice flight tests**
- **The critical shape should be assessed based on the integrated effects on handling qualities (and not purely by inspection of the lift and pitching moment characteristics).**

LEWICE3D

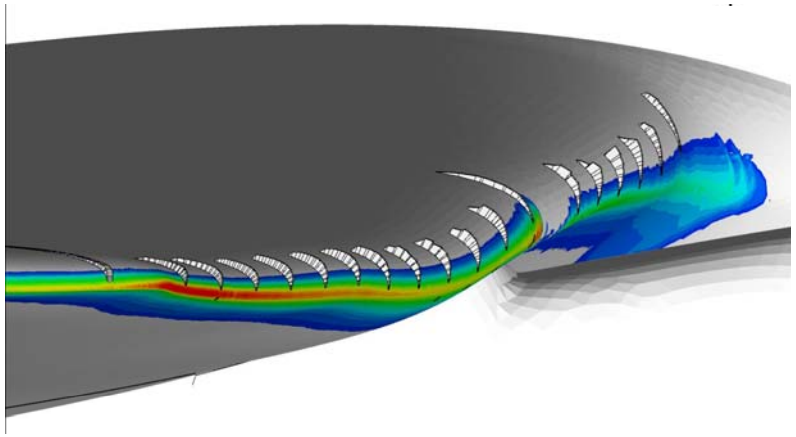
Boeing has built an ice shape generation toolkit, of which LEWICE3D version 45 is the centerpiece. The toolkit has the following features:

- **A software package that streamlines the use of LEWICE3D and makes it compatible with other Boeing processes.**
- **LEWICE3D Version 45 from NASA which includes**
  - **an improved icing roughness model, which has a large effect on heat transfer.**
  - **a new ice density model, which approximates the farthest-extent tracings of scalloped ice shapes (currently not in use at Boeing).**
  - **an off-surface water collection efficiency flux capability.**
  - **the capability to use local temperature information from flow-fields input into LEWICE3D instead of calculating the information using local surface pressure.**
- **The initial verification of the Boeing internal package was completed utilizing icing tunnel data.**
- **The system is under version control and synchronized with a particular version of LEWICE3D tool.**

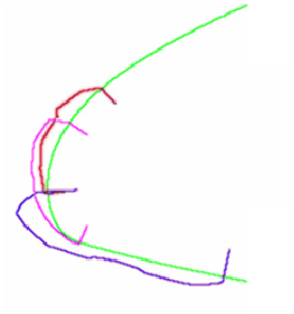
Airplane study

General shape generation process

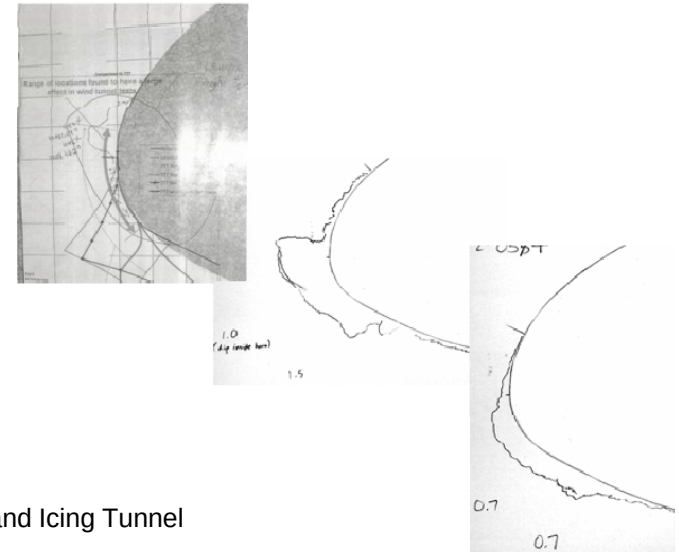
- **Define representative mission profiles**
- **Generate 3D Navier-Stokes flow solutions**
- **With the flow solutions, generate ice shapes using LEWICE3D**
- **Verify ice shapes using icing wind-tunnel tests**



A range of LEWICE predicted shapes were considered



Shape extremes verified with BRAIT



Notes: -Sketch and tracings may not be the same scale
-BRAIT is the Boeing Research Aerodynamics and Icing Tunnel

Summary – Ice Accretion Modeling Tools

- **LEWICE3D captures 3D icing information**
  - **impingement limits, water catch, and some shape characteristics**
  - **spanwise characteristics which allow for creation of 3D ice shapes**

- **LEWICE3D allows for rapid generation of ice shapes throughout the entire Appendix C icing envelope**
  - **Provides for a broad look at many ice shapes.**
  - **Supports Product Development cycles for Aero/Systems requirements and design, and wind-tunnel test configuration ice shape development.**

- **LEWICE3D cannot be used as a black box. With an understanding of the icing envelope, you can use the code to determine the range of ice shapes required for an exhaustive analysis of aerodynamic performance and handling qualities.**

Boeing's Goals

Some of Boeing's goals for 3-D ice accretion simulation tools from an aerodynamics perspective

- **Eliminate icing tunnel testing for the generation of ice shapes used for Aerodynamic analysis**
- **Streamline the icing process**
  - **Preparation/execution for Product Development aero configuration development**
  - **Minimize schedule flow for ice shape development**
  - **Establish standard methods/approaches for ice shape determination with the regulatory agencies**
- **Improve the effectiveness of the entire process**
  - **Understand the applicability and uncertainty of the information generated by the tools**
  - **Ensure that the ice shape features that matter are captured**

Cooperation

Why would Boeing have "Interest in supporting and approaches for validation data and inter-code comparisons studies?"

- **The cooperation would lead to the building of a database which includes ice shapes representative of large commercial airplane configurations. This would ensure tool development improvements include consideration of these configurations.**
- **Beneficial in terms of developing standard, verified, and validated tools that are accepted by the various regulatory agencies around the world.**
- **Working cooperatively with other organizations would improve our mutual understanding of icing-tunnel testing and data.**
- **Boeing would be willing to support future AIRA working groups to continue developing the principles of this workshop**


BOEING

LEWICE3D

Return

- Conditions considered for all of 14 CFR Part 25/CS 25 APPENDIX C
- Use a similitude approach to test the range of conditions in an icing tunnel
- Use the icing-tunnel ice shapes to compare against LEWICE3D ice shapes.
- Verify that the LEWICE3D predictions cover the range of possible ice shapes