Review of the NATO/RTO Ice Accretion Code Evaluation Workshop

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Presented to AIRA

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NATO/RTO WG Members

Eric Duvivier, DGAC, France (un-official member)
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Didier P. Guffond, ONERA, France
David W. Hammond, British Aerospace, U.K.
Eugene G. Hill, FAA, U.S.A.
Jack van Hengst, Fokker Services, The Netherlands
Richard J. Kind, Carleton University, Canada (Chair).
Sophie LeBerre, CEPr, France
Giuseppe Mingione, CIRA, Italy
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Outline

- Purpose
- Background
- Synopsis
- Recommendations

Purpose of the Workshop

- Provide a forum for public evaluation of existing ice accretion simulation software
- Aid developers/users/regulators in understanding the current state of the art
- Promote the development of standardized methods for evaluating software performance

Background

- Workshop first proposed during April 1994 meeting of AGARD WG 20
- NATO/RTO WG on Ice Accretion Modeling formed in Sept. 1998
- SAE Ice shape measurement and comparison workshop held in Seattle in April 1999
- Experimental database identified at Oct. 1999 meeting in Ft. Walton Beach, FL
- Ice shapes distributed to participants in 2nd quarter of CY 2000
- Blind results returned to WG in Sept. 2000
- Workshop held in Capua, Italy (CIRA) in Dec. 2000

Background

- Workshop was designed to be a blind test of the icing codes; I.e. the ice shapes were not distributed until all of the computations were completed
- Ice shapes were obtained from several sources to allow for differences in facilities, measurement methods, etc.
- Since some of the code developers were also the suppliers of the ice shapes, not every comparison was blind; Participants identified which comparisons were blind
- Ice shapes were then sent to participants prior to workshop to allow for “tweaking”

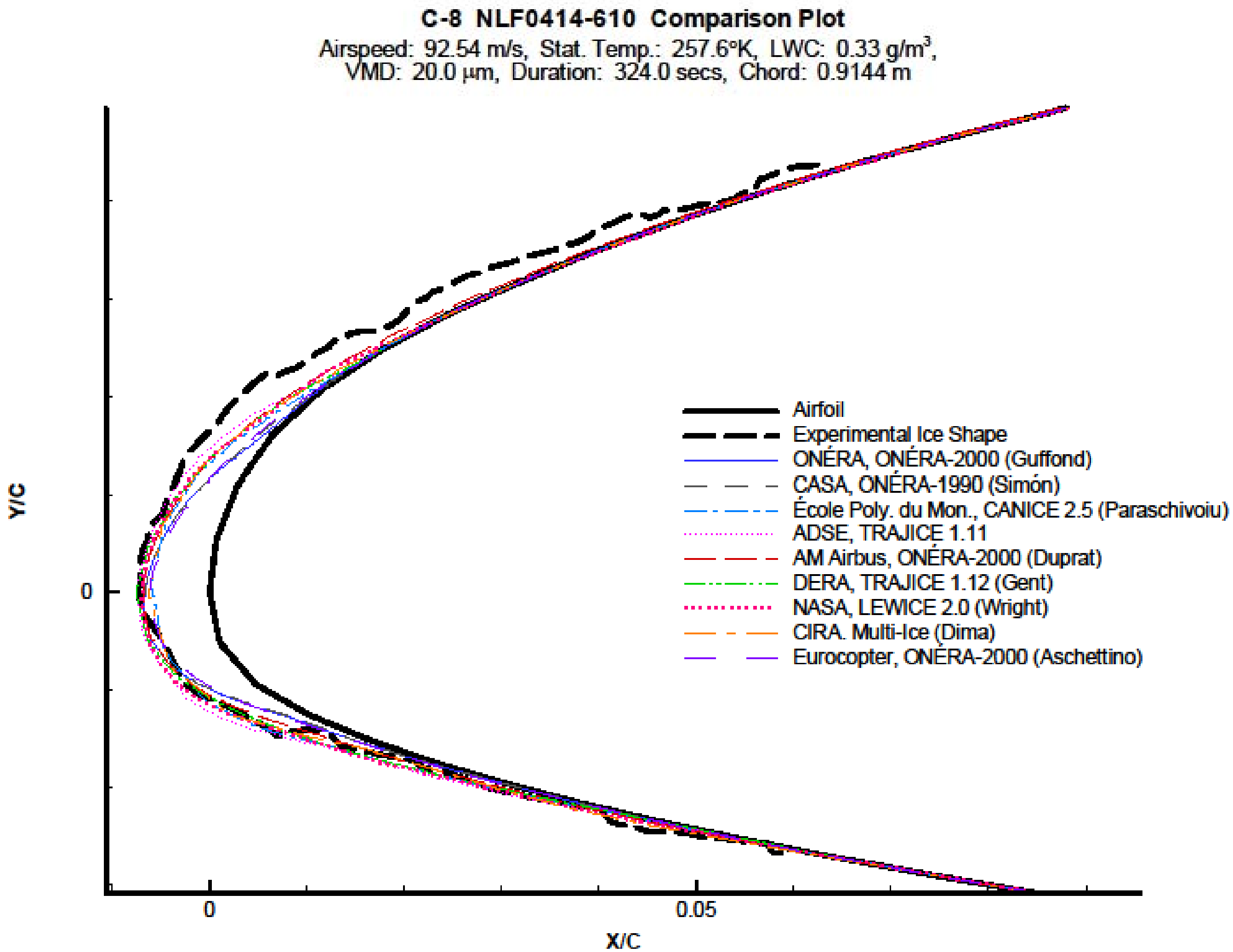
Core Data Cases

Case No.	Title	Provider	Description
C-1.	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
C-2.	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
C-3.	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
C-4.	DERA data (Artington icing tunnel)	Gent	NACA-0012
C-5.	DERA data (Artington icing tunnel)	Gent	NACA-0012, SLD
C-6.	LEWICE2 Validation data (IRT)	Potapczuk	GLC airfoil
C-7.	LEWICE2 Validation data (IRT)	Potapczuk	GLC airfoil
C-8.	LEWICE2 Validation data (IRT)	Potapczuk	NLF airfoil
C-9.	LEWICE2 Validation data (IRT)	Potapczuk	NLF airfoil
C-10.	LEWICE2 Validation data (IRT)	Potapczuk	NLF airfoil
C-11.	Multi-element Airfoil data (IRT)	Potapczuk	Multi-el. airfoil
C-12.	Multi-element Airfoil data (IRT)	Potapczuk	Multi-el. airfoil
C-13.	INTA/NASA Scaling Tests-533	Feo	NACA-0012, 533mm
C-14.	INTA/NASA Scaling Tests-267	Feo	NACA-0012, 267 mm
C-15.	Super Puma Run 8 (CEPr tunnel)	Guffond, Henry	Blade section, Test No. 8
C-16.	Super Puma Run 19 (CEPr tunnel)	Guffond, Henry	Blade section, Test No. 19
C-17	BRAIT Test Run 1017	Shah	Run 1017; NACA-0012
C-18	BRAIT Test Run 1018	Shah	Run 1018; NACA-0012

Optional Data Cases

Case No.	Title	Provider	Description
O-1	Jetstream 41	Hammond	In-flight icing
O-2	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
O-3	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
O-4	NASA Twin-Otter data	Potapczuk	In-flight icing (not available)
O-5	DERA data (Artington icing tunnel)	Gent	small cylinder
O-6	DERA data (Artington icing tunnel)	Gent	small-cylinder, SLD
O-7	DERA data (Artington icing tunnel)	Gent	large-cylinder
O-8	DERA data (Artington icing tunnel)	Gent	large-cylinder, SLD
O-9	LEWICE2 Validation data (IRT)	Potapczuk	NACA-0012
O-10	LEWICE2 Validation data (IRT)	Potapczuk	23014(mod)
O-11	LEWICE2 Validation data (IRT)	Potapczuk	LTHS airfoil
O-12	LEWICE2 Validation data (IRT)	Potapczuk	NLF airfoil
O-13	LEWICE2 Validation data (IRT)	Potapczuk	NLF airfoil

Sample Comparison Plot from the Workshop



Workshop Participants

Participant	Affiliation	Code Used
S. Aschettino	Eurocopter	ONERA 2000
N. Boer, F. Spek	ADSE	TRAJICE PC 1.11
C. Dima	CIRA	CIRA Multi-ice
G. Duprat	Aerospatiale Matra Airbus	ONERA 2000
R. Gent	DERA	TRAJICE PC 1.12
D. Guffond, R. Henry	ONERA	ONERA 2000
D. Hammond	BAe	ICECREMO
I. Paraschivoiu	Ecole Polytechnique de Mtl.	CANICE
F.J. Simon-Calero	CASA	ONERA 1990
W. Wright, M. Potapczuk	NASA	LEWICE 2.0

Synopsis

- Workshop was held on December 6&7, 2000 at the CIRA facility in Capua, Italy
- The datasets were described for the audience by Roger Gent of DERA
- Each participant presented their comparisons of simulation to experiment
- Discussion periods followed each presentation and after all the presentations

Synopsis

- Results indicated that most of the codes could do rime shapes and many glaze shapes adequately
- Difficult cases were high alpha, high M and cylinders
- No clear winner although DERA felt that the TRAJICE2 code was better than most
- TRAJICE2 was definitely better on cylinder shapes due to a correlation for convective heat transfer on a cylinder that other codes did not use
- Most comparisons were performed using the “co-plotting” technique
- Gent tried to systematize the evaluation of “co-plotted” shapes
- NASA was only organization to perform quantitative comparisons

Synopsis

- A report of the Workshop is available
- Report is available on the Web at http://www.rta.nato.int/Pubs/RDP.asp?RDP=RTO-TR-038 and contains:
  - All experimental data sets
  - All predictions from participants
  - All presentations from the workshop
  - Narrative description of the proceedings
  - Thick code for evaluation of the code predictions
  - Thick code results for each code prediction

Synopsis

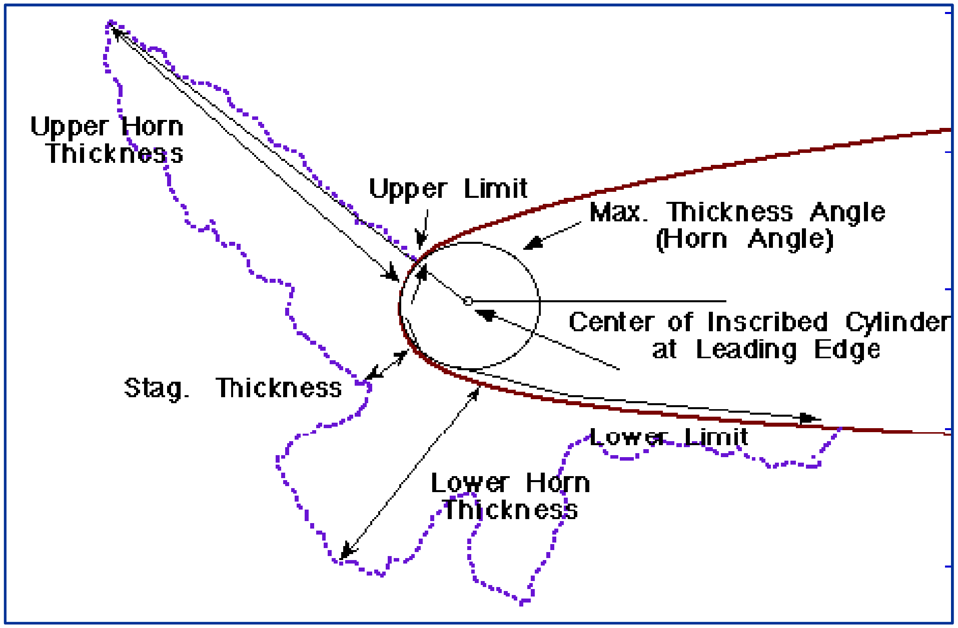
- Flight test comparison discussion centered on the difficulties associated with obtaining information from an inherently unsteady and highly variable environment
- I showed some tracings from a couple Twin Otter flights indicating the unsteady nature of the cloud data
- No real discussion of where to go in such comparisons
- Gene Hill indicated that this was still desirable from the point of view of the FAA

Recommendations

- Continue development of quantitative methods for comparison
- Connections must be made between code comparisons and requirements on accuracy; these are probably application specific
- More data from flight tests should be made readily available
- Another workshop should be held in a few years to assess the progress of ice accretion simulation software

Quantitative Ice Shape Comparison Parameters

- Icing limit
  - Upper and lower
- Horn height
  - Upper and lower
- Stagnation freezing fraction
  - Leading edge minimum thickness
- Horn angle
  - Upper and lower
- Iced area
- Ice weight (if measured)



Quantitative Evaluation of LEWICE Performance

Comparison of LEWICE results to experimental variation based on percent difference in measured ice shape quantities

- **Spanwise variability: 2.5% +/- 1.8**
- **Repeatability: 2.6% +/- 1.8**
- **Tracing technique: 1.3%**
- **Overall experimental error: 2.5% +/-1.8**
- **LEWICE comparison to exp.: 7.2% +/- 4.**