Validation Process for LEWICE by Use of a Naviér-Stokes Solver

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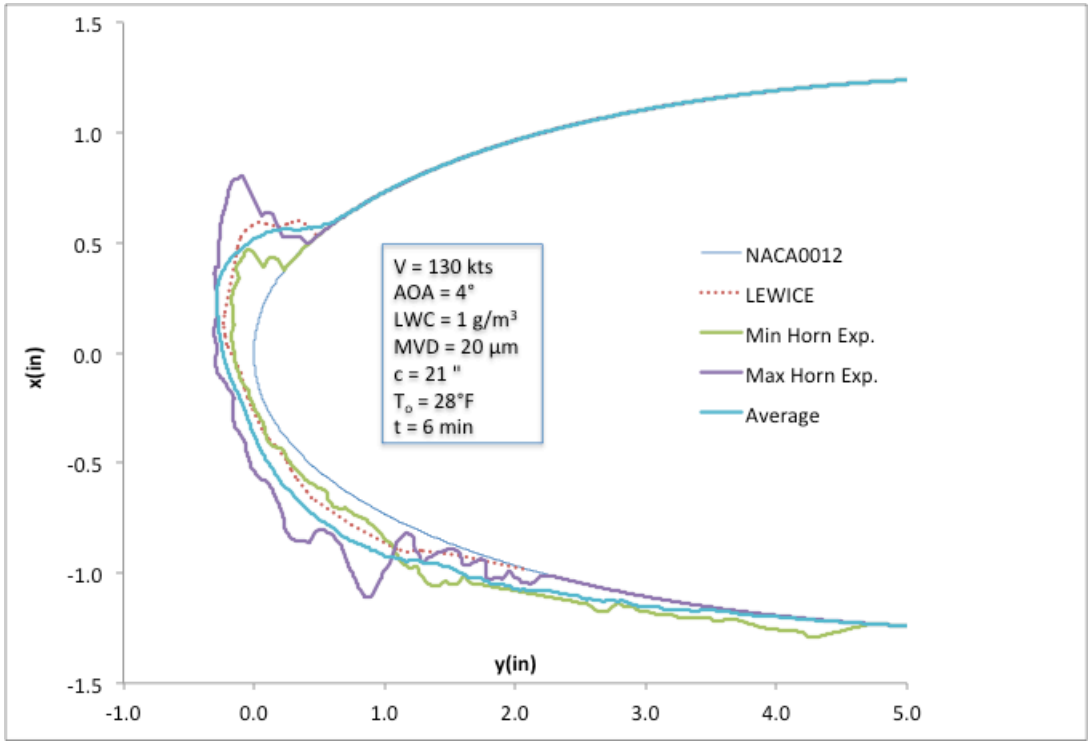
Outline

- Validation History
- LEWICE-Pointwise-FUN3D Script
- Validation Process
- Results

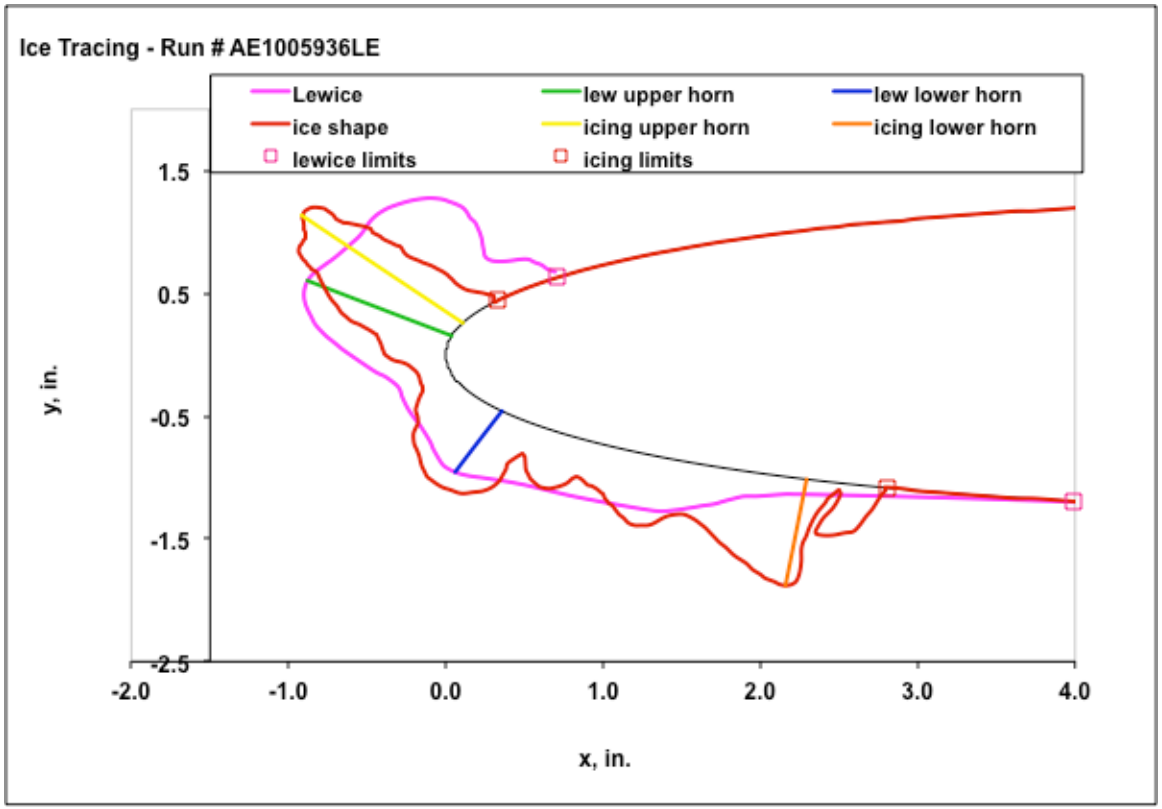
Validation History

- Many icing Codes Use a Small Set of Cases for Validation
- Typical Shape (below) from Tunnel Calibration Test
- 46 tracings available
  - Warm Glaze Shows Wide Variation in Experiment Shapes



Geometric Validation

- **Previous LEWICE Validations Were Limited to Geometry Comparison (THICK Utility)**



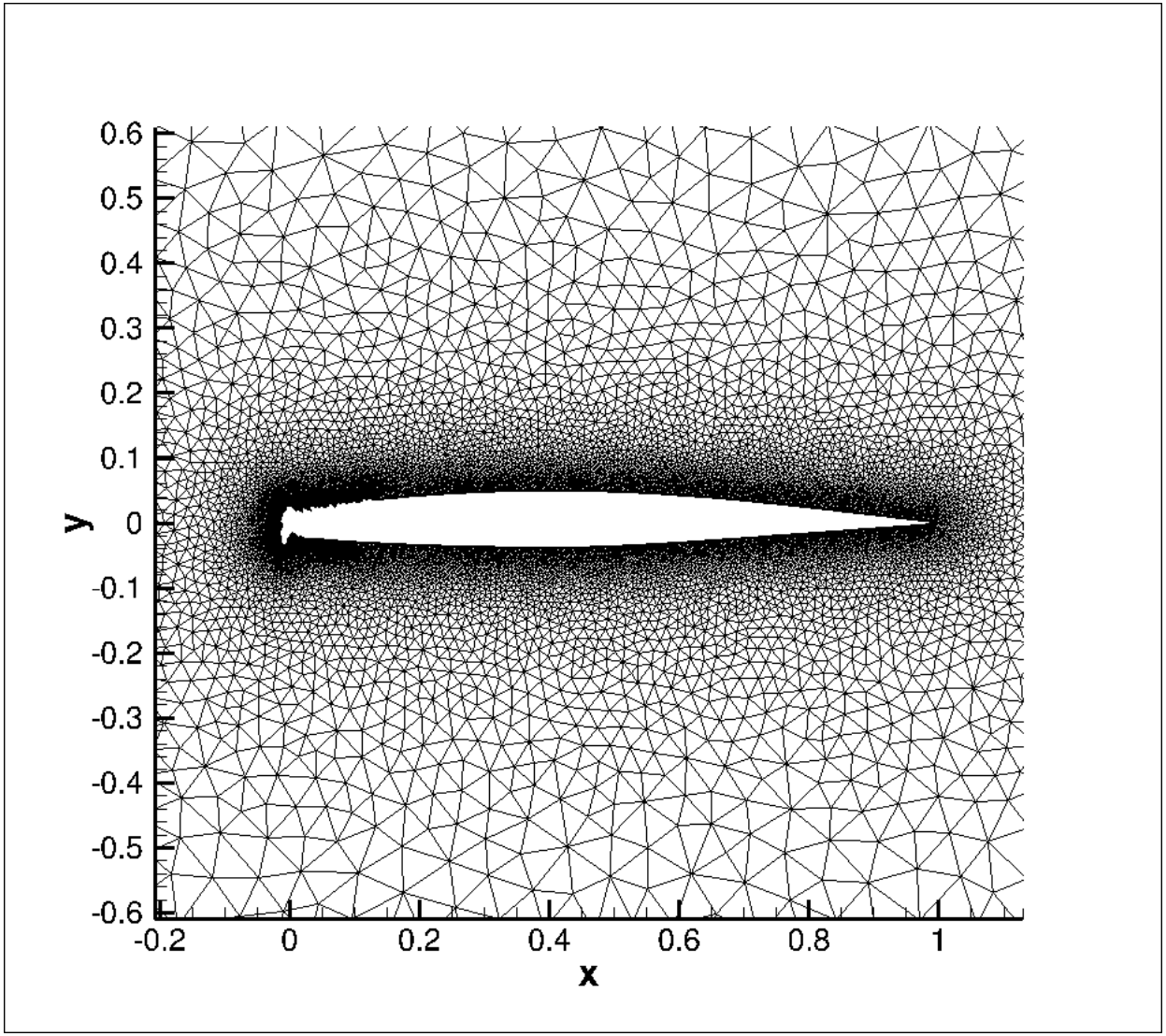
Revised Validation

- Perform Geometric Comparisons as Before
- Perform Naviér-Stokes Calculations On Tracings from Experiment and LEWICE Predictions
  - 12 conditions (all large glaze ice shapes)
  - Compare lift and drag (AOA from -6° to 8°)
- Three Conditions have Experimental Aero Data
  - Compare CFD to experiment
  - Show variation in aero performance
    - Repeat shapes
    - Variation of shape along span
    - Smoothing
- Solutions performed with NASA FUN3D
  - Wilcox 2006 turbulence model

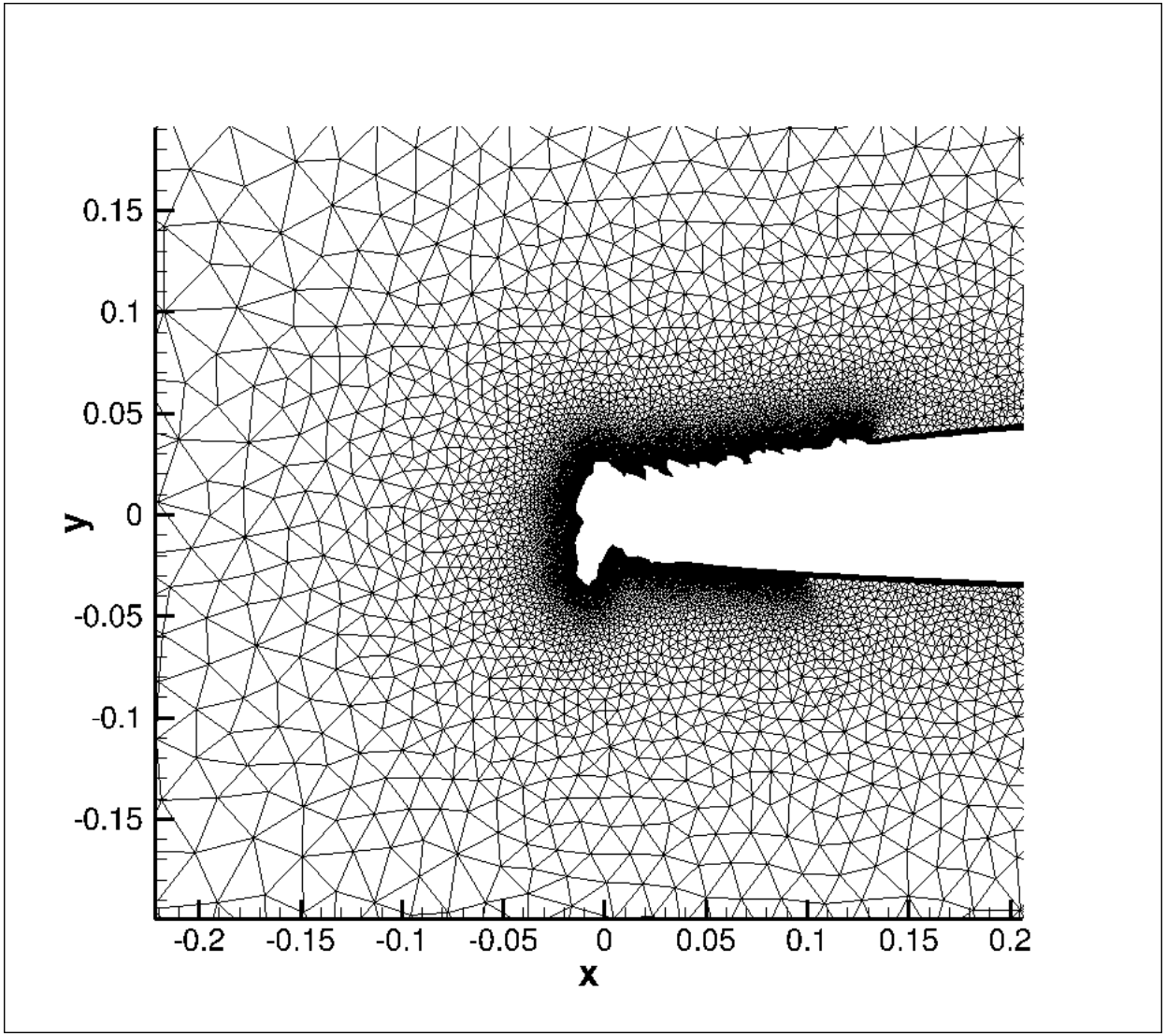
Conditions

Airfoil	Chord (m)	Air Speed (m/s)	AOA (deg)	Total Temp (° C)	LWC (g/m^3)	MVD (μm)	Time (s)	Mach	Re*10-6
NACA0012	0.53	102.9	4	-5.6	1.8	30	360	0.32	4.40
NACA0012	0.91	77.1	0	-8.3	1	15	1224	0.24	5.67
NACA23012	**0.46**	**102.9**	**2**	**-2.2**	**0.75**	**15.4**	**300**	**0.31**	**3.68**
NACA23012	1.83	90.0	2	-5.0	0.94	15	600	0.28	13.03
BizJet	0.30	139.4	0	-7.9	1.12	19	138	0.44	3.58
BizJet	0.46	88.4	0	-6.1	1.47	29	240	0.27	3.22
BizJet	0.61	89.4	0	-6.0	1.3	35	360	0.27	4.34
BizJet	0.61	89.4	0	-13.0	1.27	43	360	0.28	4.57
BizJet	**0.91**	**90.0**	**6**	**-0.8**	**0.54**	**20**	**1350**	**0.27**	**6.32**
NLF0414	**0.91**	**66.9**	**2**	**-3.1**	**0.54**	**20**	**1350**	**0.20**	**4.71**
LTHS	0.91	130.2	0	-1.4	0.563	21	1476	0.40	9.47
NACA0015	0.35	95.2	0	-5.5	0.75	19	600	0.29	2.68

Sample Grid



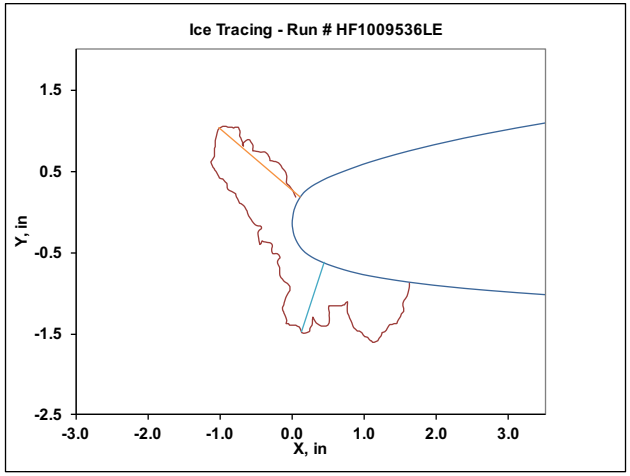
Sample Grid

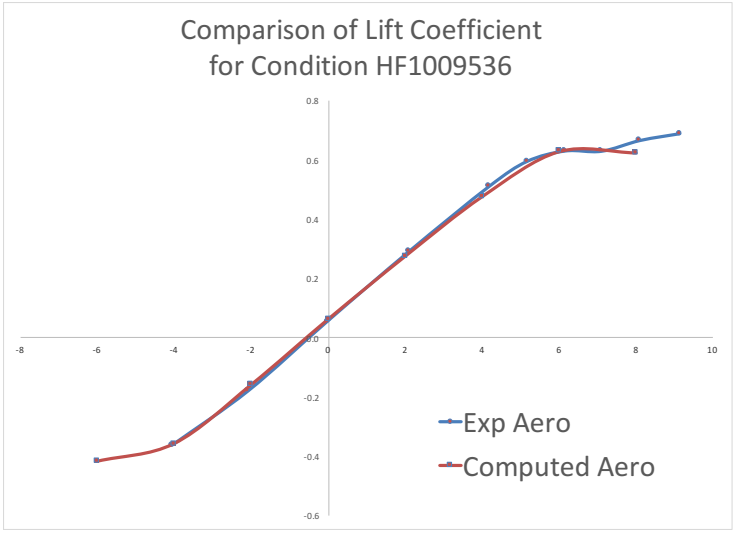


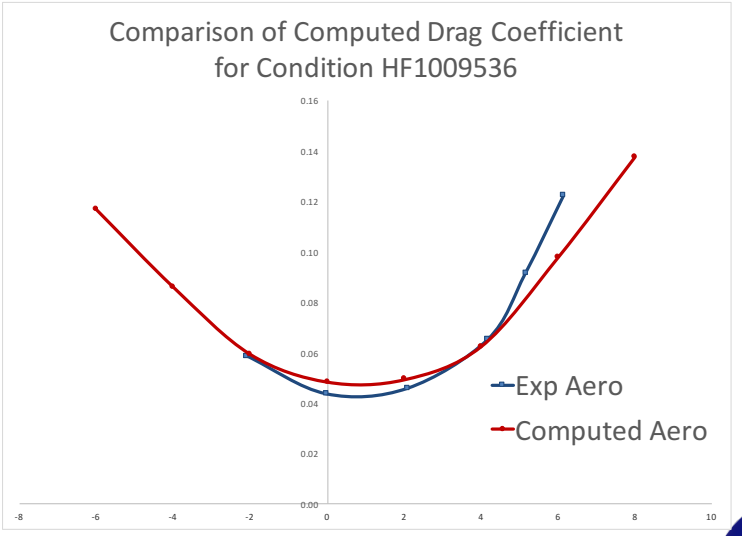
Validation Results

- Geometric Differences between LEWICE and Experiment Less Than Experimental Variability of Full Database
- Geometric Differences of Experimental Shapes Chosen Relatively Small

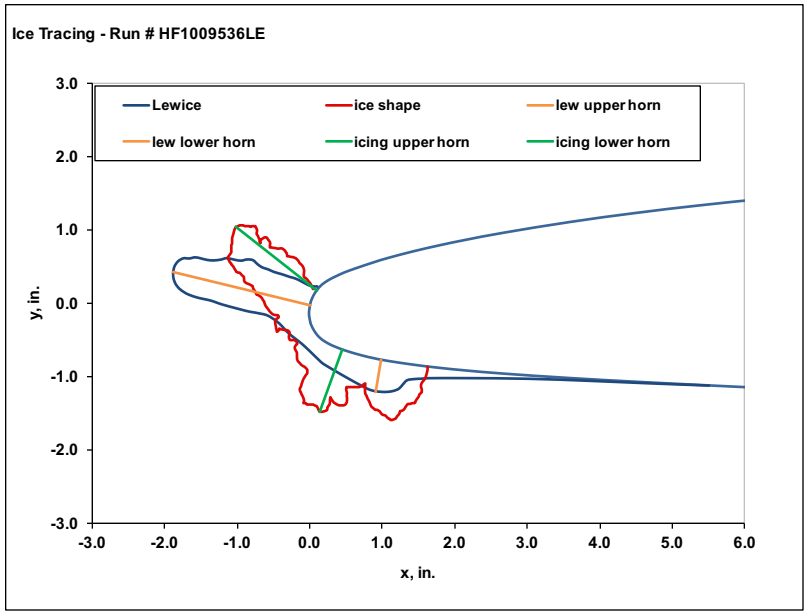
HF1009536 Aero Comparison

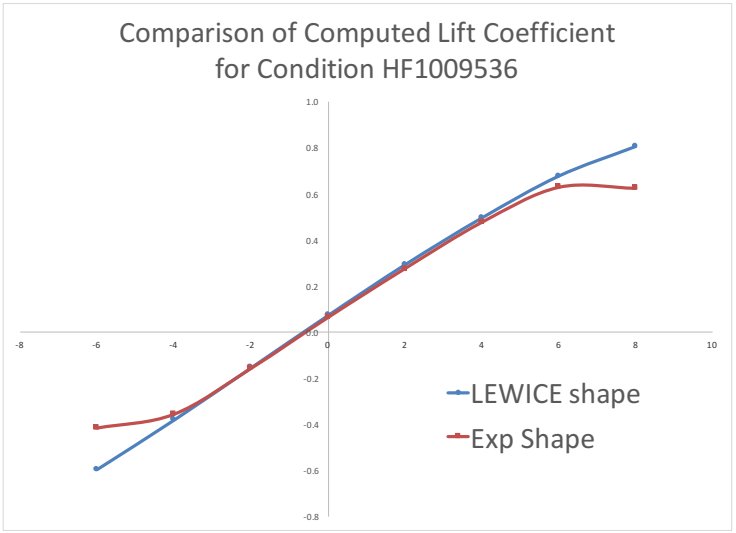


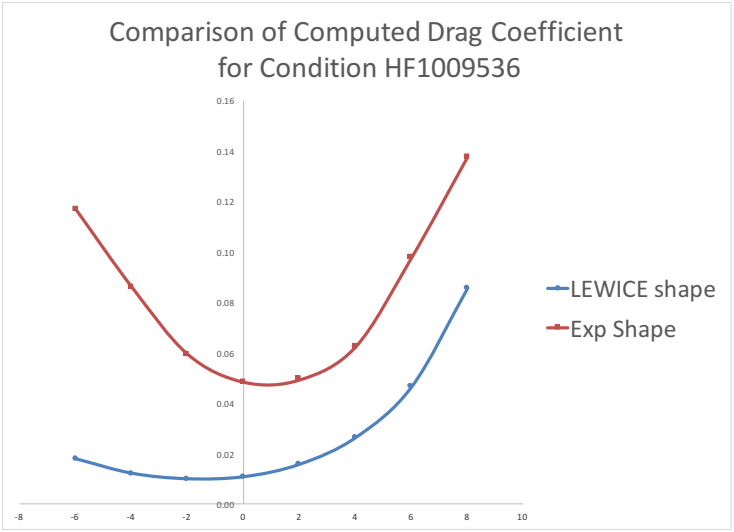




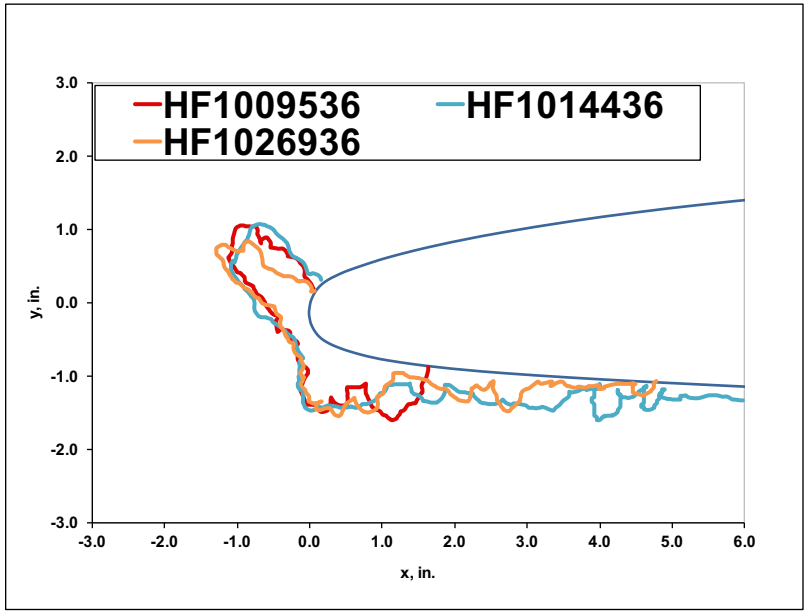
HF1009536

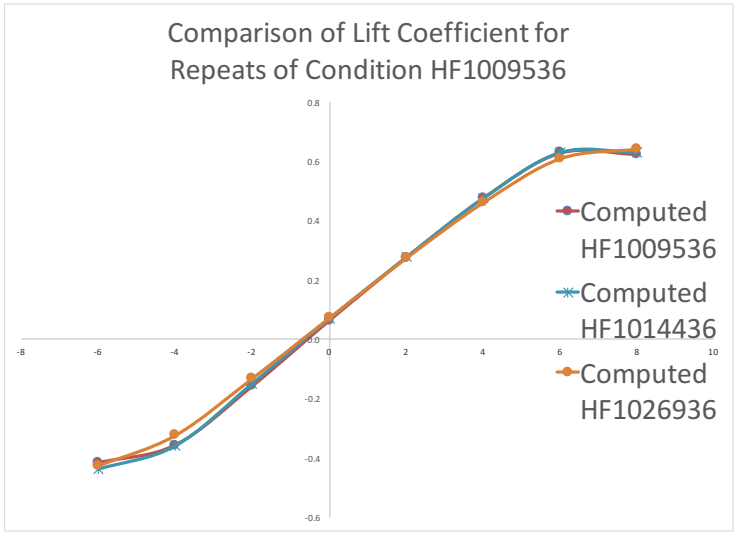

Ice Tracing - Run # HF1009536LE
Lewice
ice shape
lew upper horn
lew lower horn
icing upper horn
icing lower horn
y, in.
x, in.

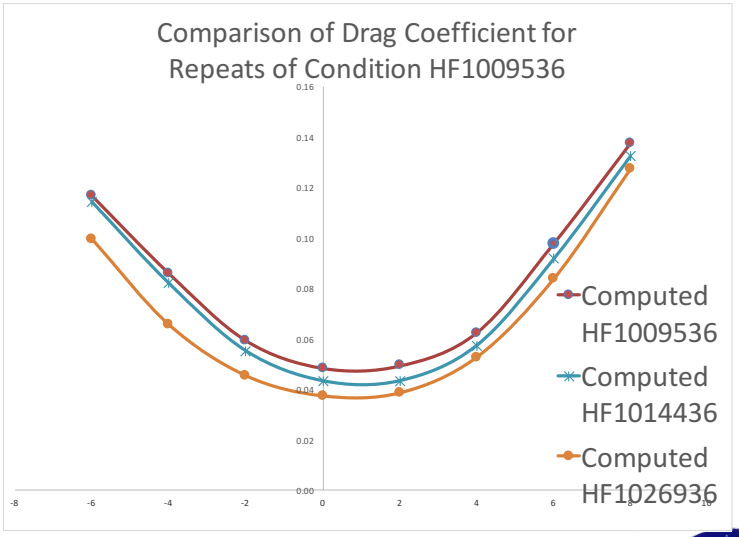

Comparison of Computed Lift Coefficient
for Condition HF1009536
LEWICE shape
Exp Shape


Comparison of Computed Drag Coefficient
for Condition HF1009536
LEWICE shape
Exp Shape

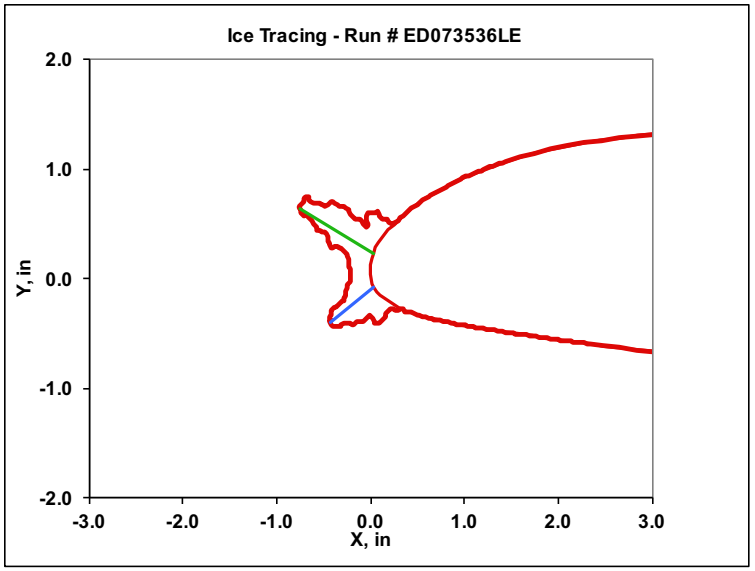
HF1009536 Repeatability

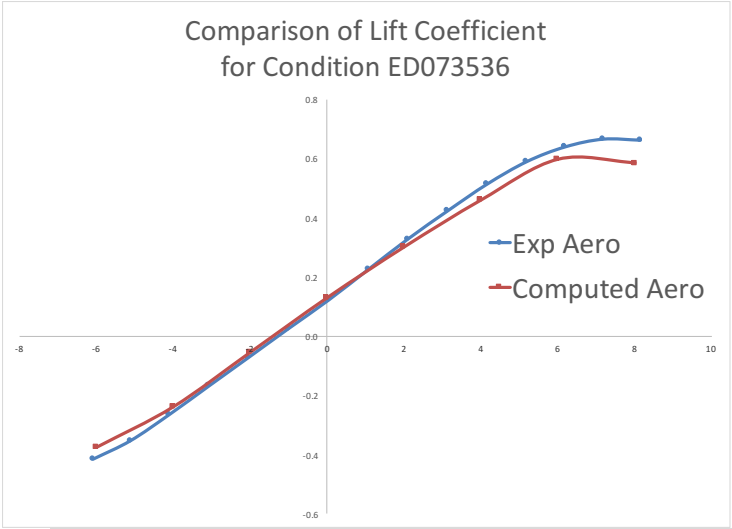


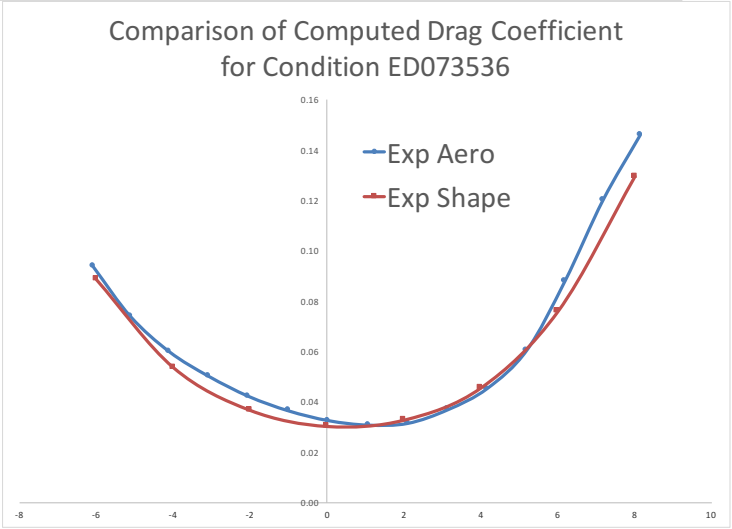




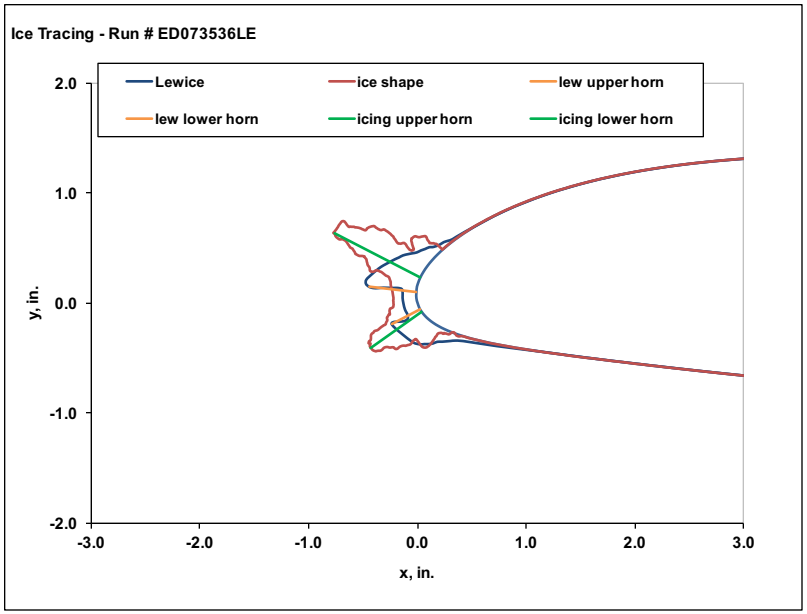
ED073536 Aero Comparison

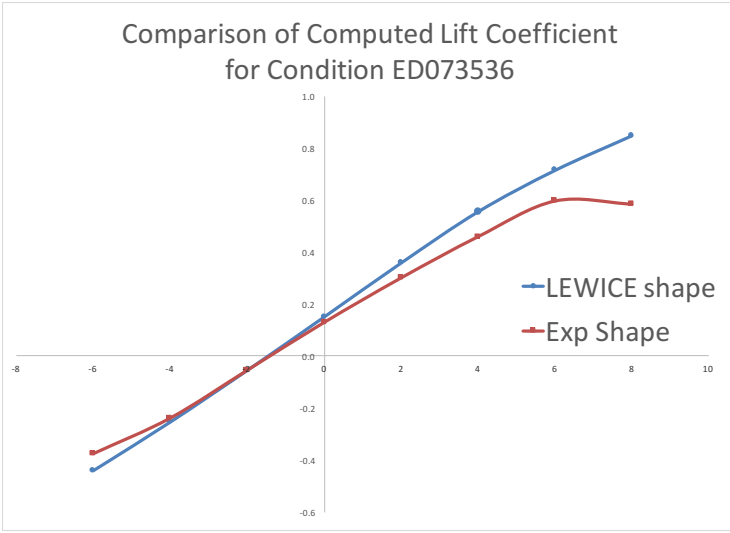


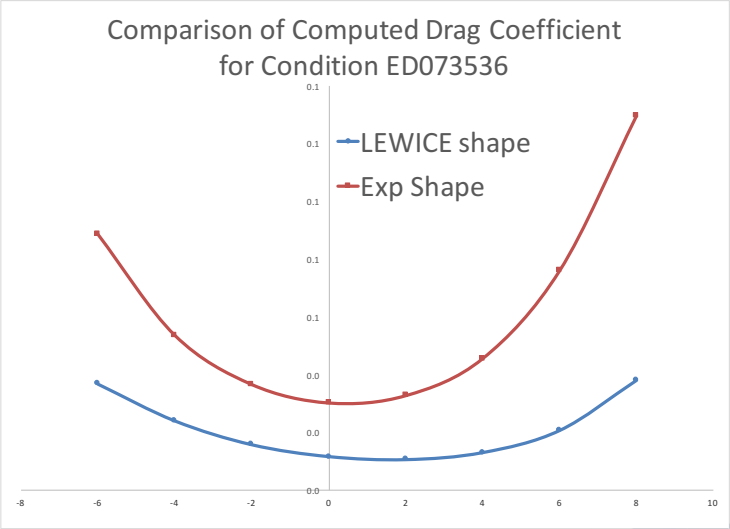




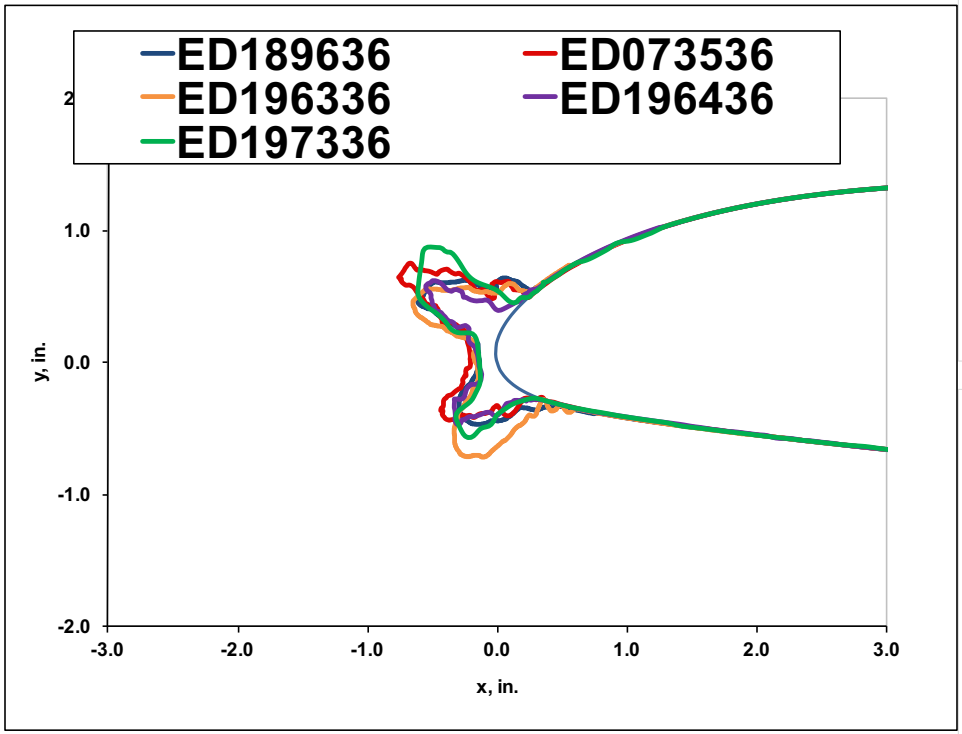
ED073536

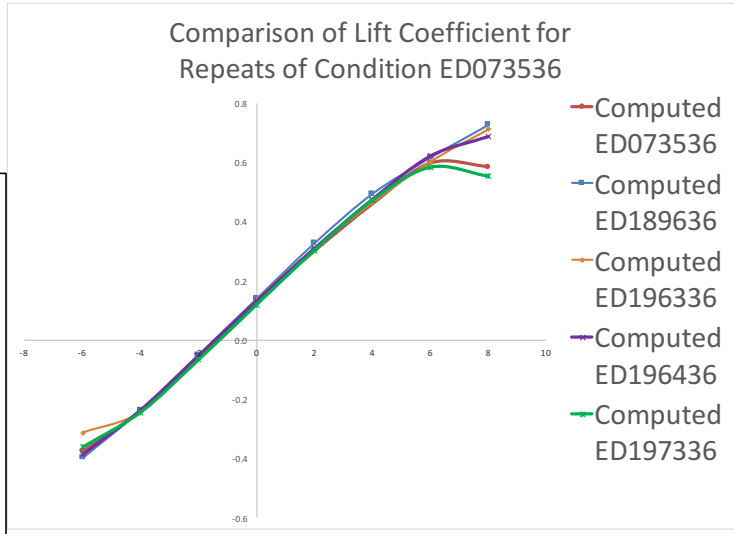

Ice Tracing - Run # ED073536LE
Lewice
ice shape
lew upper horn
lew lower horn
icing upper horn
icing lower horn
2.0
1.0
0.0
-1.0
-2.0
y, in.
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
x, in.

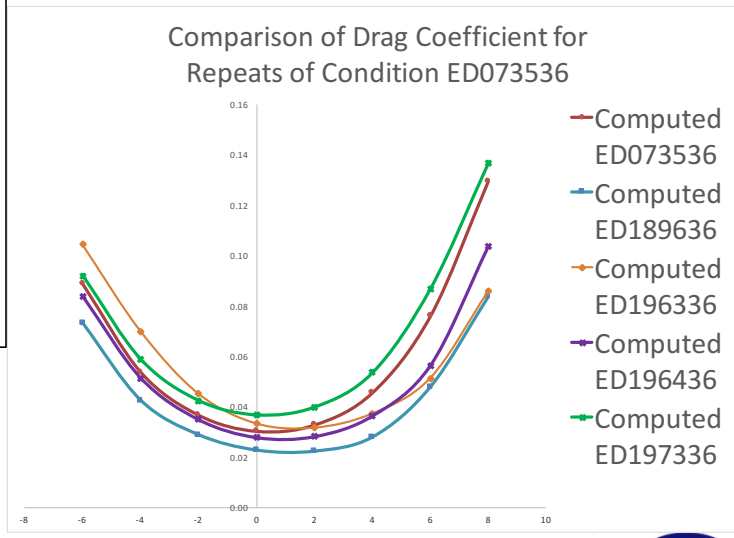

Comparison of Computed Lift Coefficient
for Condition ED073536
LEWICE shape
Exp Shape


Comparison of Computed Drag Coefficient
for Condition ED073536
LEWICE shape
Exp Shape

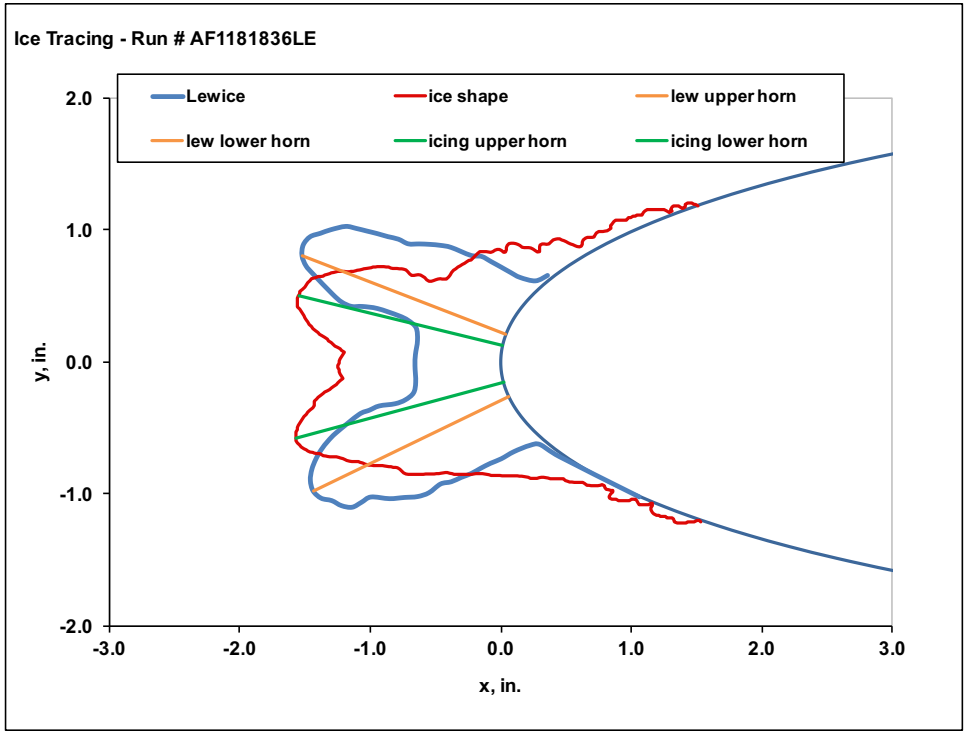
ED073536 Repeatability

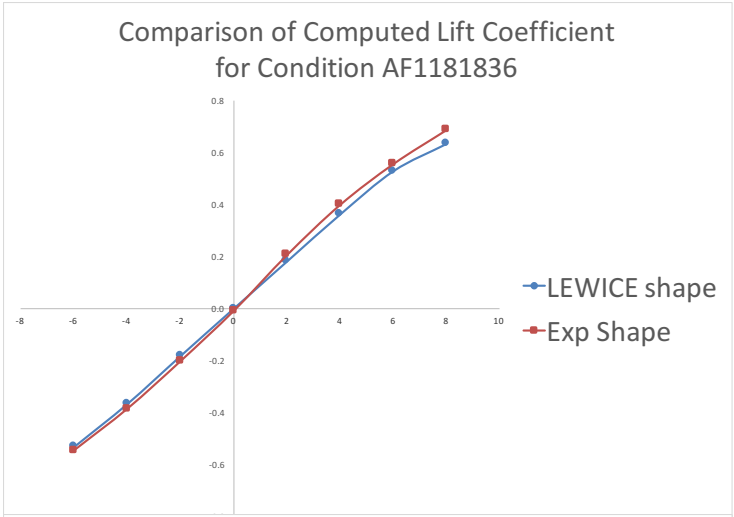


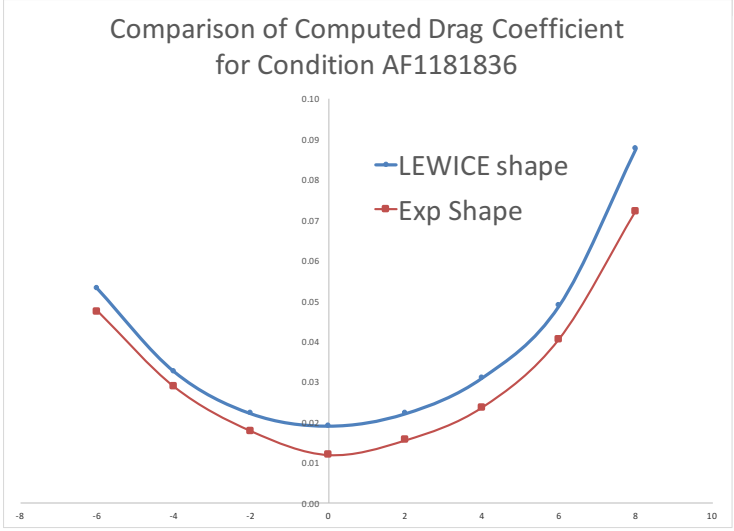




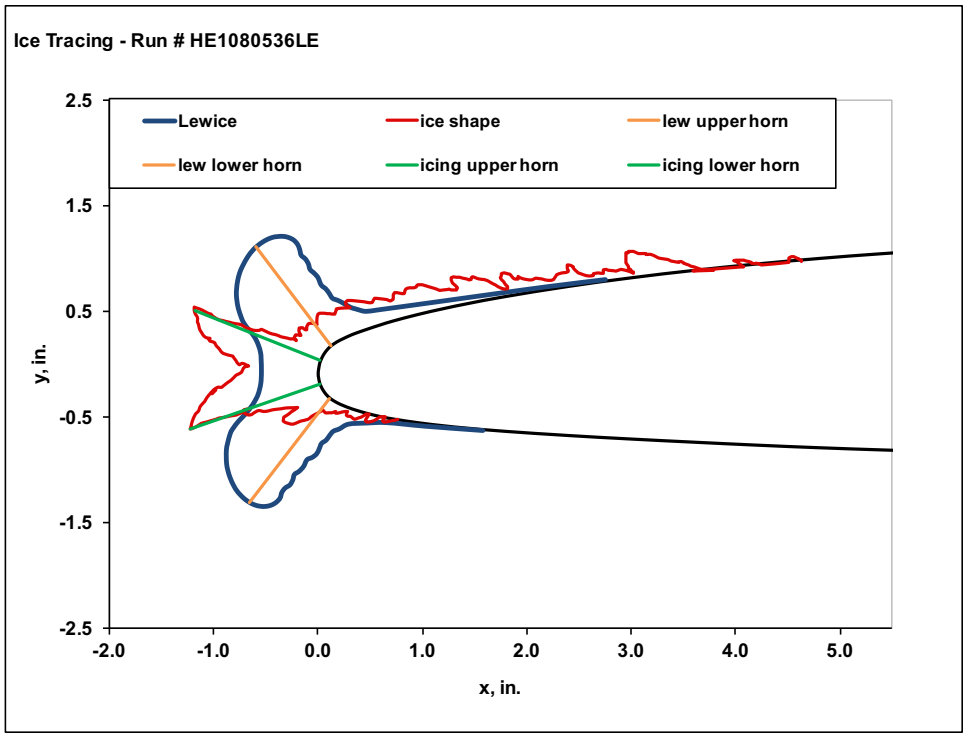
AF1181836

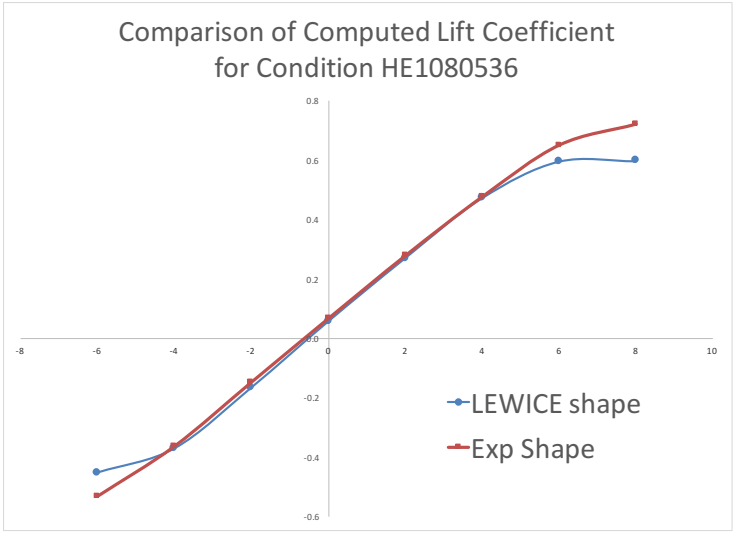

Ice Tracing - Run # AF1181836LE
Lewice
ice shape
lew upper horn
lew lower horn
icing upper horn
icing lower horn
2.0
1.0
0.0
-1.0
-2.0
y, in.
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
x, in.

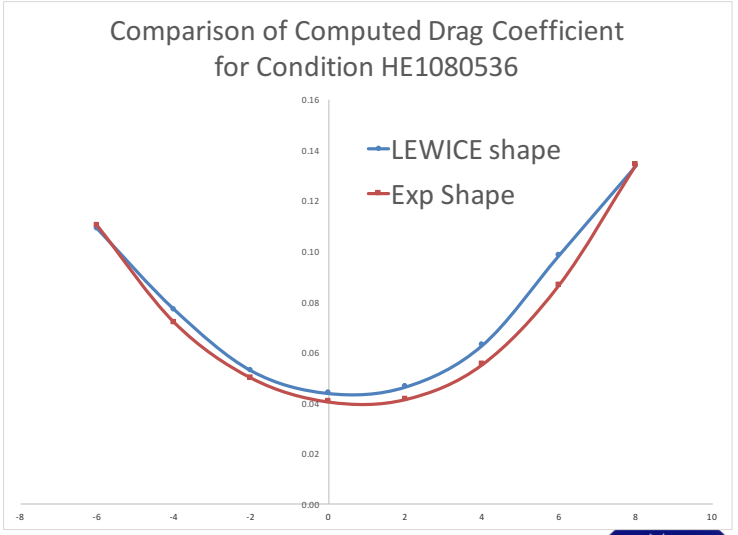

Comparison of Computed Lift Coefficient
for Condition AF1181836
LEWICE shape
Exp Shape


Comparison of Computed Drag Coefficient
for Condition AF1181836
LEWICE shape
Exp Shape

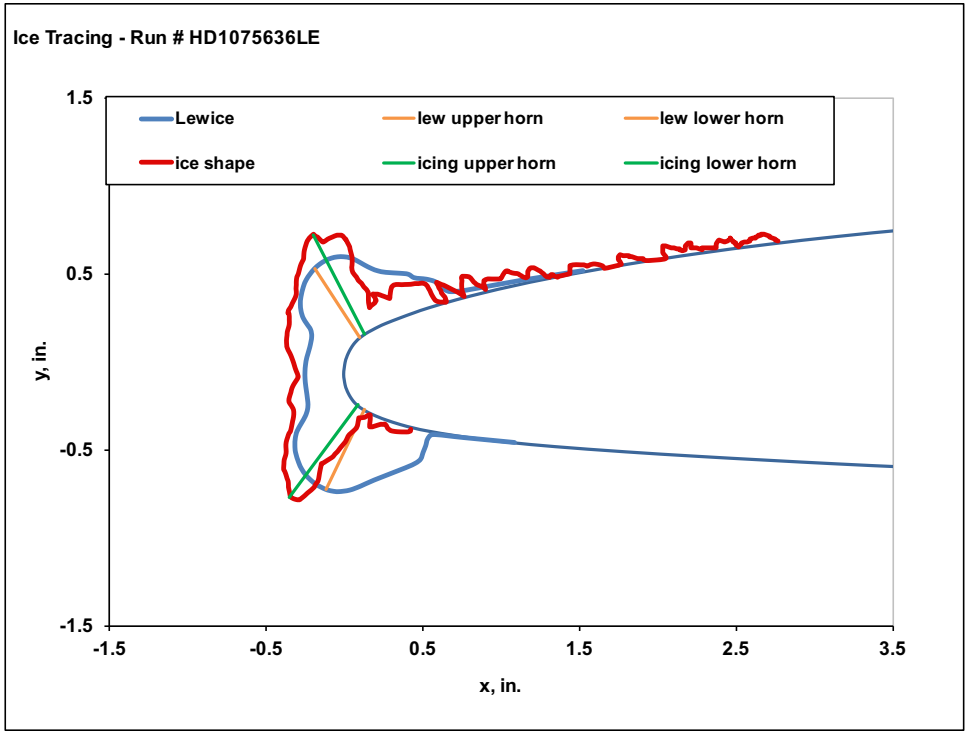
HE1080536

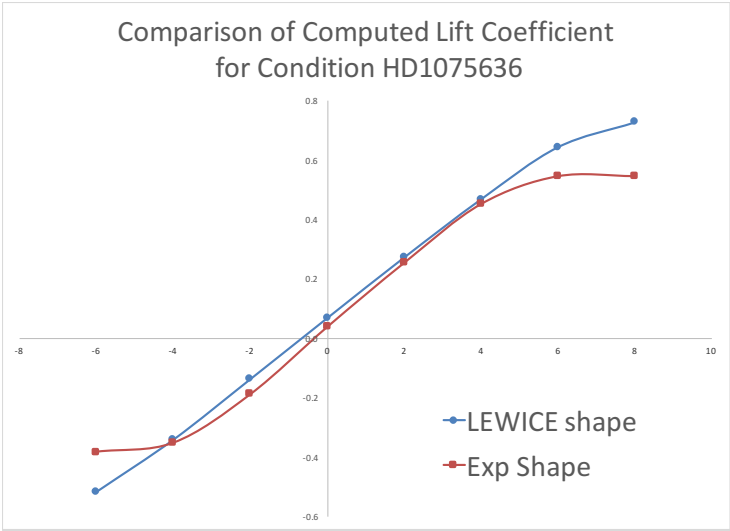

Ice Tracing - Run # HE1080536LE
Lewice
ice shape
lew upper horn
lew lower horn
icing upper horn
icing lower horn
2.5
1.5
0.5
-0.5
-1.5
-2.5
y, in.
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
x, in.

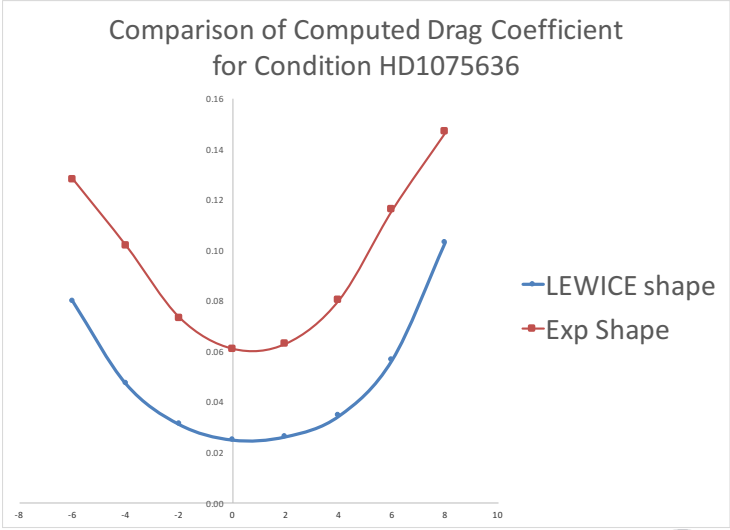

Comparison of Computed Lift Coefficient
for Condition HE1080536
LEWICE shape
Exp Shape


Comparison of Computed Drag Coefficient
for Condition HE1080536
LEWICE shape
Exp Shape

HD1075636


Ice Tracing - Run # HD1075636LE
Lewice
lew upper horn
lew lower horn
ice shape
icing upper horn
icing lower horn
1.5
0.5
-0.5
-1.5
y, in.
-1.5
-0.5
0.5
1.5
2.5
3.5
x, in.


Comparison of Computed Lift Coefficient
for Condition HD1075636
LEWICE shape
Exp Shape


Comparison of Computed Drag Coefficient
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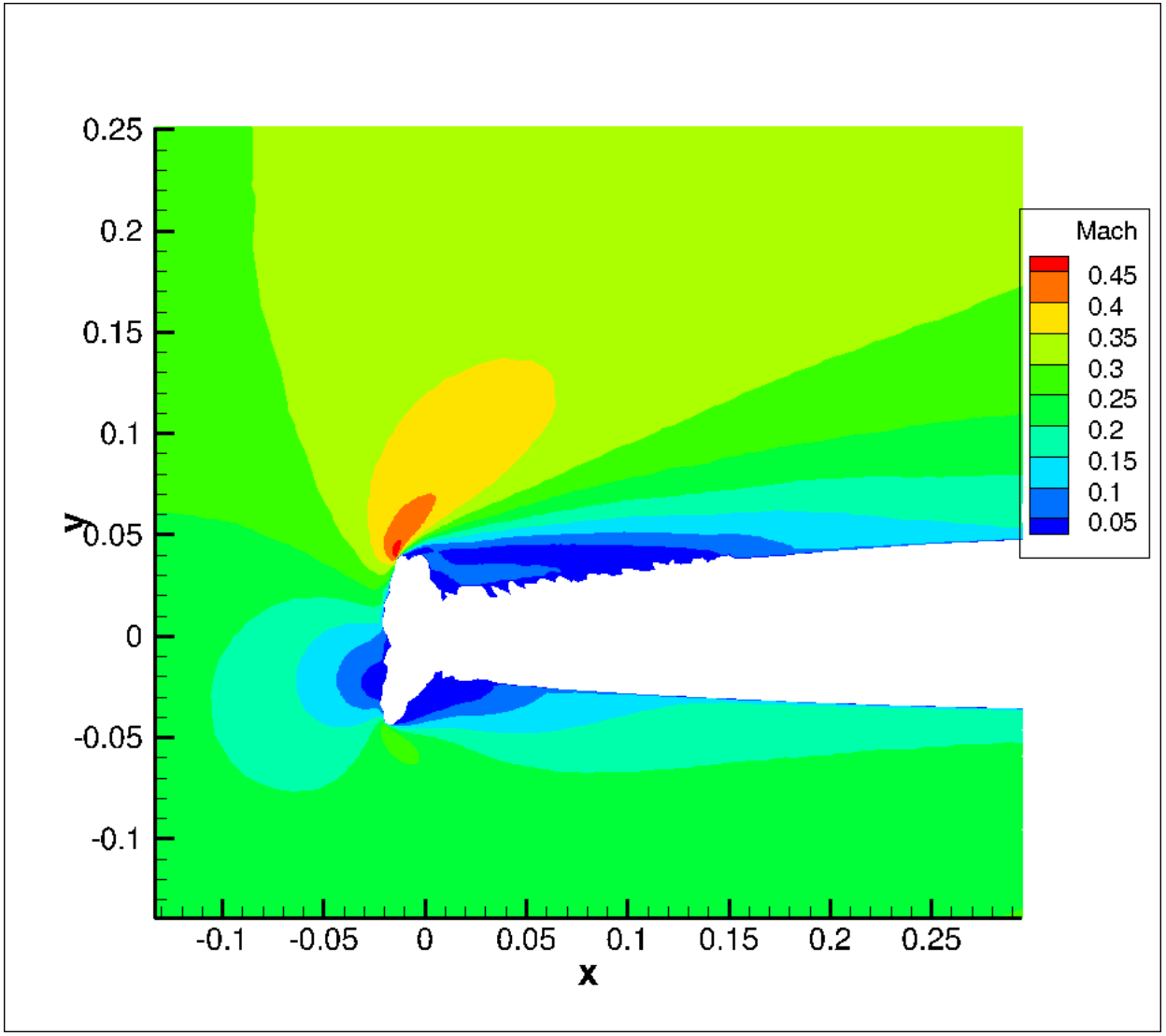
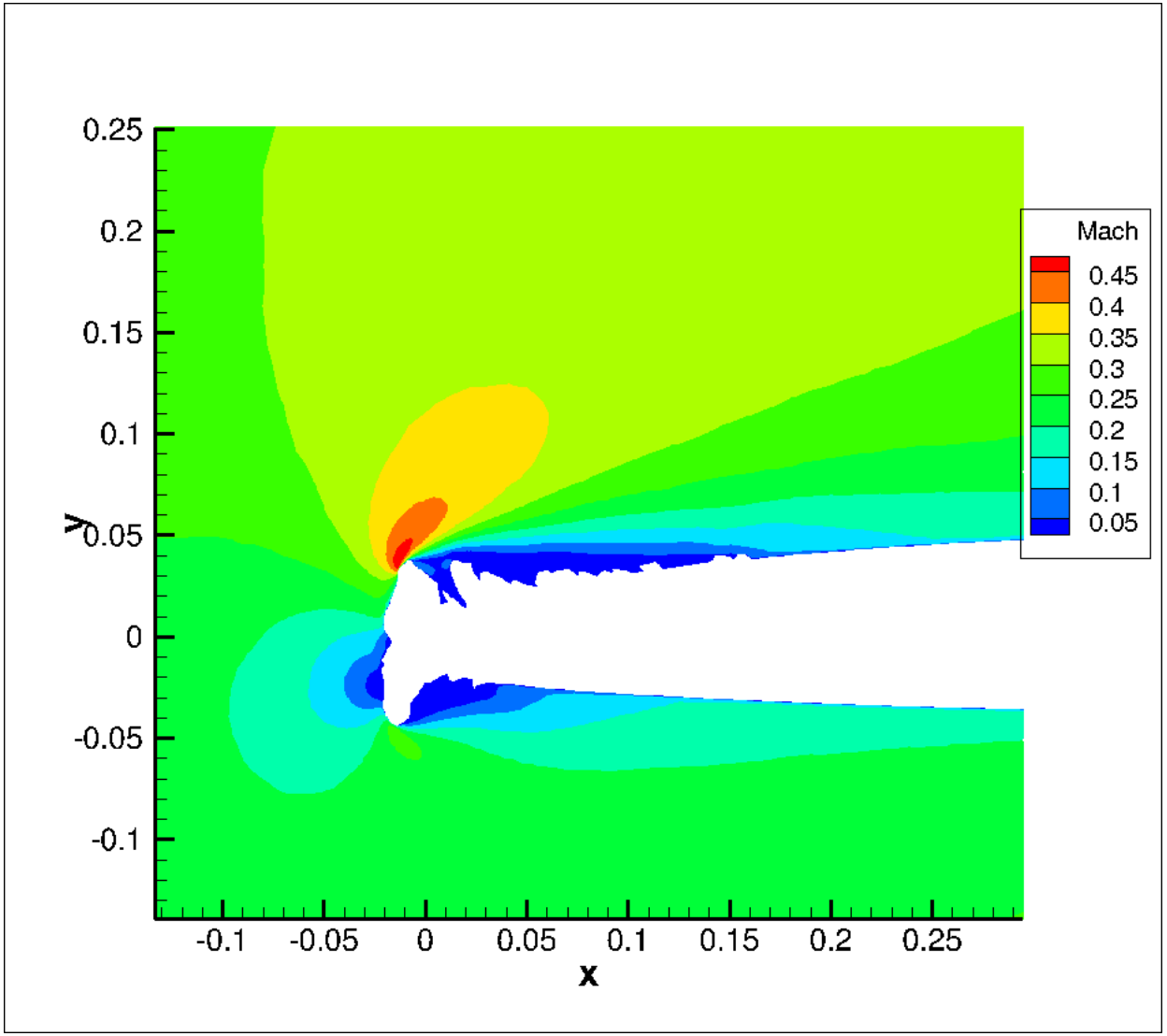
LEWICE shape
Exp Shape

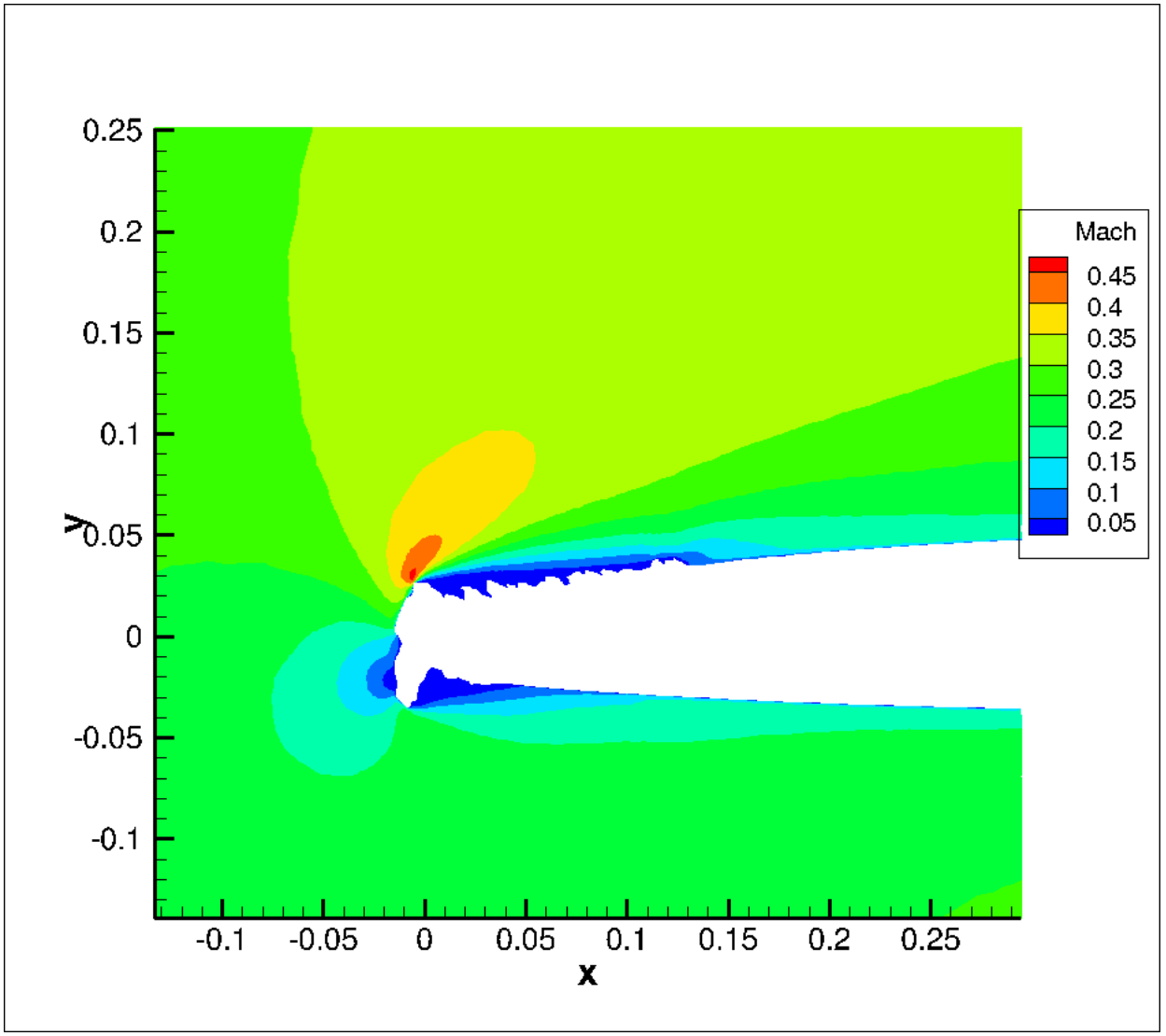
Mach Contours for HD1075636



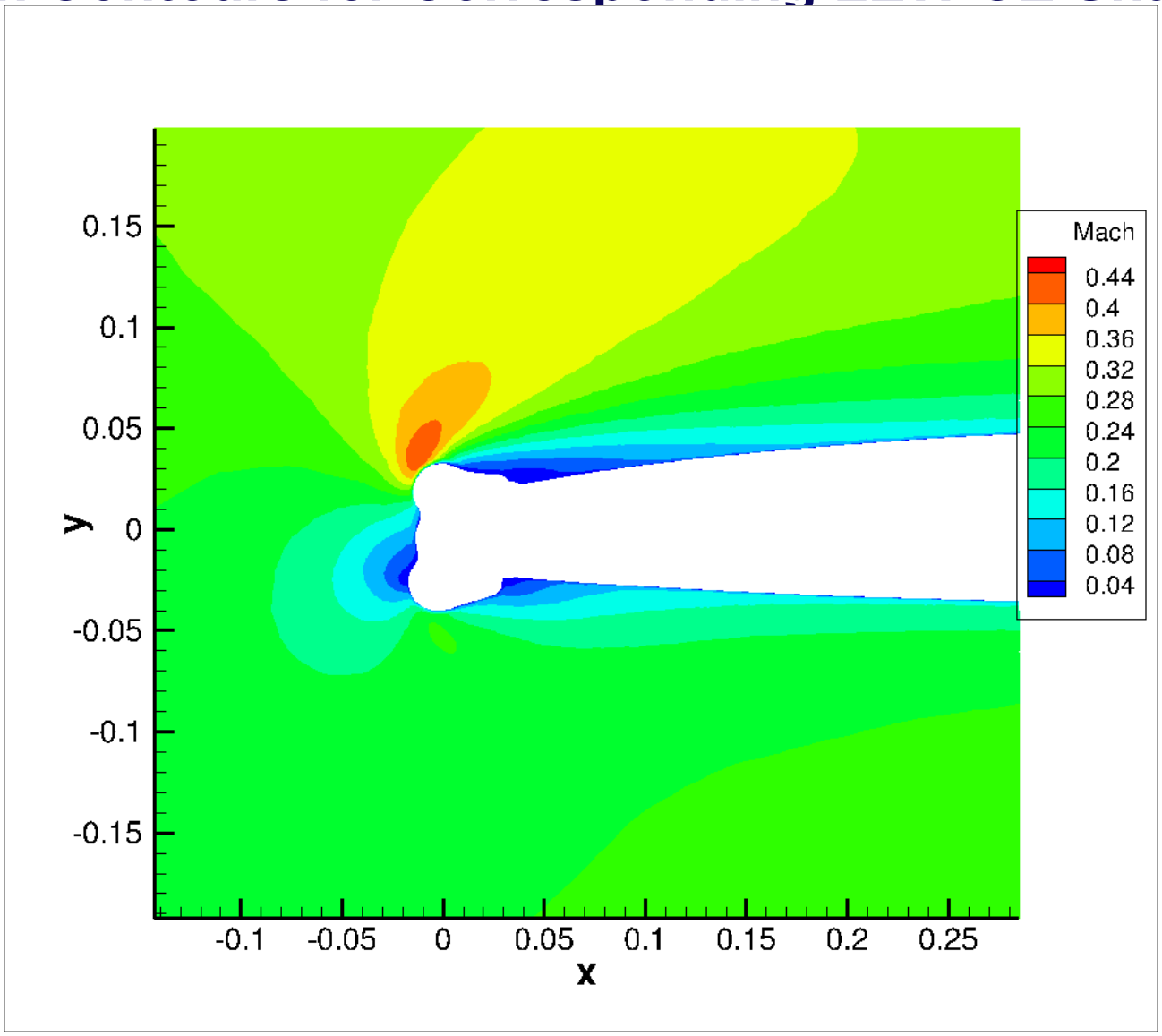
Mach Contours for HD1075736



Mach Contours for HD1075936



Mach Contours for Corresponding LEWICE Shape



Conclusions

- LEWICE model updated to include additional grid options
- New python script allows user to run hundreds of cases with or without Naviér-Stokes
- Geometric comparison shows good agreement with Experiment
- This study suggests that geometrically similar shapes can produce different performance characteristics
- Lift and drag calculations of ice shapes show favorable agreement with experiment