STAR-CCM+ Icing Analysis for NACA0012 Case

Jeewoong Kim, Daniel Griffiths

Sikorsky, a Lockheed Martin Company

Presented 23 September 2026

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STAR-CCM+ Icing Analysis for NACA0012 Case

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3rd AIAA Ice Prediction Workshop
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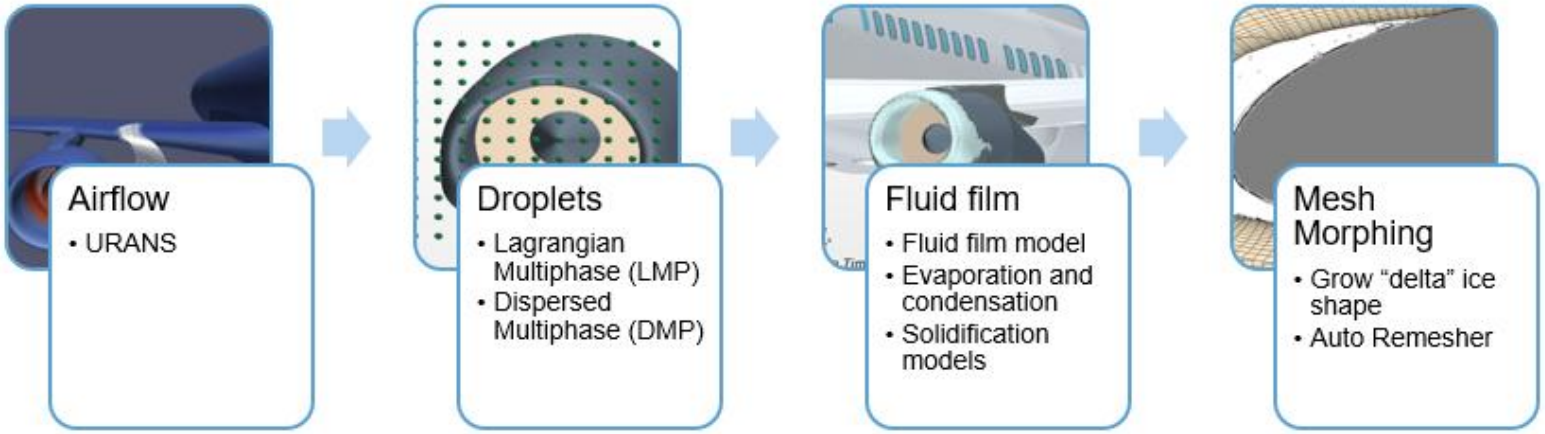
Siemens Simcenter STAR-CCM+

STAR-CCM+ Icing Analysis Workflow



Ref. : STAR-CCM+ ice accretion modeling slides (Scott Wilensky)

STAR-CCM+ Icing Simulation Approaches

	Airflow	Collection Efficiency	Cost / Run time	Fidelity
Single-shot	solved once	unchanged	Low / fast	Increase
Multi-shot	updated periodically		Medium / fast	
Fully Coupled	updated at each time step		High / slow	

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Results

- Flow Solver Grid Convergence
- Using IPW-3 Committee Grids

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CFD Solution (Cp & Collection Efficiency)

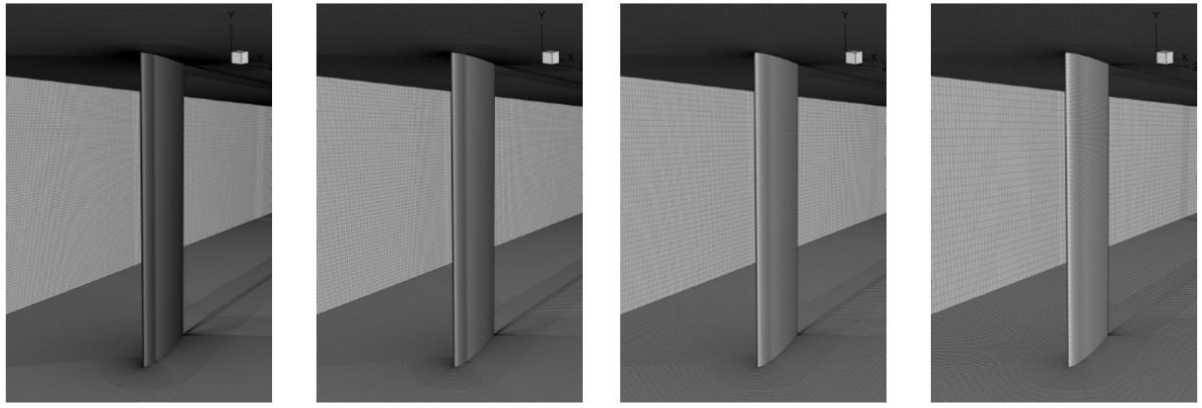
NACA 0012 Case

- Chord length : 21 in
- Wingspan length : 72 in
- Angle of attack : 4 deg.
- Reference area = 1512 in^2
- Mean aerodynamic chord (M.A.C.) = 21 in
- Grid sensitivity : 4 levels

National Aeronautics and Space Administration

Grid Levels

Level	1	2	3	4
Nodes	60,450,029	27,308,300	11,234,674	5,947,691



Level 1 Level 2 Level 3 Level 4

Mach	Velocity	Static Temperature	Density	Static Pressure	Speed of sound	mu	Re_chord
nd	m/s	K	Kg/m^3	Pa	m/s	kg/m-sec	nd
0.3114	102.15	267.75	1.1884	91337	328.03	1. 68917E-05	3.8441e6

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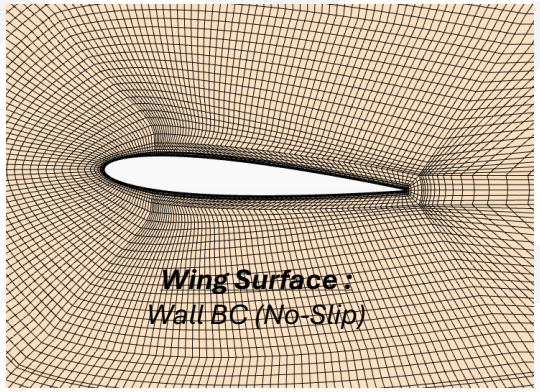
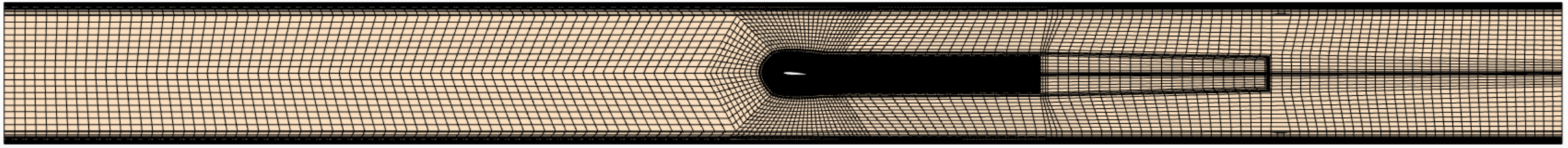
STAR-CCM+ Setup

Setup	Description
Software	Simcenter STAR-CCM+ v2510
Flow Algorithm	Coupled Flow Solver
Turbulence Model	SST (Menter) K-Omega
Droplet Formulation	Dispersed Multiphase (Eulerian)
Droplet Drag Model	Spherical (Schiller-Naumann)
SLD Effects	None

NACA 0012 Case



Tunnel Outlet:
BC: Pressure Outlet



Tunnel Inlet:
BC: Velocity Inlet
Magnitude + Direction
Flow Direction: parallel to tunnel length
Velocity Magnitude: Ref. freestream
Temperature: Ref. static temperature

Tunnel Walls:
Wall BC (No-Slip)

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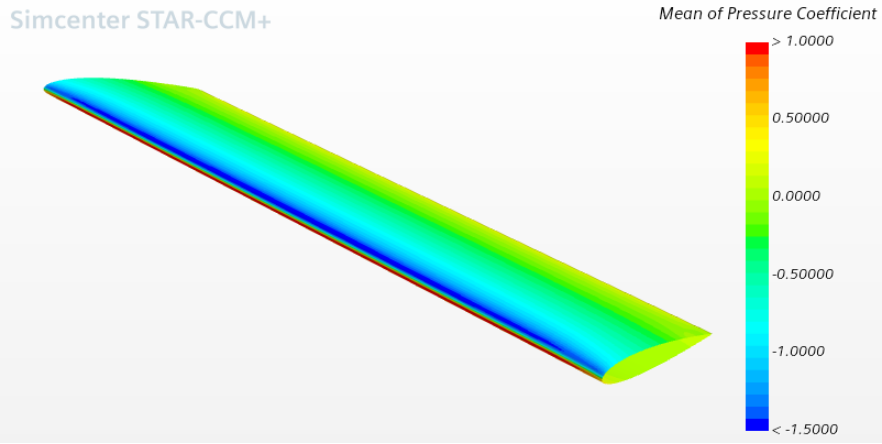
CFD Solution (Cp)

Mach	Velocity	Static Temperature	Density	Static Pressure	Speed of sound	mu	Re_chord
nd	m/s	K	Kg/m^3	Pa	m/s	kg/m-sec	nd
0.3114	102.15	267.75	1.1884	91337	328.03	1. 68917E-05	3.8441e6

NACA 0012 Case

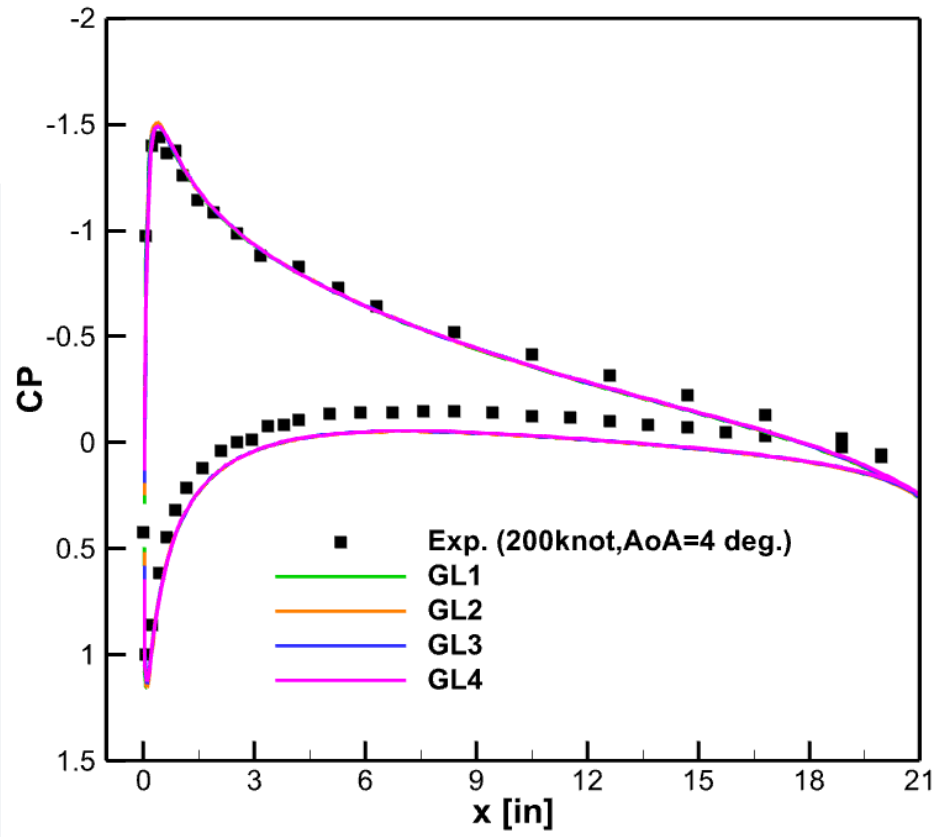
- Steady simulation
- SST (Menter) K-Omega
- Cp : averaged over last 1000 iterations



Averaged Pressure Coefficient (GL1)

Grid Levels

Level	1	2	3	4
Nodes	60,450,029	27,308,300	11,234,674	5,947,691



Comparison of Pressure Coefficient (y=36 in span)

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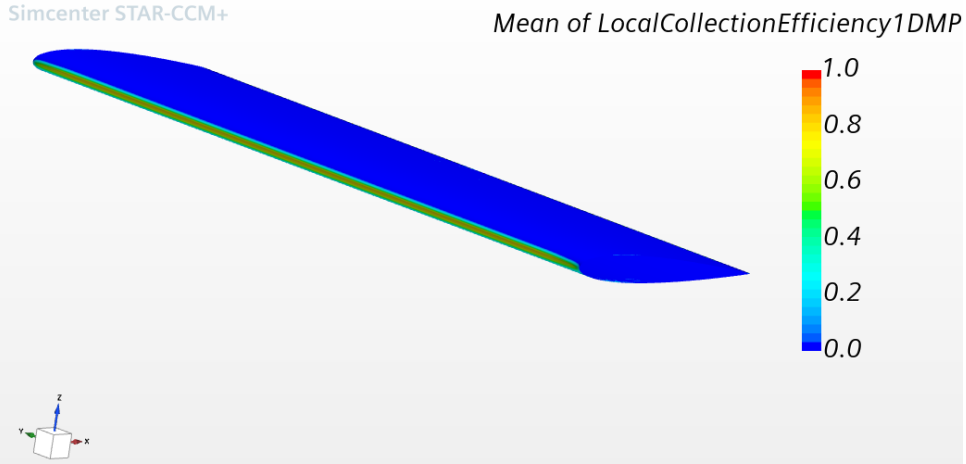
CFD Solution (β)

Mach	Velocity	Static Temperature	Density	Static Pressure	Speed of sound	mu	Re_chord
nd	m/s	K	Kg/m^3	Pa	m/s	kg/m-sec	nd
0.3114	102.15	267.75	1.1884	91337	328.03	1. 68917E-05	3.8441e6

NACA 0012 Case

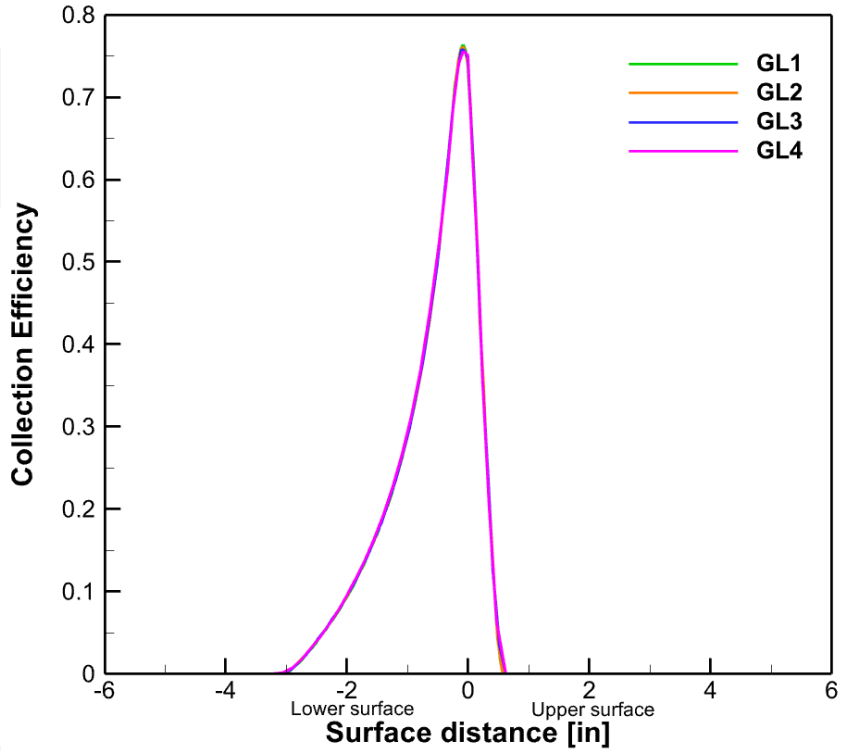
- Steady simulation
- SST (Menter) K-Omega
- Eulerian, MDV=20 µm, LWC=0.55 g/m^3
- Averaged over last 1000 iterations



Averaged Collection Efficiency (GL1)

Grid Levels

Level	1	2	3	4
Nodes	60,450,029	27,308,300	11,234,674	5,947,691



Comparison of Collection Efficiency (y=36 in span)

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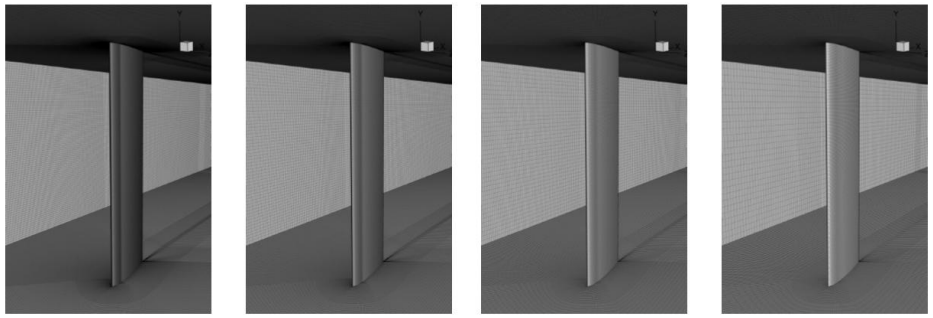
CFD Solution ($C_L/C_D/C_M$)

NACA 0012 Case

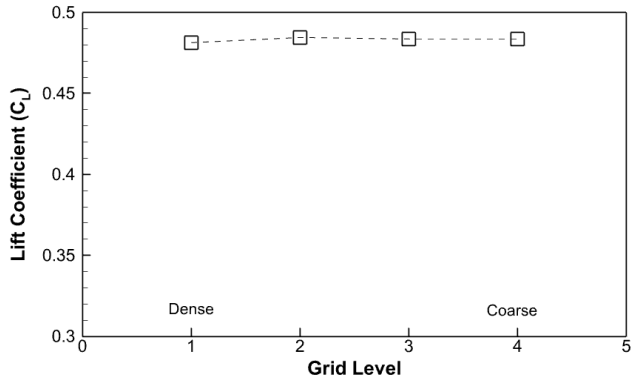
- Steady simulation
- SST (Menter) K-Omega
- Averaged over last 5000 iterations

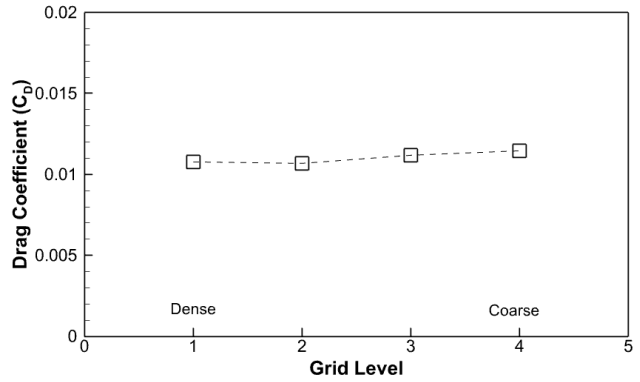
Grid Levels

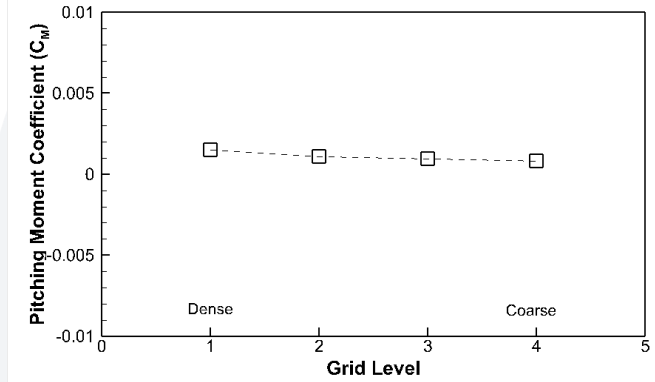
Level	1	2	3	4
Nodes	60,450,029	27,308,300	11,234,674	5,947,691



Level 1 Level 2 Level 3 Level 4







Level	C_L	C_D	C_M
L1 (dense)	0.48128	0.01075	0.00151
L2	0.48448	0.01070	0.00110
L3	0.48348	0.01200	0.00096
L4 (coarse)	0.48367	0.01144	0.00080

Averaged CL/CD/CM (last 5000 iteration)

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Results

- Ice Accretion

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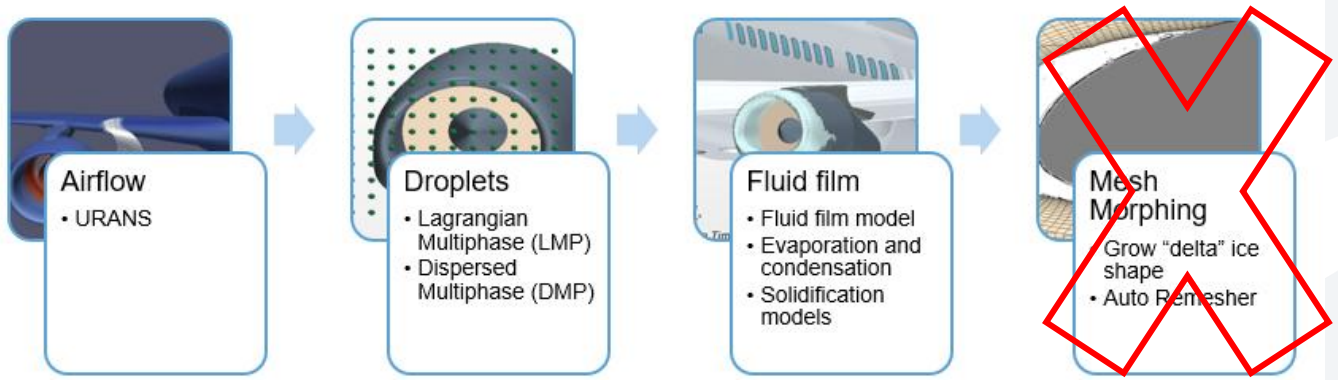
STAR-CCM+ Icing Simulation Approach

Ice shape predictions using grids from IPW-3

- w/o Mesh Morphing : convergence issue (diverging flow solution)
- w/ Mesh Morphing : not working (STAR-CCM+ requires baseline part)

Ice shape predictions based on STAR-CCM+ internal meshing

- Tunnel wall case : working w/o Mesh Morphing
- Open-air case (freestream BC)
    - w/ Mesh Morphing
        - Coarse mesh : negative thickness issue
        - Dense mesh : looks like there is max. CPU limit w/ mesh Morpher
    - w/o Mesh Morphing : working



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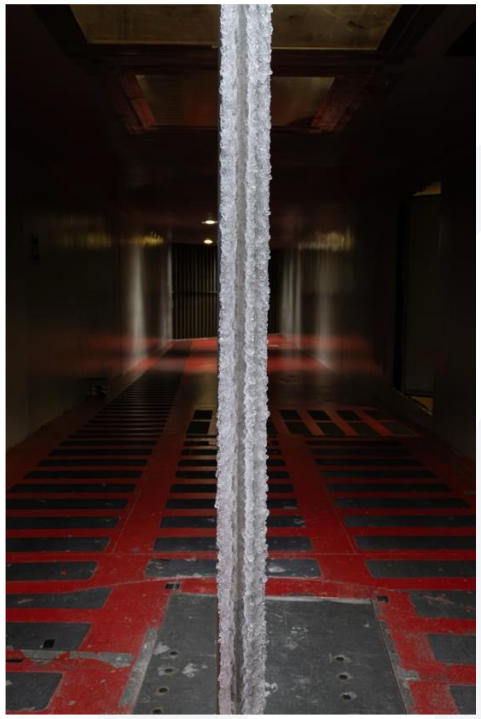
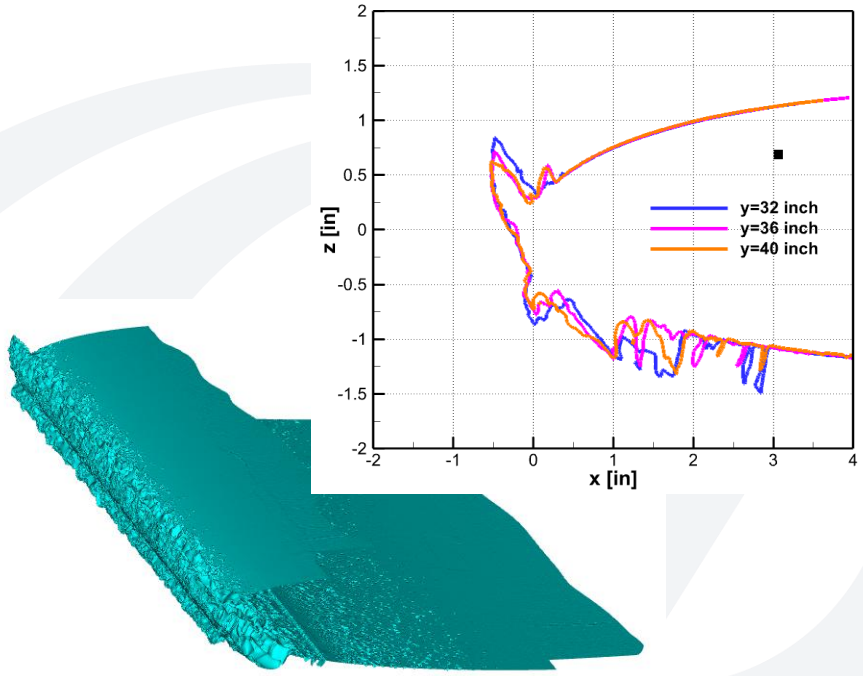
STAR-CCM+ Icing Simulation (AE3933)

NACA 0012 Case

- Chord length : 21 in
- Wingspan length : 72 in
- Angle of attack : 4 deg.
- Reference area = 1512 in^2
- Mean aerodynamic chord (M.A.C.) = 21 in



NASA Icing Research Tunnel



Processed Ice Shape (AE3933)

Mach	Velocity	Static Temperature	Density	Static Pressure	Speed of sound	mu	Re_chord	LWC	MDV	Time
nd	m/s	K	Kg/m^3	Pa	m/s	kg/m-sec	nd	g/m^3	μm	min
0.3127	102.19	265.8	1.2	91554	326.83	1. 6794E-05	3.8947e6	0.55	20	7

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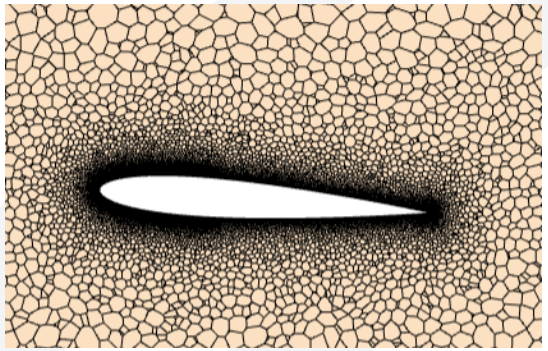
STAR-CCM+ Icing Simulation Setup

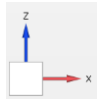
Setup	Description
Software	Simcenter STAR-CCM+ v2510
Flow Algorithm	Segregated Solver
Turbulence Model	SST (Menter) K-Omega
HTC Method	Recovery Temperature
Droplet Formulation	Dispersed Multiphase (Eulerian)
Droplet Drag Model	Spherical (Schiller-Naumann)
SLD Effects	None
Thermodynamic Algorithm	Fluid Film model (SWIM)
Ice Density Model	Constant (901.3 kg/m^3)
Surface Roughness	Constant (0.1 mm)
Ice Accretion Steps	Single-shot

NACA 0012 Case

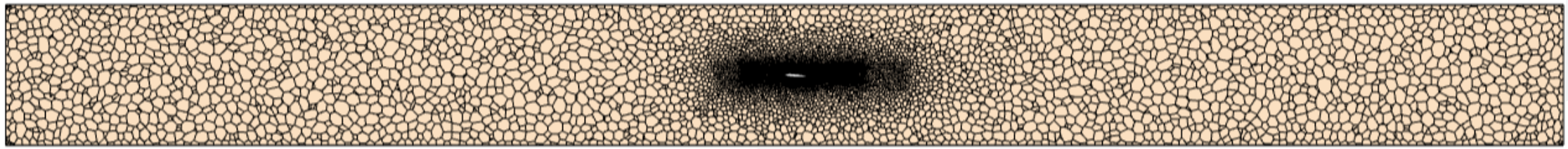


Wing Surface :
Wall BC (No-Slip)

Tunnel Outlet:
BC: Pressure Outlet



side view



Tunnel Inlet:
BC: Velocity Inlet
Magnitude + Direction
Flow Direction: parallel to tunnel length
Velocity Magnitude: Ref. freestream
Temperature: Ref. static temperature

Tunnel Walls:
Wall BC (No-Slip)

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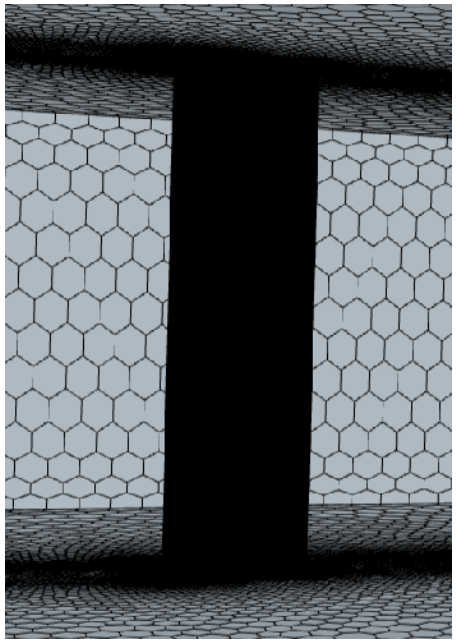
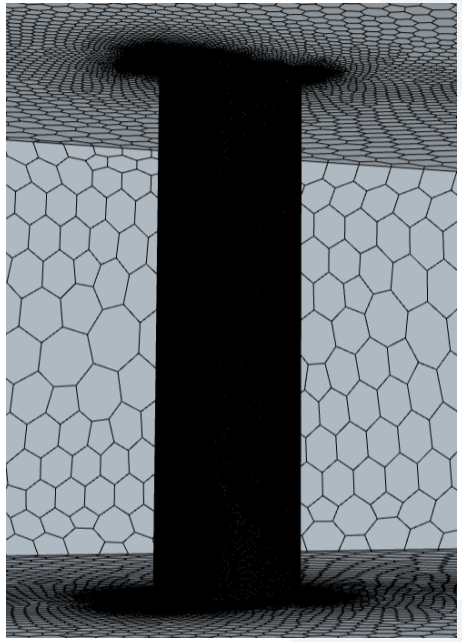
STAR-CCM+ Icing Simulation (Grid Sensitivity)

Grid Level

Level	L1	L2	L3
Total Cells	90,950,717	23,679,093	6,647,803
Total Nodes	338,615,007	88,405,359	25,385,820



Level 1



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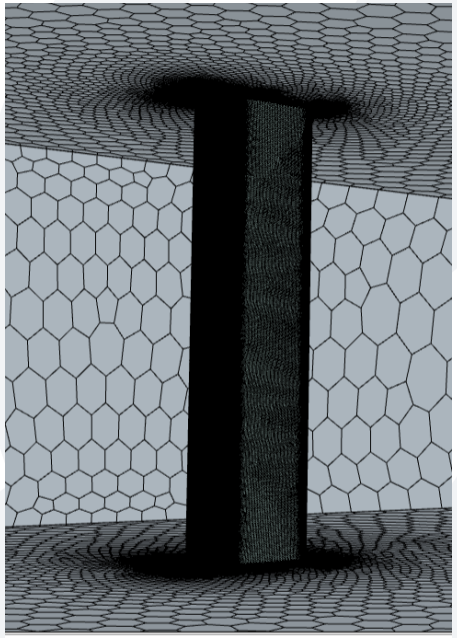

Level 3

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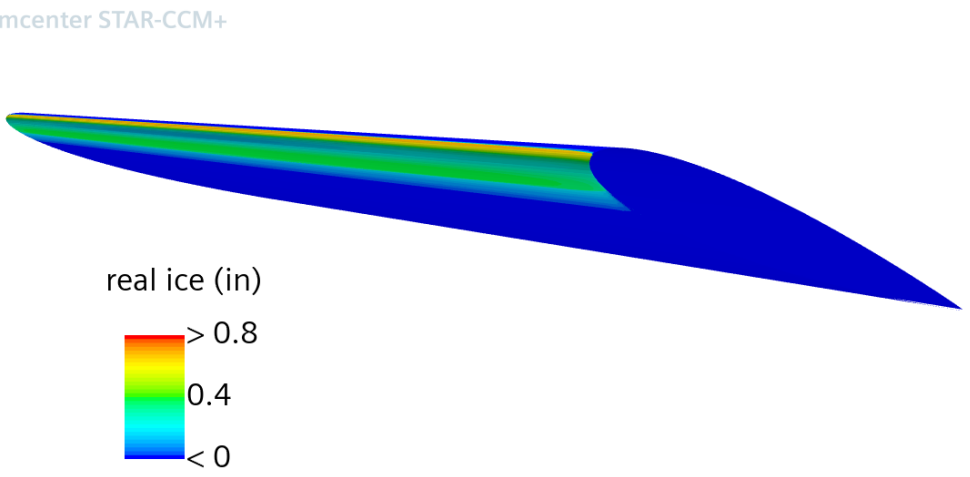
Ice Shape Comparison

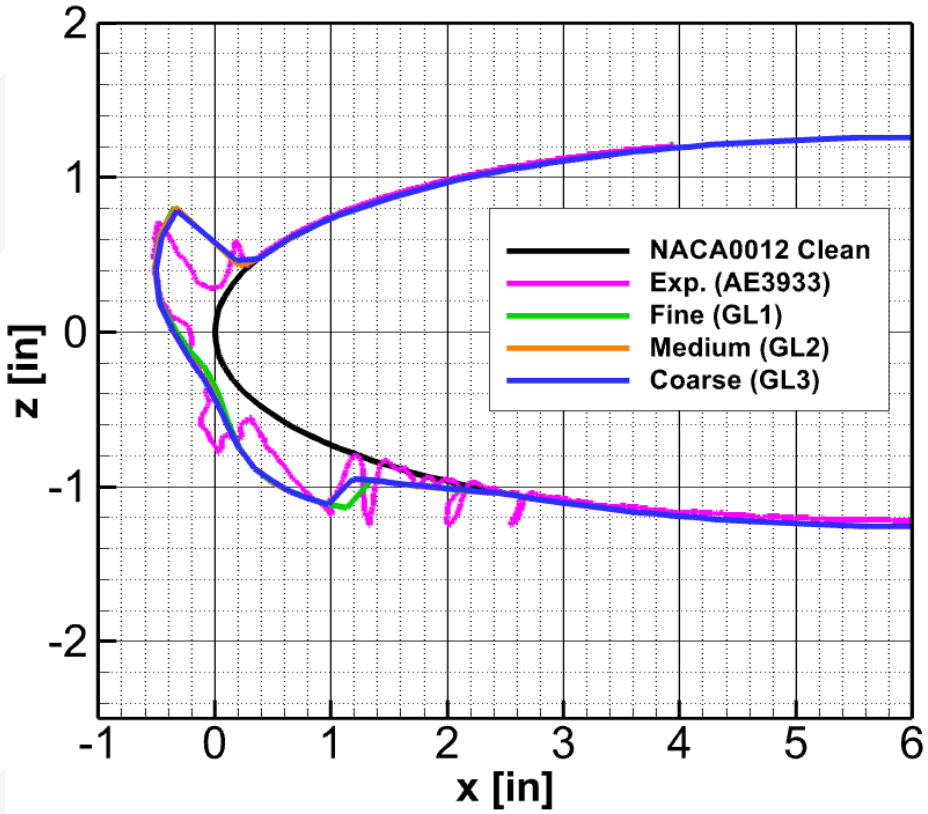
Grid convergence
- Upper surface : good agreement for max. ice thickness
- Lower surface : marginal difference among predictions

NACA 0012 Case

- **Grid convergence on Ice shape**
  - Surface roughness : 0.1 mm
  - Ice density : 901.3 kg/m^3
  - MVD : 20 µm (uniform)



Ice Thickness (GL1)



Comparison of Ice Shape(y=36 in span)

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Results

- Sensitivity Study

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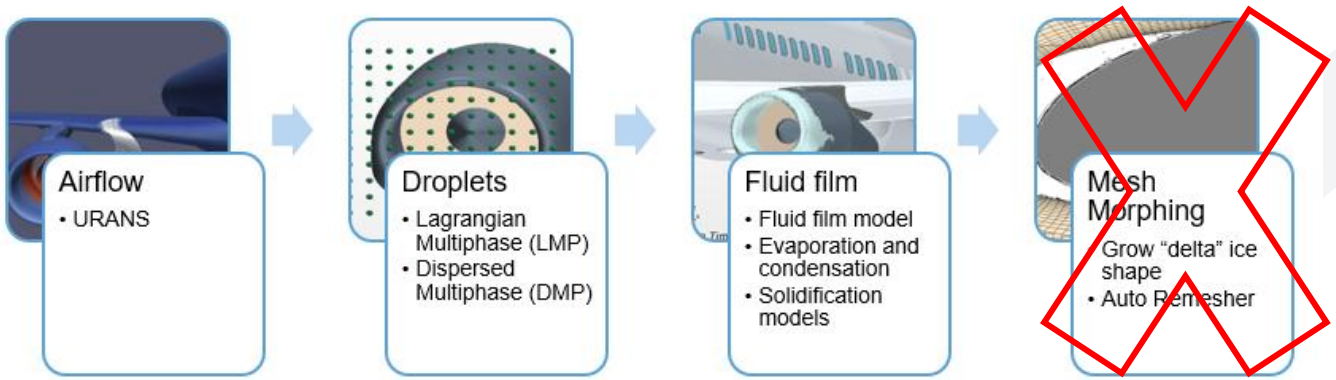
STAR-CCM+ Icing Analysis : Sensitivity Study

Simulation Setup

- STAR-CCM+ internal meshing (coarse mesh) w/o Mesh Morphing

Sensitivity study

- Surface roughness (default : 0.1 mm)
- Solid time scale factor (default : 20)
- Time step size (default : 0.01 sec)



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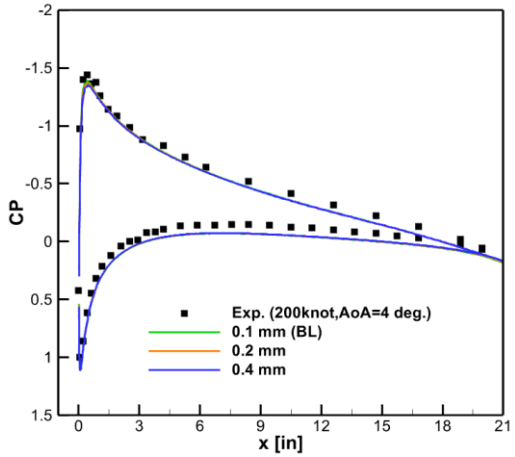
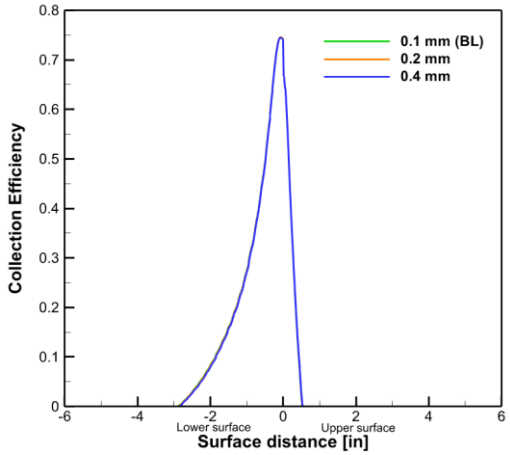
Sensitivity Study (Surface Roughness)

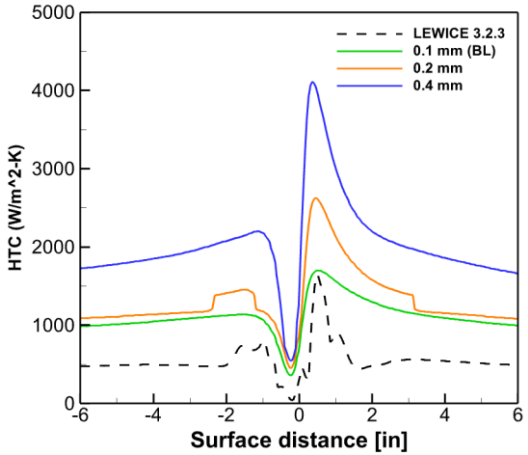
NACA 0012 Case (AE3933)
- **y=36 in span**



Comparison of Cp

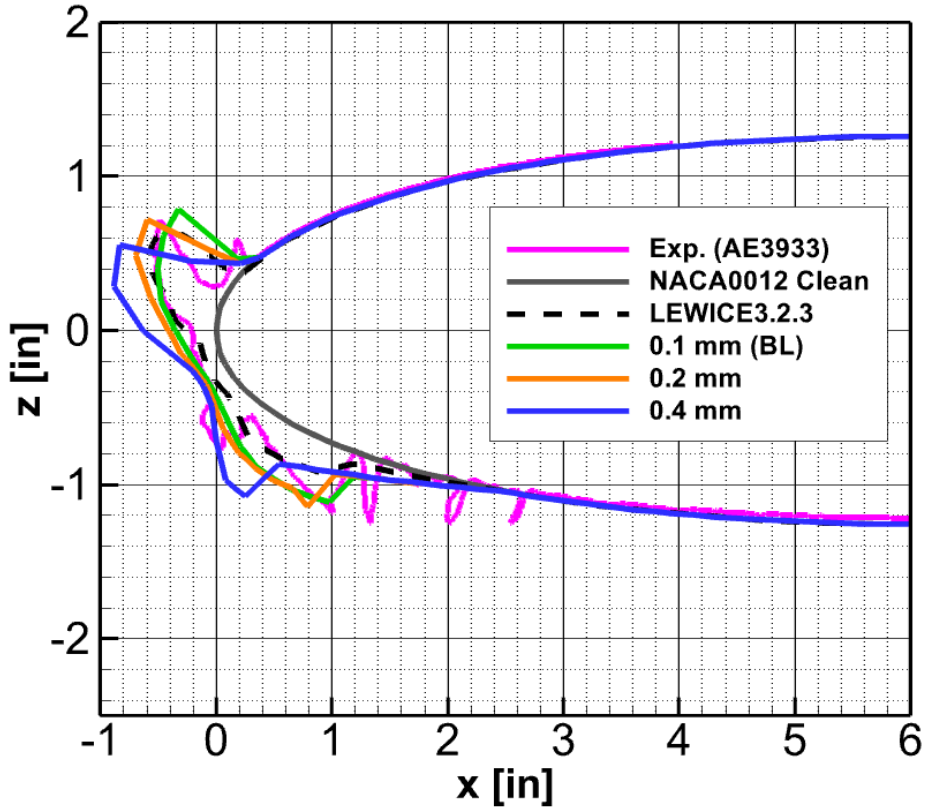


Comparison of Collection Efficiency



Comparison of HTC (W/m^2-K)

Surface Roughness
- No significant effect on airflow & droplet solution
- HTC increase as surface roughness increases => increase of ice thickness



Comparison of Ice Shape

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Sensitivity Study (Solid Time Scale Factor)

What is “Solid Time Scale Factor” in STAR-CCM+?

- Assumption in typical icing simulation
    - Much larger characteristic time scale for the ice layer growth than the time scale which characterizes the flow
- Utilizes above assumption and allows for the use of small enough time-steps to resolve the flow and nonlinearities associated with the ice accretion process
- Extrapolates the ice layer growth rate into the future and scales the mesh morphing process by the selected factor
- If a **Solid Time-step Factor** of **K**, the **Maximum Physical Time** of the simulation can be reduced by “**1/K**”

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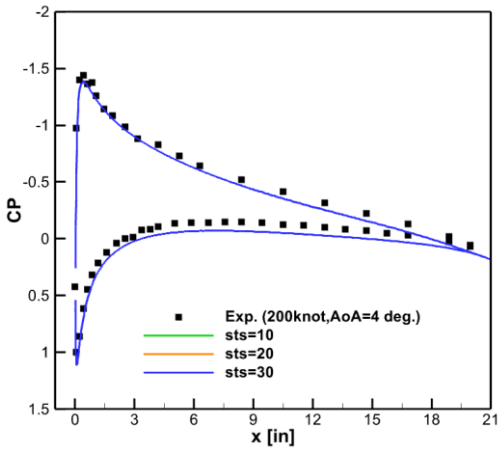
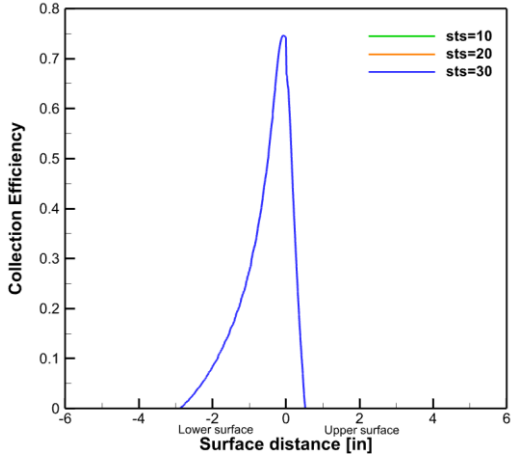
NACA 0012 Case (AE3933)
- y=36 in span

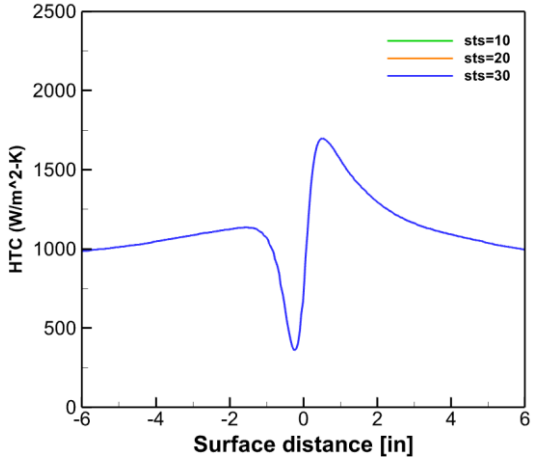
Sensitivity Study (Solid Time Scale Factor)



Comparison of Cp

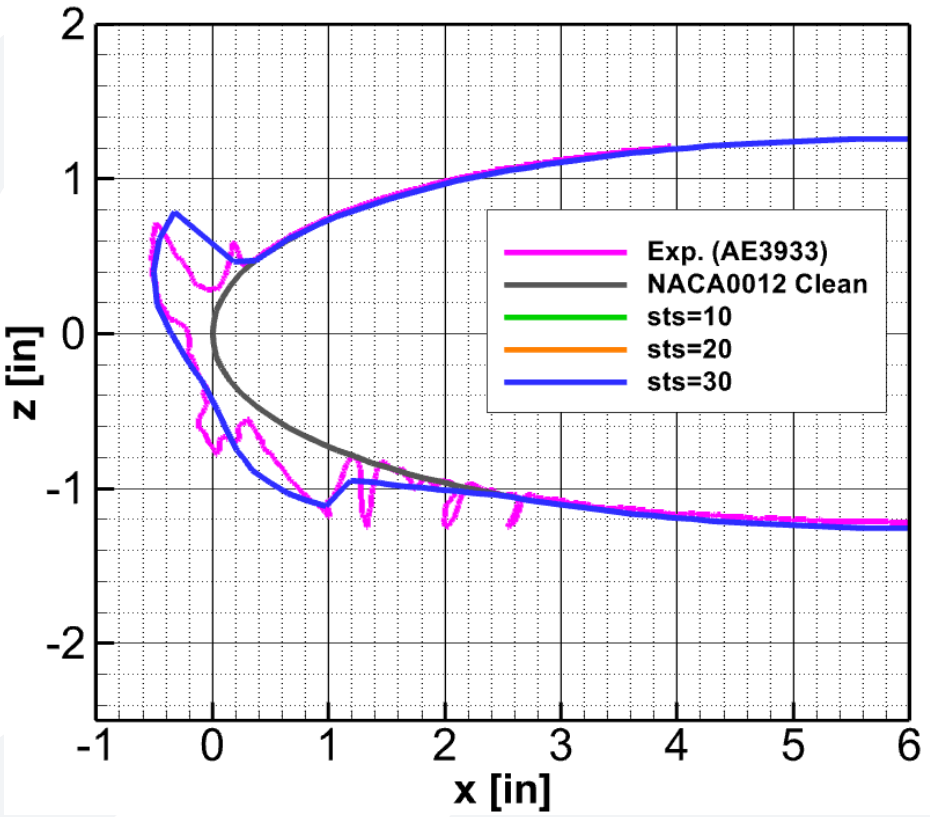


Comparison of Collection Efficiency



Comparison of HTC (W/m^2-K)

Solid Time Scale Factor
- No significant effect on results
- Larger solid time scale factor => speed-up run time



Comparison of Ice Shape

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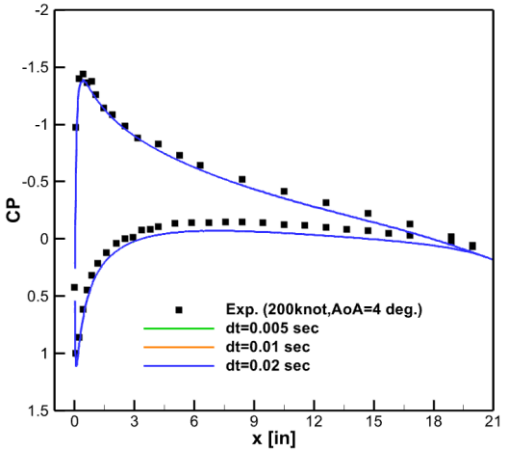
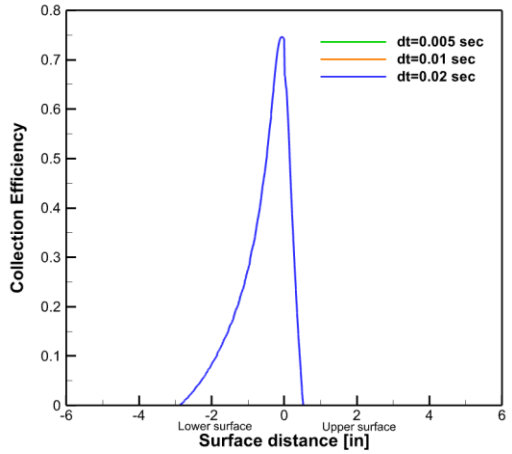
Sensitivity Study (Time Step Size)

NACA 0012 Case (AE3933)
- **y=36 in span**

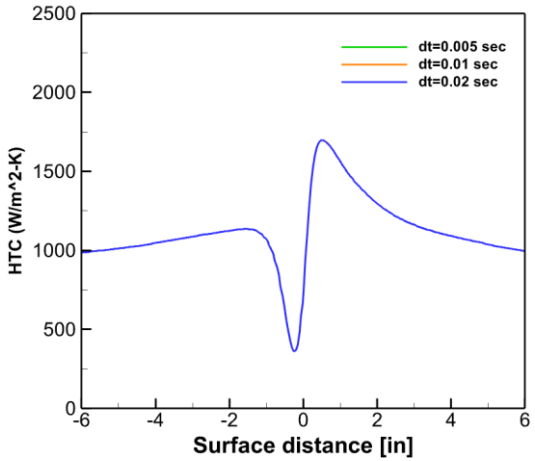


Comparison of Cp

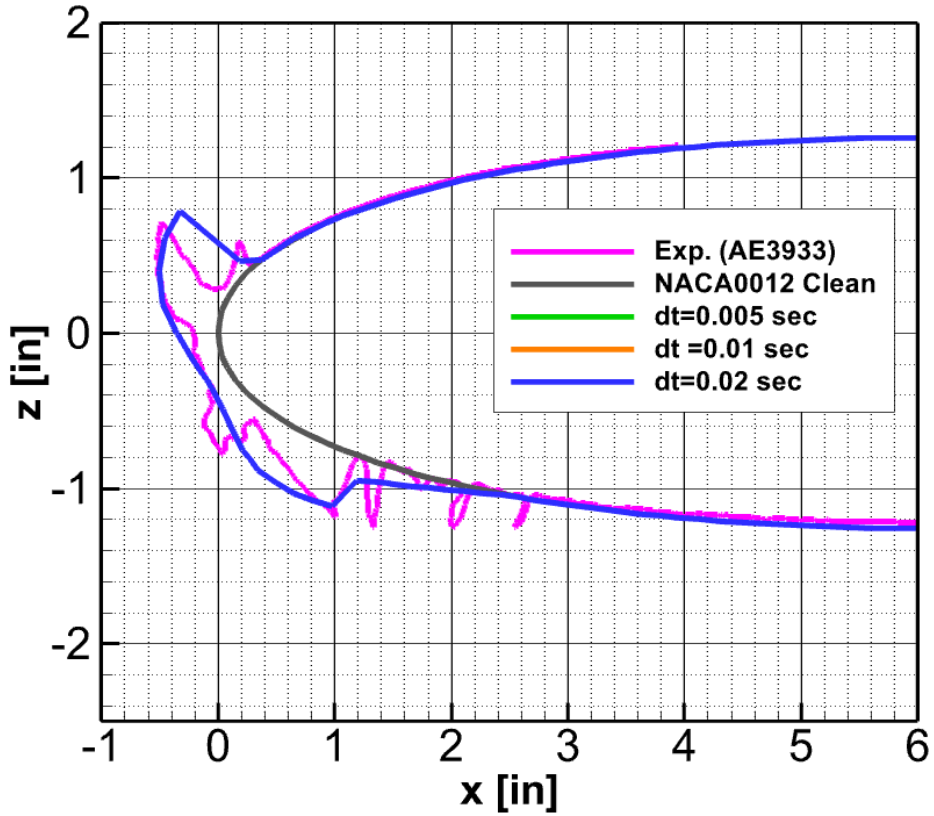


Comparison of Collection Efficiency

Time step size
- No significant effect on results
- Larger time step size => speed-up run time



Comparison of HTC (W/m^2-K)



Comparison of Ice Shape

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Conclusions

Mesh Convergence Analysis

- Surface pressure, collection efficiency distribution: marginal difference
- Airloads (CL/CD/CM): clear trend as mesh is refined
- Ice shape: marginal difference

Sensitivity Study

- Surface roughness:
    - No significant effect on airflow & droplet solution
    - HTC increase as surface roughness increases => increase of ice thickness
- Solid time scale factor & Time step size
    - No significant effect on results

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Thank You