

IPW-1 Participant Data Comparison and Submission Information

IPW-1 Organizing Committee

19 April 2021

Rev 3

IPW-1 Data Comparison and Submission

Participants are requested to provide the information, data and comparison plots as described on the following charts.

- Documentation of simulation approach (chart 3).
- Plot list for code-to-experiment comparison (charts 4 through 7).

The Workshop committee will generate additional code-to-code comparisons described on chart 4.

- This requires the Participants to submit their data in certain formats described in charts 8 and 9.
- Specific instructions on where and how to submit data will be provided later.

Documentation of Simulation Approach

General description of the CFD, impingement, and ice growth models [how it was set up and the work was done]

Description could also include:

- Water vapor pressure as function of temperature
- Drag model (tabular value)
- Thermal conductivity for materials (Aluminum, air, etc.) as function of temperature
- Dynamic air viscosity (as function of temperature)
- Particle water density & thermal conductivity (as function of temperature)
- Particle distribution (for confirmation; will be provided for experimental cases)
- Order of accuracy (1st or 2nd order)
- Drop rebound characteristics & splash model, if applicable

Plot List for Each Experimental Case

Code-to-Experiment (completed by each Participant)

- CP vs. X/C plot
 - From clean geometry (no ice)
 - Along row of pressure taps
 - Whole chord
 - (pressures from artificial ice shapes out of scope)
 - Non-dimensionalized by chord provided
- Ice Geometry and Clean Geometry plot
 - Cut normal to leading edge (usually)
 - Tracing or cut through MCCI from scan
 - Plot CPmax point from experiment and stagnation point from ice code on Clean Geometry
 - Plot line showing max thickness and location with thickness value and angle value callout from experiment and code
 - Units are in meters (matching CFD geometry)
- Ice Mass/unit_length along the Highlight line (if measured; units are in kg/m)
- Collection Efficiency vs. Arc Length from code and experiment corresponding to experimental cut line (if measured from dye strips; arc length units are in meters)

Code-to-Code (completed by Workshop committee)

Multi-iteration codes must plot first/last iteration as appropriate but have option to include other iterations.

- Clean arc length for first and last iteration (meters)
 - Need to map ice thickness to clean arc length anyway; include other parameters during mapping process
- Anchor $S=0$ to highlight location clean and perpendicular to the highlight for ice

Recommended parameters list to plot vs. arc length on cut normal to leading edge:

- CP
- Convective Heat Transfer Coefficient (W/m^2K)
- Freezing Fraction (calculated by code's energy balance; calculation may vary code to code; nondimensional)
- Collection efficiency
- Film/Ice Temperature (surface temperature, Kelvin)
- Roughness (k, meters)
- Ice Density (code input setting or code output, kg/m^3)
- Ice Thickness (use clean arc length for first and last iteration; meters)

Also show for each cut: Integrated code-predicted IceMass/Unit_length along the Highlight line value at cut location (Kg/m)

Ice Geometry and Clean Geometry Plot

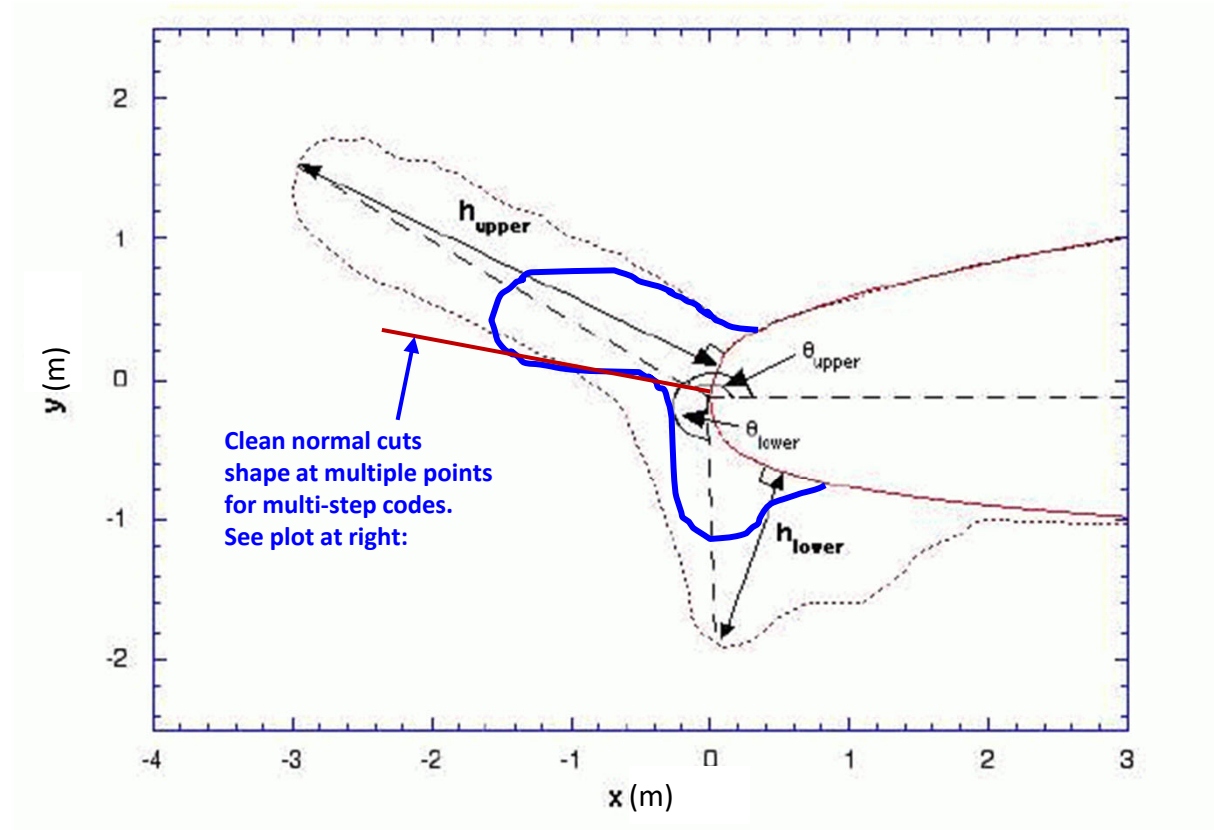
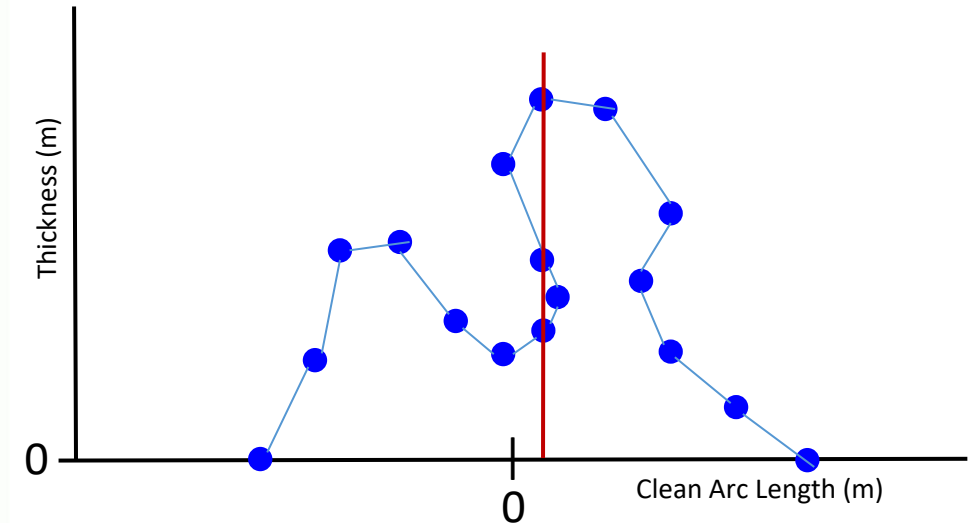


FIGURE 1 – Definition of Lower and Upper Horn Angle

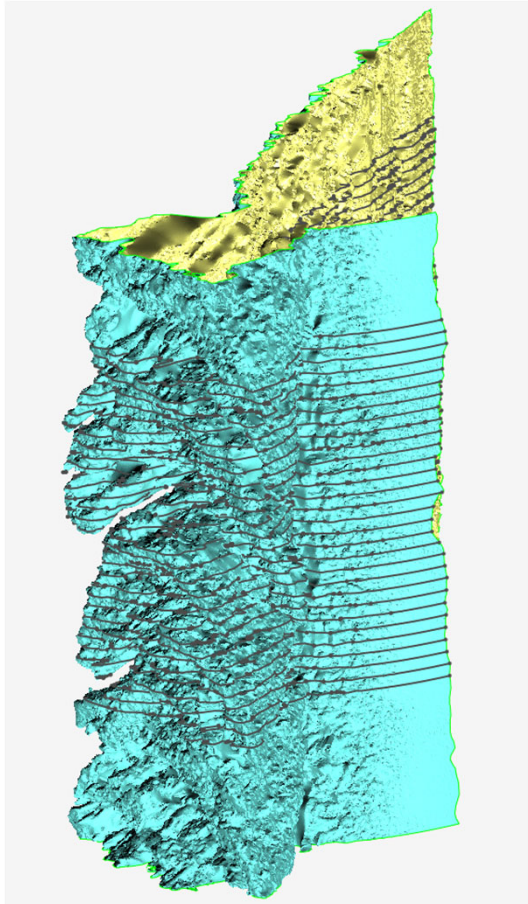


For some multi-step ice shapes there is not a function of thickness with clean arc length but rather a multi-valued relation.

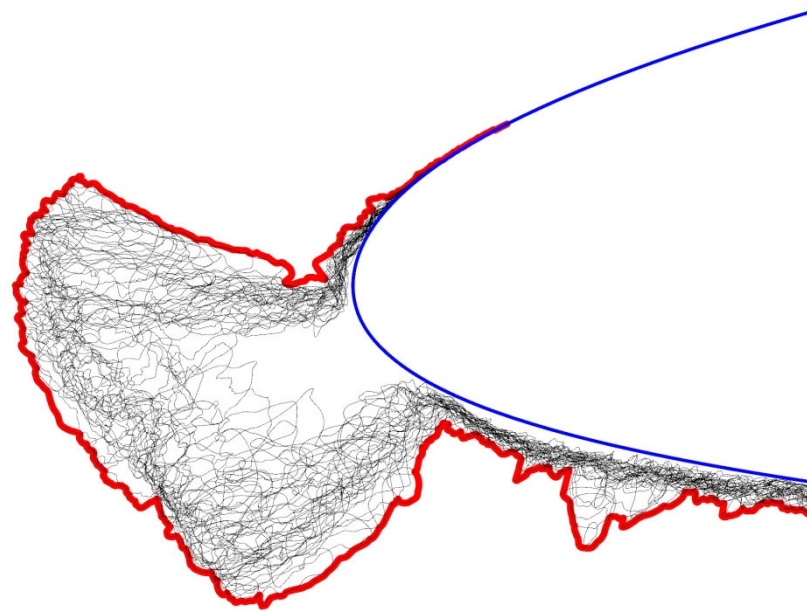
So resulting points from these ice cuts need to be connected correctly when plotting, as shown above.

Fortunately, many codes such as TECPLOT and ENSIGHT generate these ordered strings of points with multiple parameters of interest using their cutting tool.

Maximum Combined Cross Section (MCCS) Process Description



The experimental MCCS data files describe the number of cross sections and distances used to generate the MCCS.



Obtain Outer Boundary of the Combined Cross Section Cuts

It is requested that participants generate an MCCS from their codes since average or minimum ice shape experimental data are not available from scans or tracings at this time.

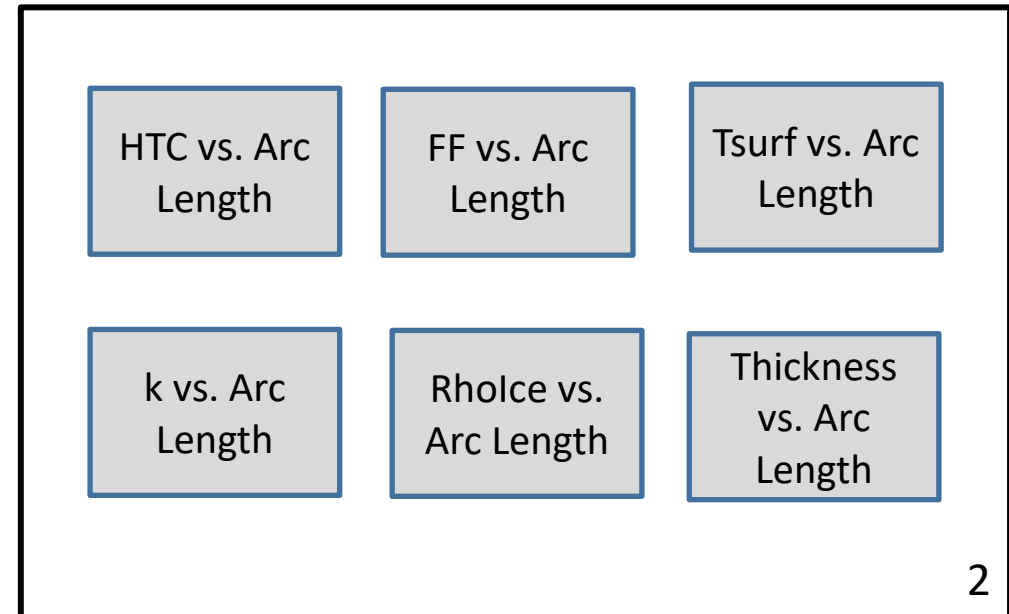
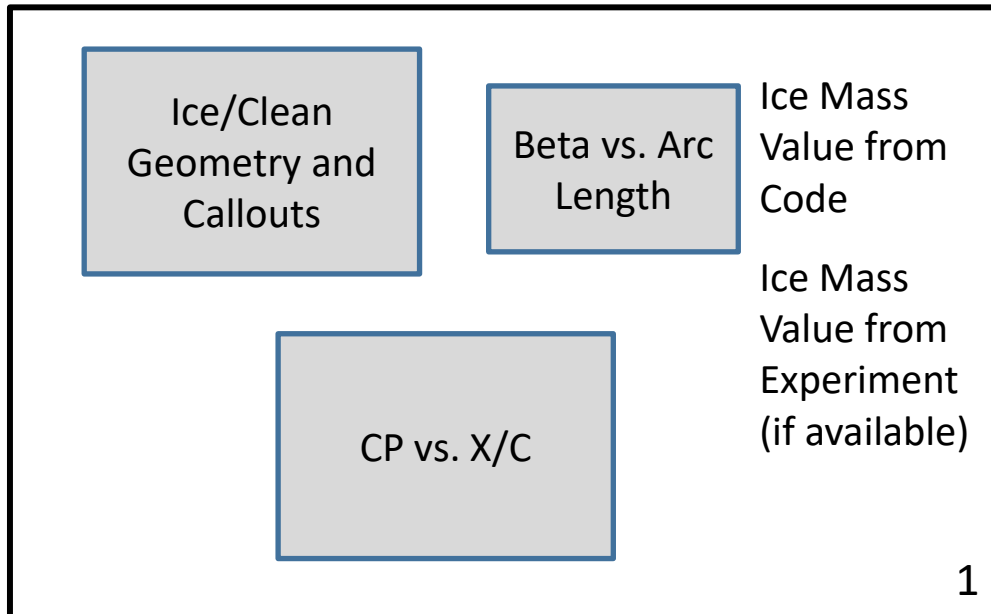
- For a code with scallops, a similar MCCS process shown at left should be used.
- For a code that calculates ice void density (average density based on MCCS accounting for voids due to scallops), the resulting output value(s) should be shown per the Plot List.
- For a code that takes the ice void density as input, the input value(s) should be shown per the Plot List.

Trying to match the MCCS is of great interest because it provides a standard and conservative 2D representation of 3D scallops that is commonly used.

An Idea for Template Structure

Experimental Case

Two pages of plots created per code for each experimental comparison case:



Data Submission Format

Required:

- Solution files in a Tecplot compatible format (.plt, .zplt, .dat, ...). A list of instruction and template files is given in chart 10;
- All the required cuts and integration (e.g. Ice mass, ice thickness, horn length/angle) done by the participants;
- Solution files must be named clearly with case number as defined in the workshop, participant identification and file description (e.g. case241_polytechnique_cutData.dat);
- Variable names in solution files from the participants must follow the predefined definition (e.g. Convective Heat Transfer Coefficient = HTC). See Table 1 on chart 9;
- All required data mapped to the clean arc length (clean and iced cut data) with the highlight as reference;
- The cut coordinates should be rotated so that the airfoils are at 0 degrees, to avoid confusion if CADs with rotated geometries in tunnels are used;
- Data given in SI units when applicable (e.g. Convective Heat Transfer Coefficient in W/m^2K). See Table 1 on chart 9;
- Single-zone surface cut with data at nodes to avoid possibly wrong interpolation by Tecplot from face centers to nodes, especially for multi-zone surface solutions.

Data Submission Format

Table 1: List of required variables on surface

Variable Name	Description	Units
X, Y, Z	Clean X, Y, Z coordinates	m
X,Y,Z_iced	Iced X, Y, Z coordinates for final ice shape	m
s	Curvilinear coordinate along cut with s=0 at highlight	m
Beta	Collection efficiency	-
Cp	Pressure coefficient	-
HTC	Convective Heat Transfer Coefficient	W/(m ² K)
FF	Freezing fraction	-
Ts	Surface temperature	K
k	Surface roughness	m
Rholce	Ice density for final ice layer	kg/m ³
X2D, Y2D	Clean X, Y coordinates in a plane with geometry at AOA=0 and HL at origin	m
X2D,Y2D_iced	Ice X, Y coordinates in a plane with geometry in same referential as clean	m
s_Clean	Curvilinear coordinate along clean cut with s=0 at highlight	m
hlce	Ice Thickness for ice shape	m

Table 2: List of required auxiliary data

Description	Units
X, Y, Z coordinates of highlight (for reference)	m
Upper/lower horn length	m
Upper/lower horn angles	°
Integrated code-predicted ice mass per unit length	kg/m

Data Submission Format

List of files provided:

- **README.instructions.txt** [DO NOT SUBMIT]: contains the detailed instructions about these files and the data submission (inspired from HLPW4).
- **participantName_participant_info.dat** [REQUIRED]: Contains the participants information and simulation methodology for all cases (possibly multiple runs per case).
- **caseN_participantName_cutData.dat** [REQUIRED]: Contains the template file in Tecplot ASCII format that can be filled with at least the required cut(s) of the first layer of ice with data computed on the clean geometry (Beta, HTC, etc.) and optionally all other layers of ice. Participants can also include ice information (hIce and sClean), but it is not mandatory.
- **caseN_participantName_finalIceShape.dat** [REQUIRED]: Contains the ice related data (hIce, X/Y2D_ice, sClean). It is separated from the cut data in case participants send the ice shape in the form of a M CCS built from multiple cuts. The ice shape can also be provided in the form of a single cut, which would then be the ice shape of the last layer. This file also contains auxiliary data such as the horn length since it concerns the final ice shape (M CCS or not).
- **caseN_participantName_auxiliaryData.dat** [OPTIONAL]: Contains the previously mentioned auxiliary data. It can be submitted by participants who prefer to send the required data files in binary formats and cannot add auxiliary data in them.