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NTI's Services for In-flight Icing Certification

FENSAP-ICE™ as an Aid-to-certification

FENSAP-ICE™ for IPS Design

NTI Support to Icing Tunnel and Natural Flight Tests

Introduction

To obtain a type design certification, it must be demonstrated that an aircraft, rotorcraft or jet engine can sustain safe flight into known or inadvertent icing conditions. As part of this certification process, several paragraphs of the design and operability standards are dedicated or related to performance in icing. Usually equipment, except for engines and propellers, is certified prior to the aircraft to Technical Standard Order (TSO), whereas engines and propellers have their own parts in the FAA or EASA regulations. When all equipment have been demonstrated to be flight-worthy, and that the aircraft has also been tested in ground icing tests, it passes a Type Inspection Authorization (TIA) and is deemed ready for the final demonstration through natural icing trials, when all systems are operational simultaneously. However, before reaching this point, a number of icing tests and numerical studies are required.

Icing CFD *simulation* has become an integral part of the certification process. *Even if numerical methods may sometimes not be explicitly listed in the means of compliance for a given aircraft program, it is highly probable that CFD was used in aid of certification*. Most often, it is used for icing similitude analyses, to correct for altitude, speed or chord length in the case of truncated airfoils, or in the facilities design phase to ensure an adequate simulation of real-life altitude icing through physical tests. Numerical results from similitude analyses are an integral part of the certification documents and require approval like any other evidence presented to demonstrate compliance.

Numerical simulation can also be used as means of compliance, or alternate means of compliance. The use of CFD as part of the icing certification is widely accepted when it is part of a company's best practices or engineering processes. It is crucial that the use of CFD be part of a well-defined and well-controlled procedure to ensure accuracy, repeatability and traceability. The use of CFD usually requires either jurisprudence, or demonstration of uses on previous certification programs, or credible validations on geometries of interest.

Large aircraft manufacturers may have had CFD as part of the icing certification process for several years and usually are not required to produce new validation data for every new aircraft to be certified. *So it is important to keep in mind that airworthiness authorities approve of a process, of which CFD is part, not of any particular code. FENSAP-ICE has been used by a wide breadth of manufacturers, on complex geometries, and has produced results that have been approved as part of a demonstration of compliance.*

FENSAP-ICE as an Aid-to-Certification

FENSAP-ICE is currently used in aid of certification in a variety of ways:

- Alternate means of compliance
- Icing facilities design (and similitude analyses)
- Simulated ice shapes used for Supplemental Type Certification (STC) applications

The following illustrates examples in which cases approved engineering data was produced using FENSAP-ICE. This is only a sample of FENSAP-ICE uses in the icing certification process. *Many more cases cannot be presented either because they were conducted by the OEM and NTI is not privy to the results, or they were ran by NTI as a consulting project but the OEM does not allow diffusion of the results.* OEMs are very secretive about their certification best practices and about the numerical tools they include.

Alternate Means of Compliance

The EADS/CASA C-295 is a medium military transport equipped with two Pratt & Whitney Canada PW127G turboprop engines. Its air induction system was scheduled for ground icing tests in an atmospheric icing tunnel at NRC, Canada. Because of an unusually warm winter, all the cold points, with temperatures colder than -10°C could not be tested. However, since the air induction system is equipped with pneumatic boots without any thermal systems, it was decided to demonstrate by CFD that all the most severe conditions were tested. A CFD model of the inlet system was created and FENSAP-ICE was used to calculate droplet impingement for conditions tested. *The comparison between visual evidence gathered during the test program and numerical results was in excellent agreement, thereby convincing the airworthiness authorities that FENSAP-ICE could be used as alternate means of compliance to virtually test the cold conditions.* The calculations showed that all the most severe conditions were tested and that the air induction system complied with the design standards.

Icing Facilities Design

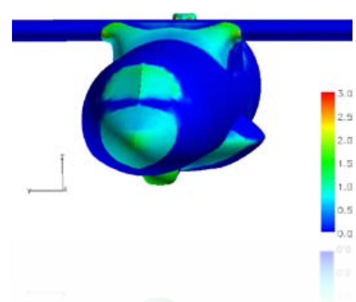
The Bell-Agusta BA609 first civilian tiltrotor aircraft is equipped with two Pratt & Whitney Canada PT6C-67A turboshaft engines. The complete nacelle/engine installation was tested in an atmospheric propulsion icing tunnel. For such installations, the nacelle and engine are submerged in a streamlined fiberglass tunnel, which is designed to conserve the capture tube shape from the aircraft flying at altitude to the isolated engine installation at sea level. *This work can only be conducted using CFD and the results are part of the certification documentation*, as it is a critical item to set up properly the ground icing tests. The picture on the right shows the impingement patterns on the BA609 in flight at altitude, which serves as the baseline for the icing similitude analyses.

FENSAP-ICE results accepted by Transport Canada: STC application of Dash 8Q400

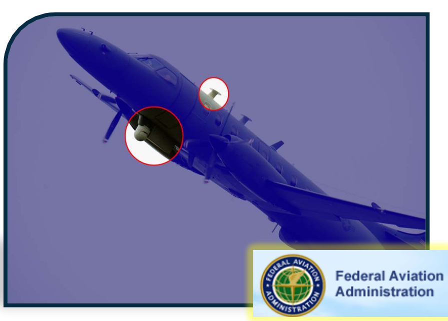
The Bombardier/De Havilland Dash 8Q400 is a regional airliner equipped with two Pratt & Whitney Canada PW150A turboprop engines. This aircraft's engine installation was tested in the same facility as the BA609 described in the previous paragraph. It required the same similitude analysis to design a contoured wind tunnel in which the nacelle is submerged. In addition, *FENSAP-ICE was used to investigate a mechanical damage issue that occurred because of ice growth in the front inlet case, which is oil heated for ice protection. FENSAP-ICE results confirmed video footage gathered during the icing program by inserting cameras in the air induction system*. These results were used to redesign the oil heating core passages in the front inlet case, which solved the problem and was demonstrated in a subsequent icing test. Because of the CFD model was already available*, FENSAP-ICE was also used to position the T1 sensor within the front inlet case to avoid ice accretion*, and thereby erroneous readings and subsequent engine instabilities due to a wrong temperature measurement. Engine settings and controls are highly sensitive to the engine inlet temperature.

FENSAP-ICE results accepted by EASA: STC application of ATR42 modification

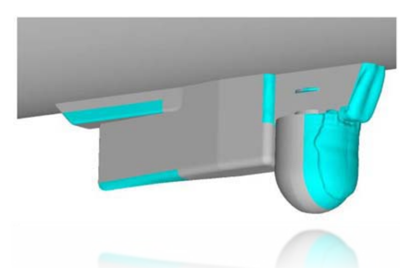
An ATR42 was modified by EADS-SOGERMA to add special instrumentation for Météo France (the French weather service). As it is mandated for retrofit or modification of an already certified platform, dry air flight tests must be conducted with the addition of simulated ice shapes on critical components. These ice shapes are produced by CFD, molded, attached to the aircraft and flown to demonstrate sufficient performance and handling qualities margin for safe flight. FENSAP-ICE was used for a number of such projects and its results were accepted by EASA and Transport Canada. The picture on the right shows the modified ATR 42 with ice accretion coloured by ice thickness in inches. These shapes were provided to the customer to be produced and flown. *The entire process from the icing CFD analyses, to flight testing and obtaining the STC (Supplemental Type Certificate) was only three months.*



FENSAP-ICE results accepted by FAA: STC application of RC-26B modification



A RC-26B was modified to add an upper-fuselage mounted SATCOM antenna and lower-fuselage forward-looking infrared (FLIR) camera. Since the pre-modified airplane was certificated for flight into known icing, an Icing CFD campaign was done using FENSAP-ICE in order to assess the possible effects of ice shedding from the added equipment. FENSAP-ICE predictions provided 3D definition of complex ice shapes were used to fabricate the artificial ice shapes for flight test. The predicted shapes were consistent with shapes determined by theoretical analysis, shapes derived from icing tanker tests, and flight-testing in natural icing conditions. Furthermore, FENSAP-ICE aerodynamic performance degradation characteristics predictions were used to evaluate the low potential flight test risk and calculated values of drag were consistent with flight test results. The use of FENSAP-ICE significantly reduced the total amount of flight-testing normally associated with an icing certification program of this magnitude. FENSAP-ICE results from this campaign were accepted by the FAA



FENSAP-ICE for Ice Protection System Design

The first step to establish an icing and flight condition matrix is obtained by combining the aircraft or rotorcraft flight envelope with the icing envelope of Appendix C and additional airworthiness guidance material. Then, the matrix is examined to identify critical conditions for a given type of ice protection system (IPS) on a certain aircraft component. For example, critical conditions for a pneumatic deicer are very different than those or an electro-thermal system. At this stage, it may be possible to establish pass/fail criteria for performance of the components or systems.

A roadmap that has been used with some of our aircraft customers, based on some widespread mistakes NTI has noticed in the design of aircraft that we have been asked to investigate after accidents involves:

1. Definition of the 3D wings and empennage geometry and all sectional geometry of the vehicle.

2. Definition of flight performance data for all normal and extreme phases of flight, such as true air speed (TAS), fuselage angle of attack, local geometric angle of attack, spanwise lift distribution, aircraft weights (maximum, minimum, intermediate), c.g. limits (aft, forward), configurations (i.e. flaps, ailerons, landing gear position), availability of excess power for the proper operation of the deicing or anti-icing system, trimmed and transient flight conditions.

3. Definition of the most critical cases for *impingement, accretion and handling qualities*. It must be remembered that worst-case impingement (high speed, low AoA) does not correspond to worst-case performance (low speed, high AoA). Some of the critical parameters from an icing point of view that have to be considered for each characteristic airfoil section include:

    - True air speed
    - Local aerodynamic angle of attack
    - Droplet size
    - Total and static temperature (for possible runback effect)
    - Altitude (air density)
    - Airfoil chord
    - Leading edge sweep
    - LWC and duration of flight in icing
    - Load factor
    - Compressibility
    - Reynolds number
    - Effect of flaps

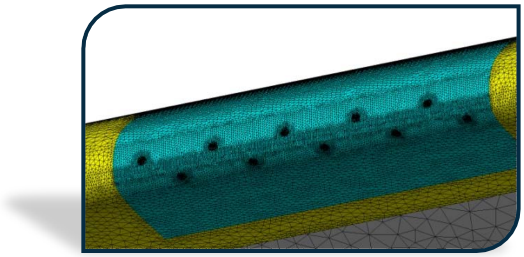
Assuming that the type of IPS for each aircraft component to cover are chosen, NTI concurrently starts generating the CAD models for this component; depending on the airflow scenario, the complete (external) geometry of the aircraft can be taken into account for the design of the wing and tail IPS simultaneously. A mesh is generated around each component,

For unprotected components NTI calculates the airflow solution via FENSAP. The air solution is then used to calculate droplet impingement on all surfaces using DROP3D. This determines the mass flow of water impinging on each point of the geometry.

Ice is grown on each unprotected surface using ICE3D.

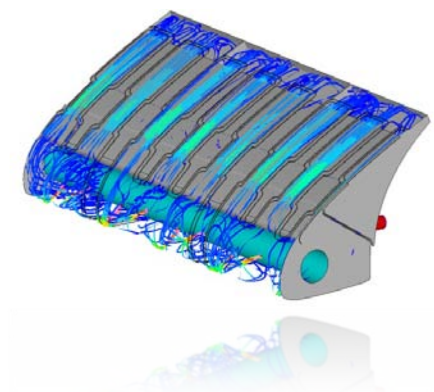
The final step is to assess the performance degradation using FENSAP.

This cycle can be repeated for several ice layers if required. Remeshing may not be necessary because FENSAP-ICE includes ALE (Arbitrary Lagrangian-Eulerian) mesh movement.



For protected components, the analysis process varies depending on the type of protection. For example, for pneumatic deicers, the analysis is similar to unprotected components for the calculation of inter-cycle ice and associated performance degradation. For hot air or electro-thermal ice protection, the calculation involves a multi-domain problem. The physical phenomena in each domain, whether it is conduction only, or conduction with phase change, or Reynolds-averaged Navier-Stokes for fluid domains, are solved iteratively in each domain. Heat fluxes are transmitted through domain interfaces in a conservative fashion and not only pure geometrical interpolation for non-matching grids.

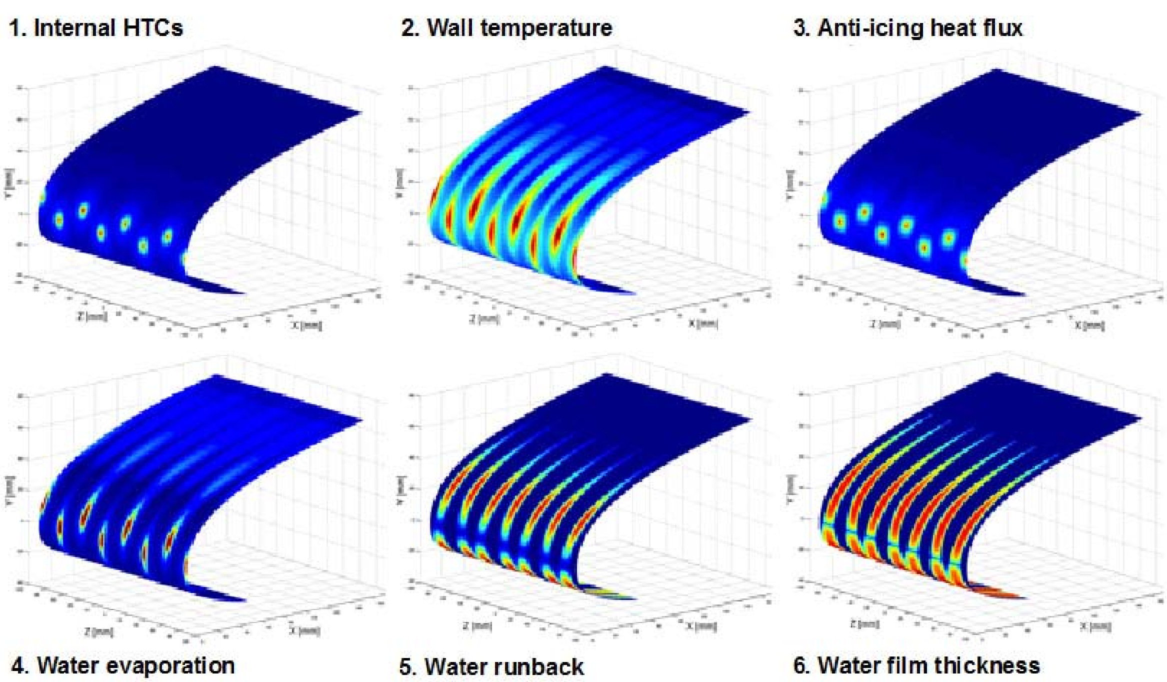
Visualization and post-processing are conducted to extract useful data such as forces and moments, droplet collection efficiency distribution or mass of ice accreted. These quantities can then be compared with the initial pass/fail criteria.



After the initial analyses, design changes can be addressed if the system is predicted to perform below expectations. Optimization of the components or systems may be conducted through additional analyses. For example, the OEM may be interested in minimizing bleed air requirements for hot air systems or electrical output to minimize generator size for electro-thermal systems. As well, it might be decided to change pneumatic boot coverage if it is insufficient.

At this stage, NTI can look at different scenarios, if required, that may not be in the icing regulations. For example, different aircraft maneuvers can be analyzed after an icing encounter to ensure that adequate stability and control margin remains despite ice accretion.

Finally, once all analyses are completed, NTI can settle on a test matrix for demonstration of compliance. Because of the thoroughness of the analyses, the risks associated with certification are mitigated by the complex 3D computations as opposed to the traditional 2D geometries.



NTI Certification Services

NTI possesses the know-how and resources to facilitate the icing certification process for customers in a number of ways, well beyond the simple use of icing CFD:

- **Project Management:**

  NTI experts can become part of an Integrated Product Team (IPT) as team member or leader to ensure successful completion of the icing certification process. NTI experts will interact with specialists from all disciplines to establish effective communication channels, and to be involved in the complete process from the beginning to obtaining the Type Certificate.

- **Interaction with Airworthiness Authorities:**

  NTI can negotiate the certification basis, prepare a compliance plan and have it approved by airworthiness authorities. In addition, NTI can present and obtain approval for engineering data and documentation for icing certification.

- **Test Facility Design:**

  NTI can select and prepare any test facility required in the icing certification process. NTI can also perform design work for any hardware, test model or instrumentation required for testing.

- **Test Preparation and Support:**

  NTI can establish a test plan and matrix according to airworthiness regulations and applicable advisory material. In addition, NTI can also perform any analyses required to support testing such as similitude analyses for example.

- **Process Integration and Streamlining:**

  NTI can establish a repeatable and documented process for icing certification if such does not exist. NTI can also assist in streamlining or improving an existing one. This includes conducting any required validations.

- **Design and Analysis:**

  In addition to performing the initial design and analysis of ice protection systems, NTI can use its vast analytical and computational expertise to improve a design, if needed, during the icing certification process.

- **Engineering Documentation:**

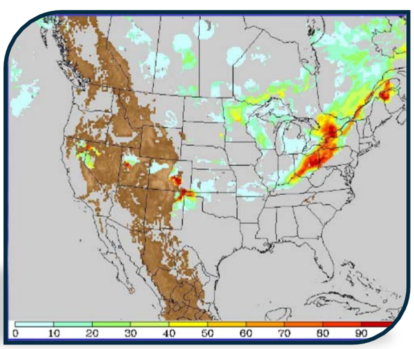
  NTI can prepare all necessary engineering documentation to be submitted to airworthiness authorities for the icing certification process

NTI-DER Support of FIKI and STC Certification

Icing certification campaigns, from the application of a Type Certificate, Amended Type Certificate, Supplemental Type Certificate, all the way to the certification of a new aircraft for Flight into Known Icing (FIKI) conditions, are known to be fairly elaborated processes, requiring a traceable and well documented process in order to produce a successful campaign. Previous icing certification experience and a thorough understanding of the different requirement often requested by the major airworthiness is thus a must.

NTI has associated itself with the Industry's top Designated Engineering Representatives (DER): John P. DOW Sr., FAA DER, Eugene HILL , FAA DER and Captain John L. SIEMENS FAA Test Pilot and Flight Analyst DER, order to provide support to its customers during an icing certification process. With experience in both: FAA and EASA regulations, NTI with its associated DERs can assist OEMs in the certification process by managing the icing certification campaign, establishing a compliance plan and preparing the necessary engineering documentation to submit to the appropriate airworthiness authorities.

NTI-LEA Support of Natural Icing Flight-Tests



One of the most challenging phases is the natural icing flight campaign to gain certification for flight into known icing. Aircraft manufacturers fly their new aircraft and/or systems into clouds, targeting specific combinations of temperature, liquid water content and droplets' size. Such conditions can be rather elusive and the time, energy and costs involved in finding, staying within, and documenting them, can be quite significant.

NTI is pleased to team up with Ben BERNSTEIN and Leading Edge Atmospherics (LEA), renown for making this rather daunting task more simple, efficient and safe. LEA has more than a decade of experience guiding a wide variety of aircraft safely into (and out of) icing conditions over the United States, Canada and Europe. These aircraft have included helicopters, small through large turboprops, business jets and large jets.

NTI-LEA work closely with pilots and flight test engineers to get the icing conditions that they need for certification. We examine historical weather data to determine optimal locations for the operations base to help maximize the opportunity to find the desired conditions. Working with the program, we put the icing weather into pilot terms, helping customers to plan flight routes effectively to make the best of sampling opportunities, and to determine critical escape routes that may be needed to maintain safety.

Newmerical Technologies International (NTI) develops and markets advanced CFD software and offers flow simulation services in the aerospace, architectural, automotive and marine markets. NTI is an acknowledged leader for in-flight icing simulation and related engineering services.

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