Towards Real-Time CFD Simulation of In-Flight Icing

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ABSTRACT

Despite the concerted efforts of manufacturers and certification agencies, incidents and accidents continue to happen to aircraft certificated to "Fly Into Known Icing" (FIKI), falsely thought of as being "immune to in-flight icing". The current successive process of CFD for ice shape prediction, then icing tunnel testing (experimental fluid dynamics- EFD), and finally flying in natural ice conditions (flight fluid dynamics-FFD), has many gaps that can only be filled by modern (three-dimensional, compressible, turbulent) CFD.

By developing "coupled" CFD tools, able to simulate both the aerodynamics and icing in a concurrent engineering way, and by viewing the aircraft as a system and not as disjoint components, it will be shown how CFD, EFD and FFD can be combined in a rigorous mathematical way to carry out a much faster, more complete and more thorough evaluation of the aircraft's FIKI, and result in a much safer aircraft.

The full paper will cover aspects of physical and mathematical modeling (impingement, accretion, de-icing, anti-icing, conjugate heat transfer, turbulence modeling), CFD (FEM, FVM, automatic mesh optimization) and give as a vivid example the actual certification campaign of China's first Regional Jet, the ARJ21.

The paper will particularly highlight a reduced order modeling (ROM) framework inching toward the calculation, via RANS, of the aerodynamics + water impingement + ice accretion + performance degradation, in real-time. The ROM methodology is based on Proper Orthogonal Decomposition, multi-dimensional interpolation and machine learning algorithms, along with an error driven iterative sampling method, to adaptively select an optimal set of snapshots. The methodology is applied for the first time to a "full aircraft" and to the "entire" icing certification envelope, providing invaluable additional CFD data to the limited ones from icing tunnels (EFD) or natural flight-testing (FFD).

The level of accuracy achieved strongly supports the drive to incorporate more CFD information into in-flight icing certification and pilot training programs, leading to increased aviation safety.

REFERENCES

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