A Robust 3D Particle Tracking Solver for in-Flight Ice Accretion Using Arbitrary Precision Arithmetics

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ABSTRACT

Simulation tools to predict in-flight ice formation are of paramount importance in the design and sizing of anti- or de-icing systems. The full problem requires computing the flow field around the body, water impingement, and the mass and energy balance on the surface. This work addresses the computation of the amount of water impinging on a surface which formally involves the simulation of the two-phase flow of air and water around a body. Due to the low concentration of the dispersed phase, this problem only presents one-way coupling, meaning that the momentum transfer from the particles has a negligible effect on the flow [1]. This, together with an Eulerian-Lagrangian description, allows the particulate to be dealt with as a post processing of the aerodynamic computation.

A particle tracking code was developed in order to integrate droplet trajectories in a previously computed Eulerian flow field. As such, it must be able to track particles in hybrid or unstructured meshes used by common CFD solvers. A known vicinity algorithm was devised to search for particles inside the mesh by computing the intersection between the particle trajectory and the faces of the mesh. Arbitrary precision arithmetics is used in the intersection evaluation in order to avoid errors when selecting the exit face if the intersection point is close to a vertex or an edge. Also non-planar faces are dealt with without any approximation in order to avoid the virtual gap problem highlighted in [2].

Upon impact, both deposition and splashing mechanisms are modelled. A local spline representation of the boundaries was introduced in order to improve the accuracy of particle-wall interactions. As the interaction models depend on the normal to the boundary at the impact point, an accurate representation of the surface is key to accurately resolve the the behaviour of impinging particles.

A parallel implementation of the solver is presented showing linear scaling due to the loose coupling of the problem limiting the message passing between processors.

The particle tracking code is validated against the experimental results by Papadakis [3] and compared with the results obtained with the OpenFoam solver on the same test case.

REFERENCES

[1] S. Elghobashi, *"On predicting Particle-Laden Turbulent Flows"*, Applied Scientific Research, Vol. 52, 1994.

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[3] M. Papadakis et al., *"Water Impingement Experiments on a NACA 23012 Airfoil with Simulated Glaze Ice Shapes"*, 42nd AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, 2004, AIAA 2004-0565.