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PARALLEL COMPUTING OF ICING ON THREE-DIMENSIONAL AIRFOILS

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In aerospace Engineering, the accurate simulation of ice accretion is a key element to increase flight safety and avoid accidents related to icing effects. The icing code developed in the NSMB solver [1] is based on an Eulerian formulation for droplets tracking, an iterative Messinger model using a modified water runback scheme for ice thickness calculation and mesh deformation to track the ice/air interface through time. The whole process is parallelized with MPI.

In this work, the icing model implemented in the NSMB solver is presented, validated on several test cases and applied to the calculation on multiple processors of the ice accretion on three-dimensional airfoils.

An Eulerian approach [2] for modeling droplet impingement on a solid structure is implemented in NSMB. While a Lagrangian model tracks each droplet separately through the computational domain by solving Newton's dynamic equation for each of them, the Eulerian model solves a droplet velocity field and a volume fraction distribution. The resolution is performed implicitly using a Stone Algorithm. The freestream values of droplet velocity and volume fraction are imposed as boundary conditions at the far field. A switching boundary condition is applied at the wall : Neumann when the incoming droplet flux is positive and Dirichlet otherwise.

The ice thickness solver is based on a modified Messinger model [3] including an upgraded runback scheme [4] and an iterative procedure for solving three-dimensional and complex multi-blocks configurations. The runback model developed by Zhu et al. [4] is used to compute in each cell located on the wall the amount of outflow liquid water going in north-south direction cells and the amount of outflow liquid water going in west-east direction cells. The neighbouring cells are then updated. The mass fluxes exchange at block boundaries is performed using message passing interface, and the whole process is repeated until a convergence criteria is met. The ice thickness is solved using the mass conservation and the first law of thermodynamic.

In case of multi-steps icing, an automatic mesh deformation and smoothing is applied to the grid to track the ice / air interface.

For validation purposes, droplet distribution and ice accretion is simulated for an extruded NACA0012 airfoil at an angle of attack of *4°*. The simulations are performed at a free-stream Mach number of *0.31* with a constant droplet diameter of *20µm*, a liquid water content of $0,55g/m^3$, a temperature of *250K* and an airfoil chord of *0.5334m*. The ice accretion duration is set at four steps of *105s*. The mean flow field is obtained from NSMB using a fourth order central scheme with artificial dissipation. Spalart-Allmaras (SA) is used as turbulence model with ONERA extension for roughness.

The grid used contains *220000 cells* divided into *4 blocks.* The liquid water content distribution is represented on Figure 1. The deformation of the mesh due to ice accretion after four timesteps of *105s* is represented on Figure 2. Results are in good agreement with numerical results of CANICE2D [5]. The algorithm is implemented for three-dimensional calculations. Results of ice accretion on a GLC-305 swept wing will be presented to demonstrate the efficiency and robustness of the method.

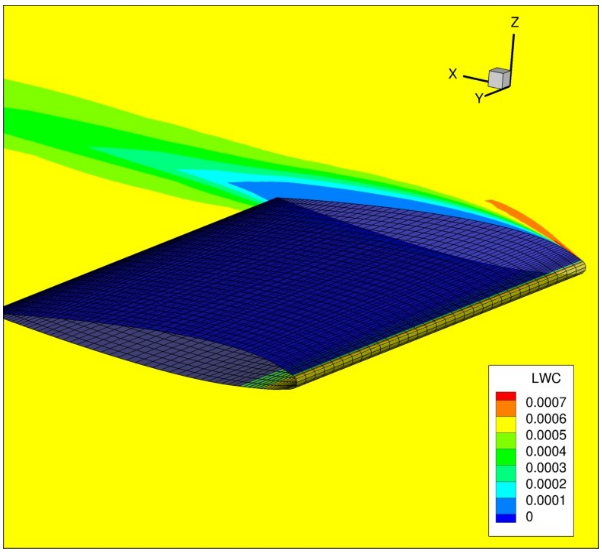

Figure 1: LWC Distribution on extruded Naca0012 airfoil

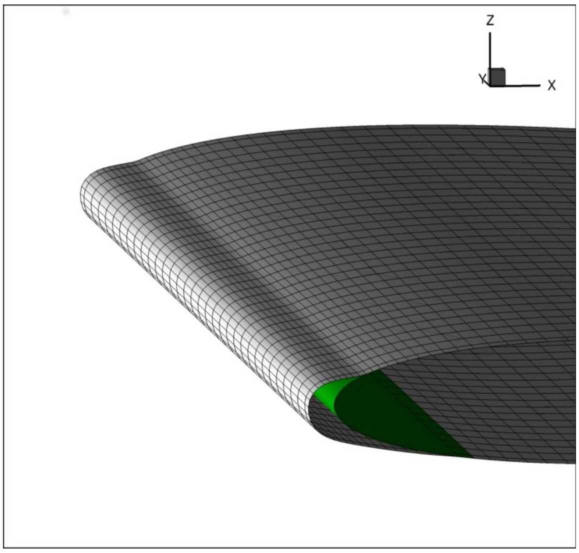

Figure 2: Ice Accretion on extruded Naca0012 airfoil

REFERENCES

[1] Vos, J., Chaput, E., Arlinger, B., Rizzi, A., Corjon, A., 1998, Recent advances in aerodynamics inside the NSMB (Navier-Stokes Multi-Block) consortium. In 36th Aerospace Sciences Meeting and Exhibit, AIAA Paper, 1998-0802, Reno, USA.

[2] H. Beaugendre, F. Morency and W. G. Habashi, 2003, FENSAP-ICE's Three-Dimensional In-Flight Ice Accretion Module: ICE3D, JOURNAL OF AIRCRAFT, Vol. 40, No. 2, March–April 2003

[3] B.L. Messinger, Equilibrium Temperature of an Unheated Icing Surface as a Function of Airspeed, Journal of Aeronautical Sciences, Vol 20, No 1,pp. 29-42, Jan. 1953.

[4] C. Zhu, B. Fu, Z. Sun and C. Zhu, 3d ice accretion simulation for complex configuration basing on improved messinger model, Int. J. Mod. Phys. Conf. Ser. 2012,19:341-350

[5] Hasanzadeh K., Laurendeau E., and Paraschivoiu I., Quasi-steady convergence of multi-step Navier-Stokes icing simulations, Journal of Aircraft, 2013, DOI: 10.2514/1.C032197