Modelling Ice Accretion due to Freezing Precipitation using a Discrete Morphogenetic Approach

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ABSTRACT

Atmospheric icing due to freezing rain and freezing drizzle occurs when airborne supercooled water drops freeze on objects they encounter. The resulting ice can accumulate to a thickness of several centimetres during severe freezing rain events called ice storms. This ice can be hazardous for ground-based engineering structures such as overhead transmission lines, wind turbines, telecommunication masts and bridge cables. But it is especially hazardous to aircraft, when the build-up of ice due to impinging supercooled cloud droplets changes the stability and control characteristics of the aerodynamic surfaces. The shedding of accreted ice can also have disastrous consequences.

Ice accretion is a complex phenomenon involving 3D multi-phase flow, heat transfer, and gravitational, viscous and shear forces. An ability to predict how ice accretes on engineering structures is essential to the prediction and mitigation of its associated aerodynamic penalties.

Most current icing models are limited by their reliance on solving continuous equations and boundary conditions. We have circumvented these limitations by developing an original icing modelling capability, which we call “morphogenetic”. It is based on a discrete formulation and simulation of ice formation physics. The original 2D development of this unique approach for the prediction of ice accretion shapes in the aerospace industry is given in [1]. Recent 3D modelling advances are described in [2-3]. Whereas traditional icing models consider continuous fluxes of impinging drops and water flow along the ice surface, the morphogenetic approach considers the behaviour of discrete ensembles of cloud drops, which impinge, move along the icing surface and freeze according to physically-based, stochastic rules. There are many advantages of the discrete morphogenetic approach. Although it can be computationally time consuming, it is relatively intuitive and straightforward to implement. It also improves on existing ice accretion models, inasmuch as it is capable of predicting simultaneous rime and glaze ice accretions, ice accretions with variable density and discontinuous ice accretions such as rime feathers and lobster tails.

In the morphogenetic ice accretion model, the mass flux of impinging droplets is divided into discrete fluid elements that consist of ensembles of individual cloud drops, all of which have identical histories. A three-dimensional, rectangular cubic lattice defines the accretion domain. By building the accretion one element at a time on this lattice, the morphogenetic model emulates the time evolution of the accretion shape in a way that mimics the real world. In our model, the fluid elements are allowed to impact randomly on the surface or on the existing ice structure in such a way that their mass distribution is consistent with the overall drop impact distribution. Once ice starts to grow, approaching fluid elements may be intercepted by protruding asperities.

REFERENCES

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