

Eulerian Method for Ice Accretion on Multiple-Element Airfoil Sections

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A computational method is presented that given the flow solution computes ice accretion on multiple-element airfoils in specified icing conditions. The numerical simulation method (Droplerian) uses an Eulerian method to determine the droplet trajectories and distribution of the Liquid Water Content (LWC). To solve the equations for the droplet trajectories and liquid water content distribution, Droplerian uses a Finite Volume Method for unstructured grids. Through the droplet velocities and Liquid Water Content at the surface of the airfoil configuration the droplet catching efficiency is calculated. The droplet catching efficiency and droplet velocities at the airfoil surface are input for the icing model, which is based on Messinger's model for ice accretion. The method includes a multi-disperse droplet distribution with an arbitrary number of droplet bins and a droplet splashing model. For a single-element airfoil a good agreement is found with measured catching efficiencies and with the ice shapes predicted by other computational methods. For increasing droplet diameter the agreement with experimental results deteriorates. The application of the method to a three-element airfoil is described. The comparison of the catching efficiency predicted by both the Droplerian method and a Lagrangian method (2DFOIL-ICE) is good. The agreement of predicted ice accretions with available experimental data is reasonable.

Nomenclature

D	Drag force [N]
f_D	Drag force per unit mass [N/kg]
g	Gravitational acceleration vector [m/s ²]
n	Unit normal vector [-]
U	Local droplet velocity [m/s]
A	Cross-sectional area [m ²]
c	Chord length [m]
C_D	Drag coefficient of a droplet [-]
d	Droplet diameter [m]
f	Liquid Water Content fraction for a single droplet bin [-]
I	Splashing term in momentum conservation equation $\left[\frac{\text{kg}}{\text{m}^2 \text{s}^2} \right]$
K	Cossali's splashing parameter [-]
K_y	Yarin and Weiss' splashing parameter [-]
$K_{c,dry}$	Trujillo's splashing threshold for a dry surface [-]
$K_{y,crit}$	Yarin and Weiss' splashing threshold [-]
LWC	Cloud liquid water content [kg/m ³]
M	Splashing term in mass conservation equation $\left[\frac{\text{kg}}{\text{m}^3 \text{s}} \right]$
N	Number of secondary droplets [-]
N_{bin}	Total number of droplet bins
Oh	Droplet Ohnesorge number [-]
R_{nd}	Non-dimensional surface roughness [-]

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