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ICING SIMULATION ON NACA AIRFOIL USING MPS METHOD

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Ice accretion is a phenomenon which forms an ice layer on a solid surface by the collision of supercooled droplets. It is known that the ice accretion on an aircraft causes engine failure and the degradation of the aerodynamic performance. In the design phase of an aircraft, an icing wind tunnel test, a flight test and a field test are preformed. However, the experiment is very expensive, and the experimental facilities are limited, because an icing experiment should be conducted in the cold environment. Therefore, an ice accretion simulation which has advantage in terms of the cost is desired, and it has been studied globally [1]. In the existing icing simulations, almost all simulations use the grid-based method. However, since the grid generation along the real ice shape is impossible, it leads to a problem that the grid system can not reproduce the ice shape in detail and can not indicate the detailed mechanism of the ice growth. In this study, we perform the icing simulation by the particle-based method that can treat the icing interface clearly and can reproduce the large deformation of the droplet.

In the present study, we perform the SLD (Supercooled Large Droplet) icing simulation using the MPS (Moving Particle Semi-Implicit) method which was developed by Koshizuka et al. [2] Since the droplet is large enough, it is considered that the effect of the gas phase on the droplet motion is negligible. Therefore, we ignore the gas phase. In addition, the droplets are assumed to be incompressible, and the rotation, the merging and the breaking out of the droplets are not taken into account, for simplicity.

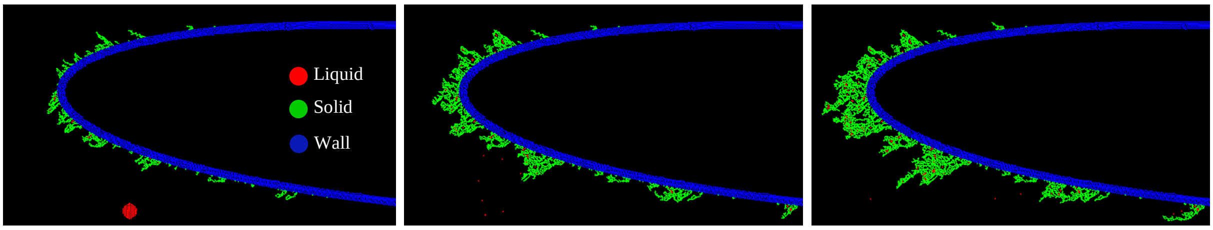
We reproduce the icing phenomenon by the following method. If interparticle distance between the liquid particle and the solid particle (or the wall particles) is 0.7 times less than the particle diameter, the liquid phase particles change into the solid particle. If it does not satisfy this phase change condition, we treat the particle as a liquid phase. The liquid particle which changes into the solid phase is treated as same way as the wall particle.

In this study, as the basic research of the SLD icing simulation by the MPS method, the simulation is performed in the simple rime ice condition, as described above. The computational target is a NACA0012 airfoil, because a lot of literatures on this airfoil are available. The computational conditions are listed in Table 1, where LWC is Liquid Water Content, MVD is Median Volume Diameter. Since we simulate SLD icing, MVD is very large.

Table 1 Computational Conditions

Exposure Time	[s]	3.0	Total Particle Number		16,058
Inflow Velocity	[m/s]	15.0	Particle Diameter	[mm]	0.5
MVD	[mm]	5.0	Density of Liquid	[kg/m^3]	1000.0
LWC	[g/m^3]	1.2	Density of Ice	[kg/m^3]	917.0
Chord Length	[m]	0.53	Kinetic Viscosity	[m^2/s]	1.79×10^{-6}

The typical computational results are shown in Fig. 1. In addition, in order to compare the ice shapes predicted by the grid-based method and the particle-based method, the simulation result by Isobe et al. [3] is exhibited in Fig. 2. Note that the computational conditions are different from the present simulation because of the limitation of the grid-based method, as listed in Table 2. Obviously, we are able to reproduce the ice shape with the whiskers that are often observed in actual icing phenomena. This ice shape can not be reproduced by the grid-based method, see Fig.2. Finally, we simulate the SLD icing with the same conditions as Isobe et al. Our simulation results will be compared with their results.



(a) $t = 1.0$ (a) $t = 2.0$ (c) $t = 3.0$

Fig. 1 Predicted Ice Shapes using MPS Method

Table 2 Computational Conditions used by Isobe et al.

Exposure Time	[s]	426.0
Inflow Velocity	[m/s]	51.0
Inflow Static Temperature	[K]	265.2
MVD	[μm]	200
LWC	[g/m^3]	1.2
Chord Length	[m]	0.533

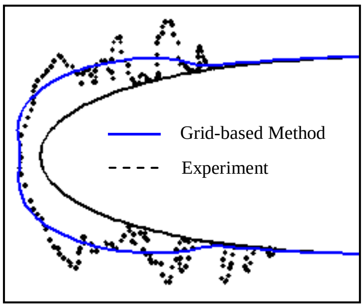


Fig. 2 Ice Shapes using Grid Method and Experiment

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