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[Extended Abstract]

Effect of SLD characteristics phenomena on icing on axial fan blade

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Introduction

Icing is a phenomena that super-cooled droplets impinge and adhere on a solid surface. Since the icing reduces aerodynamic performance and it leads to serious accidents, its mechanism should be clarified. There are many studies for the super-cooled droplets of which diameter is around 20μm, whereas in the present study we focuses on the super-cooled large droplets (SLD) [1, 2]. The diameter of the SLD is larger than 40μ m and its icing phenomenon is difficult to predict due to the characteristic phenomena: splash, bounds, deformation, and break-up.

In the present study, we perform SLD icing simulations considering the characteristic phenomena for an axial fan blade. The effects of the SLD icing on the flow field are also investigated.

Numerical Simulation

Since the time scales of flow field and icing are significantly different, the present simulation is conducted by the weak coupling: the droplet follows the flow field while droplets do not affect the flow field. The numerical procedure is as follows: generation of computational grids; calculation of flow field; calculation of droplet trajectories and collection efficiency; computation of ice shapes based on thermodynamics. This procedure is repeated five times during exposure time of 876 sec.

The flow field is computed in the Eulerian approach: a three-dimensional, compressible, and turbulent flow field are assumed and the governing equations are the continuity, Navier-Stokes, and energy equations. The droplet trajectory is computed by the Lagrangian approach and the drag, centrifugal, and Coriolis forces act on droplets. The thermodynamics computation is carried out using the extended Messinger model. As preliminary, to validate the computational code, we make icing simulations of NACA0012 wing and confirmed reasonable agreement between resultant numerical results and existing experimental results.

Figure 1 exhibits a computational target. It is a commercial axial fan (Showa Denki Co., Kairyu series A2D6H-411) and the total number of grid points is about 6 million. Although this axial fan has 12 rotor blades, only one rotor blade is simulated for simplicity.

Results

Figure 2 shows distribution of the collect efficiency on the pressure and suction surfaces, where simulations are conducted without the SLD model. The droplets adhere on the whole the surface of the pressure side, while these adhere only in the region close to the leading edge on the suction side. In the case with the SLD model as shown in Fig. 3, the collect efficiency distribution on the suction side is similar to Fig. 2(left). However, the collect efficiency on the pressure side is lower than that in the case with the SLD model since the droplets can bound there. According to a quantitative analysis, we found that the splash and bound of the SLD play important role in the icing phenomena, while effects of the deformation and breakup are small (not shown here).

In the full paper and presentation, we will discuss the effect of the icing on the flow field and estimate the total pressure loss in the iced axial fan.

References

[1] J. C. Tsao. Additional results of glaze icing scaling in SLD conditions. In *8th AIAA Atmospheric and Space Environments Conference*, 2016.

[2] C. Zhang and H. Liu. Effect of drop size on the impact thermodynamics for supercooled large droplet in aircraft icing. *Phys. Fluids*, 28(062107):23 pp., 2016.

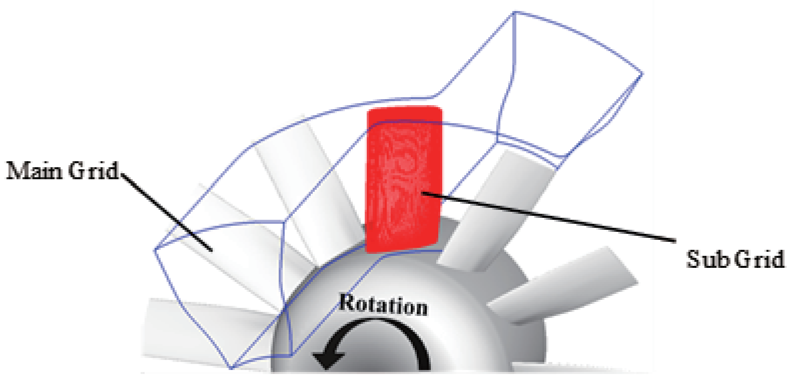

Figure 1. Computational grid around an axial fan.

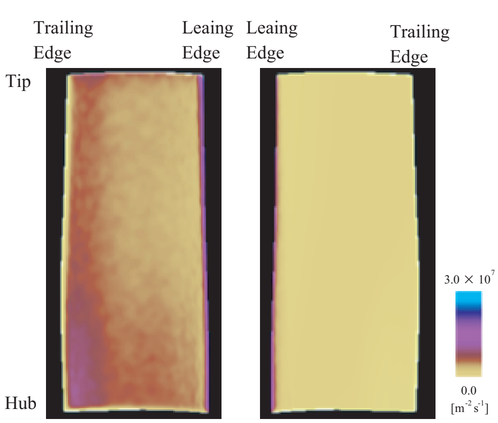

Figure 2. Collection efficiency without the SLD model: left, pressure side; right, suction side.

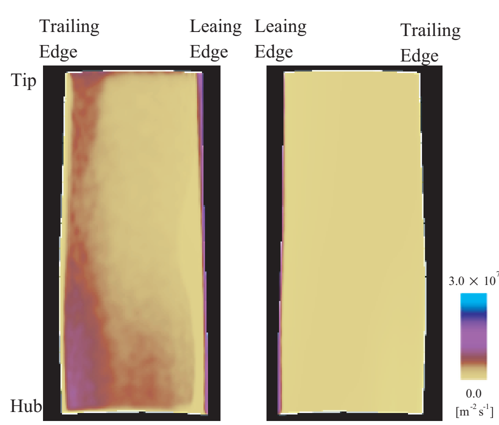

Figure 3. Collection efficiency with the SLD model: left, pressure side; right, suction side.