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ICING SIMULATION ON JET ENGINE WITH TEMPERATURE CHANGE OF SUPER-COOLED DROPLET

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There are a lot of super-cooled droplets in a cloud at the altitude of aircraft operations. These super-cooled droplets impinge and accrete on an aircraft body. This phenomenon is called ice accretion. In a jet engine, ice accretion disturbs the inlet flow, which leads to the severe performance degradation. To overcome the serious icing problems, major institutes in the world such as NASA and ONERA have been investigating the ice accretion phenomenon by using experimental and computational techniques [1].

The icing phenomenon is caused by complicated interactions of various physical conditions, which are the ambient temperature, the liquid water content (LWC), the wall temperature on the impingement surface, the impingement position, the surface roughness, the mass of droplets and so on. Among all of various physical conditions, the impingement distribution and the impingement mass of droplets and the heat transfer from the droplet to the wall has high dependence on the icing phenomena. On the icing simulation, the impingement distribution of droplets and the wall surface temperature can be obtained with sufficient accuracy. The deoplet diameter is generally modeled by the attitude of median volume dianeter (MVD), because there is poor understanding on the droplet diameter in a cloud. Additionally, the temperature of impingement droplets which is used for the heat transfer between the impingement droplet and the impingement wall is generally assumed to be the temperature of the freestream. This means that the tempearture change of droplets is not taken account. In simulating the ice accretion on such as a main wing and a tail wing, this assumption does not lead to a serious problem. However, this assumption might become a problem of accurate icing simulations in a jet engine. The flow field in the engine core is very complicated with the high speed rotation and shock waves. Furthermore, the gas temperature remarkbly changes in passing through a fan rotor and a multi stage compressor. Therfore, the above mentioned assumption of droplets temperature change is over-simplified. In this study, we simulate the ice accretion phenomenon with the temperature change of super-cooled droplets and clarify the effect of droplets temperature change on the jet engine icing to improve the predictive performance of the icing simulation.

The flow field is assumed to be three-dimensional, compressible and turbulent. The governing equations are Favre-averaged continuity, Navier-Stokes and energy equations. Droplet trajectory computation based on a Lagrangian approach is performed to obtain the droplet collection efficiency on blades. The equation of droplet motion is a simplified B-B-O equation including only the drag term and the rotation term. The temperature change of droplets is computed by the convective hear transfer equation. The thermodynamic computation is performed by use of the extended Messinger model [2]. Our computational targets are a fan blade and two FEGVs, because severe icing takes place over these components in a jet engine. The total number of the grid points is about 2.8 million. Computational conditions in this study are summarized in Table 1.

The temperature change of droplets in Run 3 is shown in Fig. 1. At whole cross span section, droplets temperature increase when they pass through the fan blade passage. In particular, the temperature of droplets near the tip is considerably changed. The temperature of these droplets decreases to about 230 K when they pass through the shock wave near the leading edge of fan blades, and then it increases to 260 K when they reach at FEGVs.

We simulate two cases which are with and without the droplet temperature change to clarify the effect of the droplet temperature change on the icing simulation. Figure 2 indicates the ice volume. In this study, the miximum difference of the ice volume is 0.71% in Run 3. Therefore, it is confirmed that the droplet temperature change does not have little effect on the ice volume in both the rime and the the glaze ice conditions.

REFERENCES

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Table 1 Computatinal Conditions

		Run 1	Run 2	Run 3	Run 4
MVD	[μm]	20	50	20	50
Inlet Total Temperature	[K]	223.15		253.15	
Inlet Total Pressure	[MPa]	0.1013			
Inlet Mach Number		0.44			
LWC	[g/m^3]	1.00			
Exposure Time	[s]	10.0			

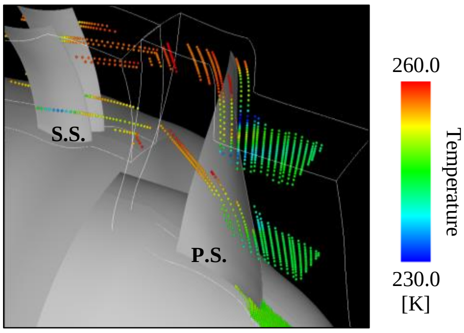

Fig. 1 Droplet Temperature (Run 3)

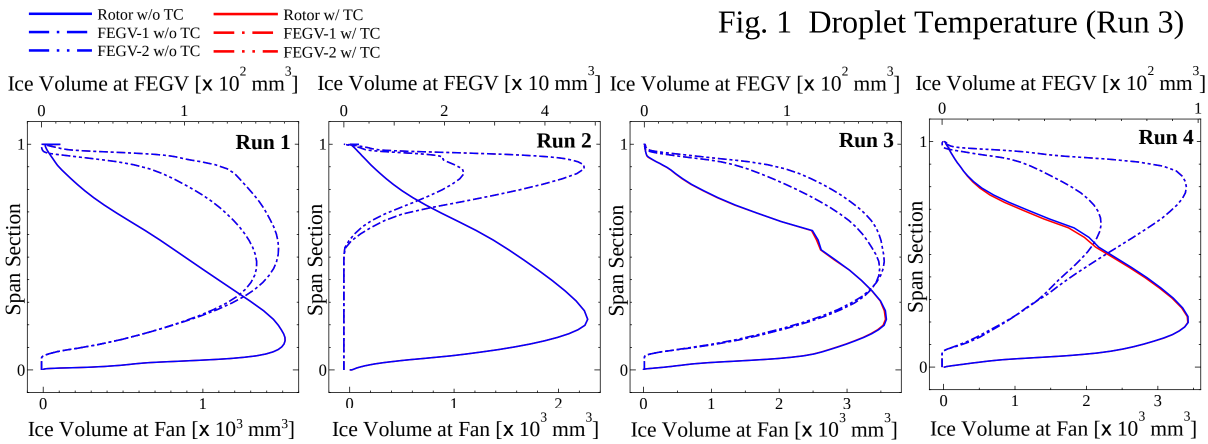

Fig. 2 Effect of Droplet Temperature Change on Ice Volume