NUMERICAL SIMULATION OF ICE CRYSTAL MELTING
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Key words: ice crystal, melting, enthalpy-porosity model.

Summary. Ice crystal melting process was simulated by enthalpy-porosity model. The results were validated by experimental data from literature. Two different conditions were considered, one is in lab environment, that is under constant air temperature. The other is in engine inside environment, that is under changing air temperature. The results show that the air temperature affects the melting process significantly, the melting rate in aero-engine is much faster than that in lab due to higher temperature; as the air temperature is higher, the mushy zone thickness becomes thinner; liquid fraction with time is almost linear.

1 INTRODUCTION
Traditional engine icing refers to icing on the exposed surface of the engine caused by supercooled water droplets. In recent years, researchers studied thrust loss events and found that icing may occur at low pressure compressor and even the first few stages of high pressure compressor and ice crystal ingestion is the main cause of icing[1]. Experiment and numerical simulation have been performed[2-3].

This study focuses on the ice crystal melting. The melting processes were analyzed under these two conditions, and also compared and discussed.

2 NUMERICAL METHOD
An enthalpy-porosity model was used to simulate the melting process. This model uses a porous analogy to describe the melting process, not attempt to precisely track the interface of the phase transition. There are assumptions in this model: when the temperature is higher than the melting point, it is the liquid zone, and when the temperature is lower than the freezing point, it is the solid zone, when the temperature is between the freezing point and melting point, it is the mushy zone. All of these zones are treated as a porous media. In liquid zone, the porosity is considered as 1, while in solid zone, the porosity is taken as 0. And in the mushy zone, the porosity is between 0 and 1.

3 VALIDATION
The method described above is validated by data from literature [2]. The diameter of the ice crystal is 357μm, and the air temperature is 298K. The ice crystal is stationary. The comparison between the experiment and simulation was displayed in Fig.1. It can be seen the
simulation result has a fairly agreement with experimental data which indicates the method can be used to simulate the ice crystal melting.

4 NUMERICAL RESULTS

Melting simulation performed under two different air temperatures. One is a constant air temperature, the other is a changing air temperature. Then two melting process were compared and discussed.

4.1 Constant Air Temperature

Fig.2 displays the liquid fraction when the air temperature is constant. It can be seen that the liquid fraction is almost linear. At the end of the melting, about t=1.7s, the melting rate decreases. That because when t=1.7s, the surface temperature is comparatively high, the melting rate become slow. When t=1.8s, the ice crystal with a diameter of 200μm melted completely.

4.2 Changing Air Temperature

Fig.3 shows liquid fraction with time. The liquid fraction increases fast before t=0.06s. After t=0.06s, the change rate of liquid fraction becomes slightly. And when t=0.068s, the ice crystal melts completely. This is much faster than the ice crystal melting in constant temperature.

5 CONCLUSIONS

By simulating the melting process of ice crystals for two cases, it is found the air temperature affect the melting process significantly. The melting process in aero-engine is much faster than that in lab, since the temperature become higher and higher in aero-engine. The inside temperature gradient along radius is greater when ice crystal flow into the aero-engine. As the air temperature is higher, the mushy zone thickness becomes thinner. Liquid fraction with time is almost linear.

REFERENCES