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Portfolio Paper

Behavior of Ice in a Hypersonic Flow

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Behavior of a piece of water ice was experimentally observed in a flow of the hypersonic wind tunnel to obtain an analogy with the flow around a comet entering the earth's atmosphere at hypersonic speed, which will experience both the aerodynamic pressure and heating.

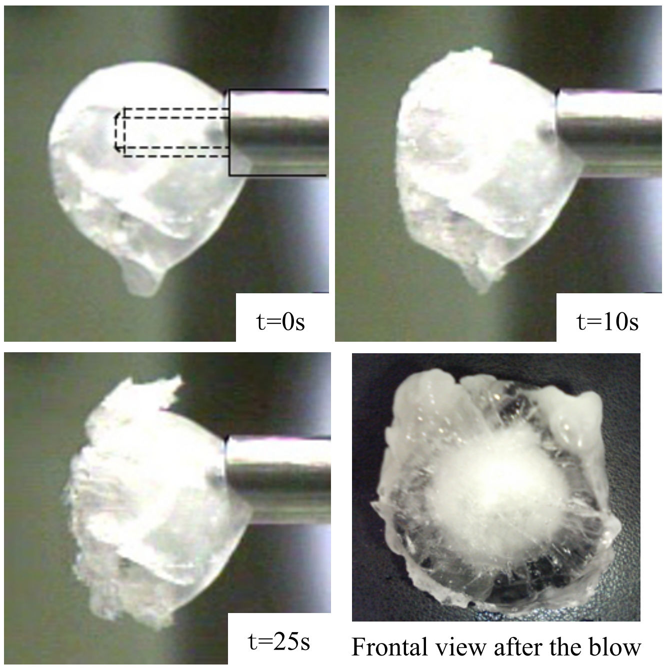

Table 1. Flow condition.

Mach Number	7.0
Stagnation Pressure	952 kPa
Stagnation Temperature	684 K
Pressure at stagnation point of ice	14.2 kPa (predicted)
Stagnation Heating Rate *	0.11 MW/m^2

*Estimated from the reference (M. E. Tauber et al., J. Spacecraft, 27:514-521 (1990))

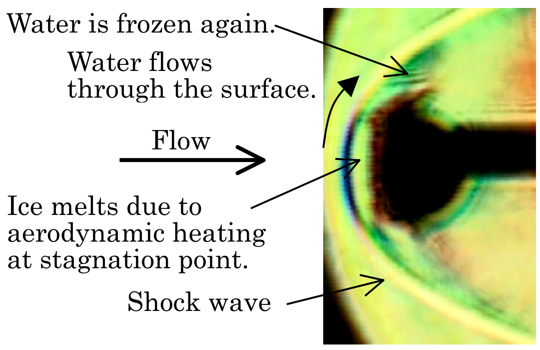

Fig. 1. Behavior of ice in a hypersonic flow.

Fig. 2. Schlieren visualization of the flow field.

The experiment was performed in the hypersonic wind tunnel at University of Tokyo, Kashiwa campus. This wind tunnel has a free-jet-type test section and the flow condition is shown in Table. 1. The initial configuration of ice is a sphere with 30 mm diameter, which is sufficiently smaller than the diameter of the uniform flow (about 120 mm in diameter). The ice sphere is attached to the sting via the screw bolt (see Fig. 1(t = 0s)). The ice sphere is injected into the flow after the steady freestream condition is established in the wind tunnel. The angle of attack is set as zero until the ice sphere has been broken into pieces due to the aerodynamic pressure and heating.

Figure 1 shows a series of snapshots taken from the video image. The flow comes from the left-hand side. Time is provided in each snapshot that measured from injection of the ice sphere into the Mach 7 flow. The schematic of the deformation process is described in a Schlieren snapshot shown in Fig. 2. In the stagnation region, the ice is melted due to the aerodynamic heating, and the liquid water flows to the downstream due to the shear force by the air flow. The presence of such water flow can be confirmed by seeing the radial streak pattern on the frontal view taken after the blow (see Fig. 1). In the downstream region, the water is frozen again because the air rapidly expands and its temperature decreases. The re-frozen ice can be seen as "horns" of ice in Fig 1.