Simulation Experiments of Shearing Ablation of Asteroids during earth Entry

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Object： Ablation is one of the most important phenomenon when an asteroid enters the earth atmosphere at hypervelocity, which largely determines the mass loss, flight trajectory, and even radiation characteristics of the asteroid. To research the typical ablation process of asteroids during earth entry, simulation experiments were conducted in an arc-heater, the effective data obtained will help to understand the asteroid ablation mechanism and support the development and validation of the ablation calculation model.

Experimental set-up

High temperature and high pressure hypersonic flow was provided by an arc-heater and a rectangular nozzle, the edge of the plate sample was tight fitting to the nozzle exit, the high temperature boundary layer of the nozzle extend to the sample surface to simulate ablation environment.

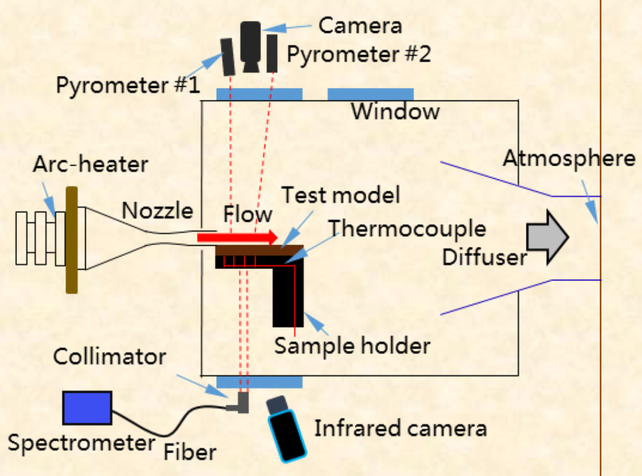


Diagram of experimental set-up

Measurement methods

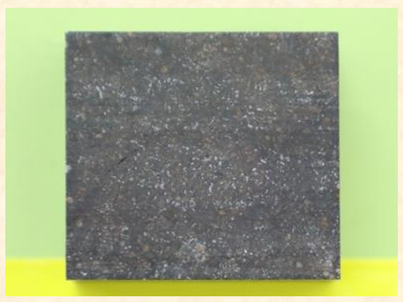
Parameter	Instrument	Remarks
Surface heat flux	Calorimeter	Parameters
Stagnation pressure	Pressure probe	
Dynamic image	Camera	During test
Gas components	Spectrometer	
Surface temperature	Pyrometer	
Temperature distribution	Infrared imager	
Ablation mass	Electronic scale	After test
Shape after ablation	Spatial digitizer	
Ablation product	EDS	

Test instrument

Spectroscopy and infrared camera

Test sample and condition

12 test samples were machined into 40mm*40mm*25mm plates, including two kinds of asteroid: ordinary chondrite and iron , the test lasted 6s.



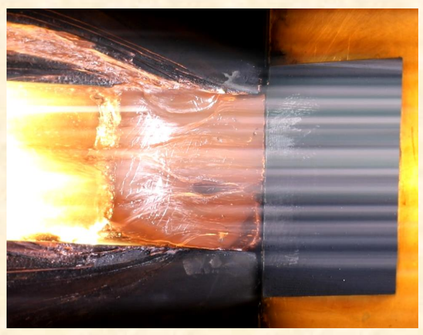
ordinary chondrite

Iron asteroid

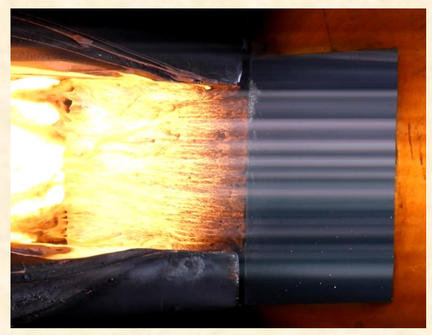
Condition	Angle (°)	Pressure (kPa)	Heat Flux (MW/m^2)	Enthalpy (MJ/kg)
Ⅰ	1	240	8.8	9.7
Ⅱ	6	151	8.9	14.9

Test Conditions

Experimental Results

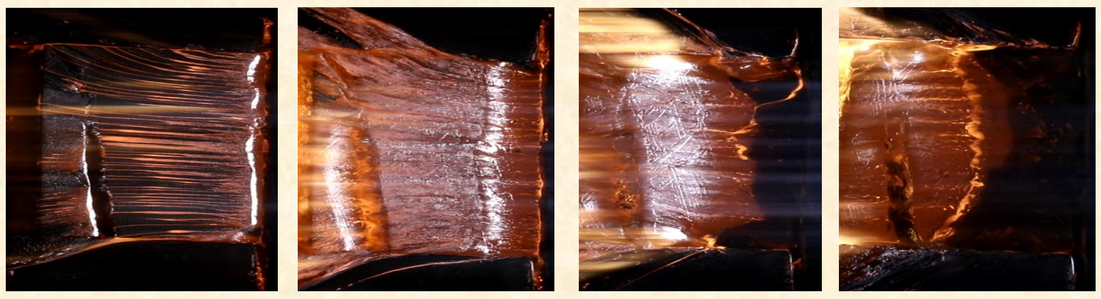


Ablation of iron asteroid



Ablation of ordinary chondrite

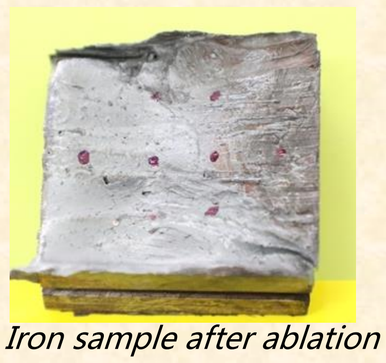
The fusion and shearing of test sample were recorded, with the ablation goes on, the flow separation on the front edge increased, the shearing of liquid layer mostly occurred on the rare part..



0.5s 2s 4s 5.5s

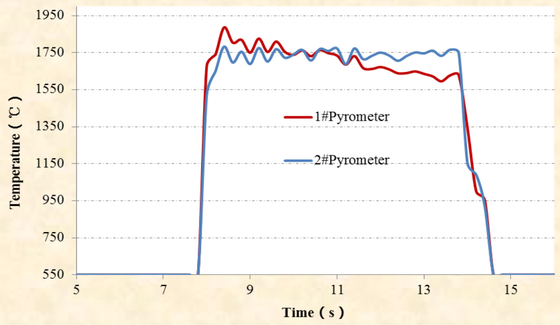
Shearing of liquid layer on iron sample (flow direction is from right to left)

Ordinary chondrite sample after ablation



Iron sample after ablation

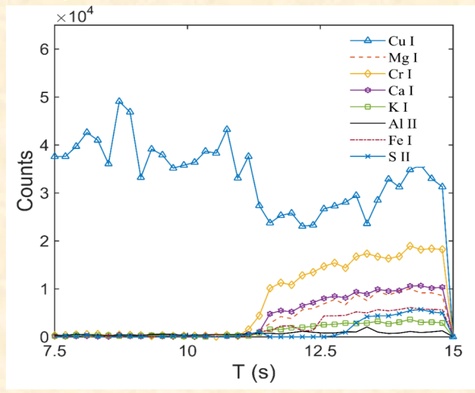
Surface temperature of ordinary chondrite samples are slightly higher than fusion point, the temperature on the upstream was dropped due to recession.



Surface temperature evolution of ordinary chondrite

- The effective heat of ablation was estimated as: 2.8MJ/kg for ordinary chondrite and 6.4MJ/kg for iron asteroid ;

$$h_{eff} = \frac{q_{cw}}{m}\left(1 - \frac{h_{hw}}{h_0}\right)$$



Elements evolution of ordinary chondrite

- Shearing effect dominated the mass loss of asteroids under test conditions ;
- Ablation under condition Ⅱ was higher than condition Ⅰ , could be related to changes in the thermal environment during recession.