ANALYSIS OF ABLATION MECHANISM OF IRON METEORITE UNDER THE CONDITION OF ARC HEATER TEST

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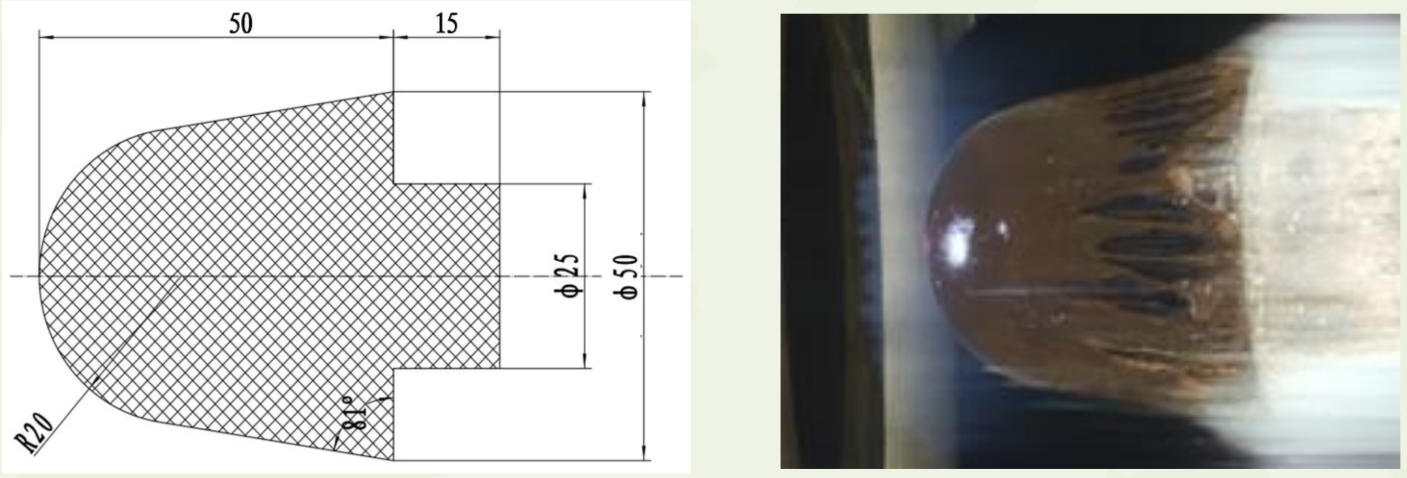
Research objectives

Iron asteroids enter the earth’s atmosphere at very high speed. Under the action of severe aerodynamic heat and radiation heating, the surface temperature of asteroids rises and the surface materials will melt away. It is of great significance to study the ablation mechanism of iron asteroids entering the earth’s atmosphere and predict their ablation situation for ground risk assessment. Based on the phenomenon of iron meteorite ablation test, this paper establishes a theoretical model of iron meteorite ablation at high temperature, and through the theoretical calculation and analysis of iron meteorite spherical cone model ablation under the condition of arc heater test, reveals the ablation mechanism of iron asteroids entering the earth’s atmosphere.

Solution technology and analysis of calculation results

The melting ablation and melting layer shear ablation model based on the iron meteorite ablation test phenomenon under the test conditions of CARDC arc heater are adopted, and the three states of iron meteorite with spherical cone model(Rn=20mm) are calculated and analyzed by using the coupling solution technology of aerodynamic heat/ablation and internal heat conduction with moving boundary. The thermophysical parameters of iron meteorite are: density 7827.234kg/m^3, specific heat 364±19J/(kg·K), thermal conductivity coefficient 42.9±15.5W/(m·K)）, radiation coefficient 0.671 and latent heat 269.55kJ/kg.



a. Experimental model of iron meteorite ablation(unit:mm)

b. Video image of ablation process of iron meteorite

Fig.1 Iron meteorite ablation test under the condition of arc heater test at CARDC

Table 2 Comparison between ablation calculation and experiment of iron meteorite cone specimen

state	stagnation point ablation rate（mm/s）			liquid layer thickness（mm）	surface evaporation rate（mm/s）	mass loss rate of liquid layer（mm/s）
	calculation（melting shear model）	calculation（melting model）	test	calculation（6mm from the object surface）	calculation	calculation
I	1.91	1.55	9#：1.97	2.9	2.07e-19	1.91
II	1.86	2.14	11#：1.55	2.3	2.76e-19	1.86
III	1.80	2.50	10#：1.56	2.2	3.34e-19	1.80

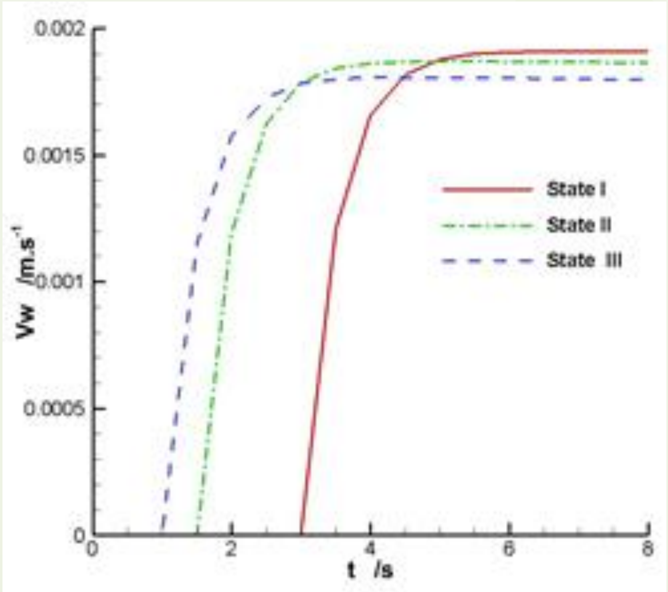


Fig.3 Variation of stagnation ablation rate with time

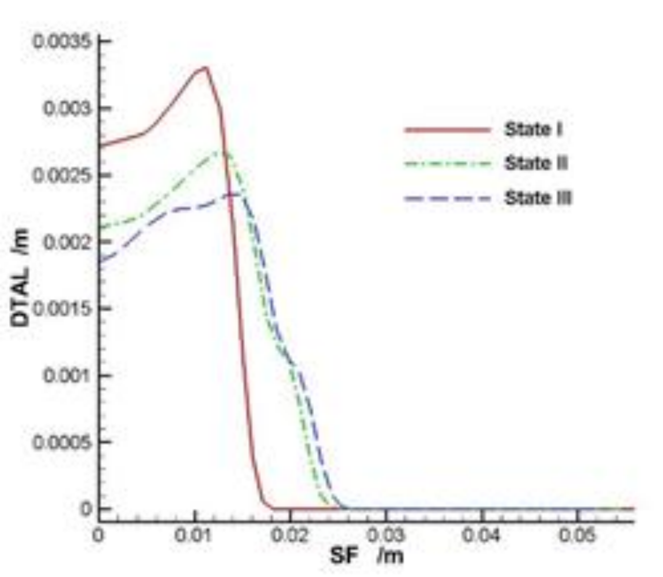


Fig.4 The thickness of liquid layer varies with the object surface

Table 1 Simulation state of ablation test

state	Arc chamber pressure(MPa)	stagnation pressure (MPa)	stagnation heat flux(MW/m^2)	stagnation enthalpy(MJ/kg)
I	1.02	0.51	13.9	7.9
II	0.66	0.34	15.1	10.2
III	0.56	0.28	19.5	14.3

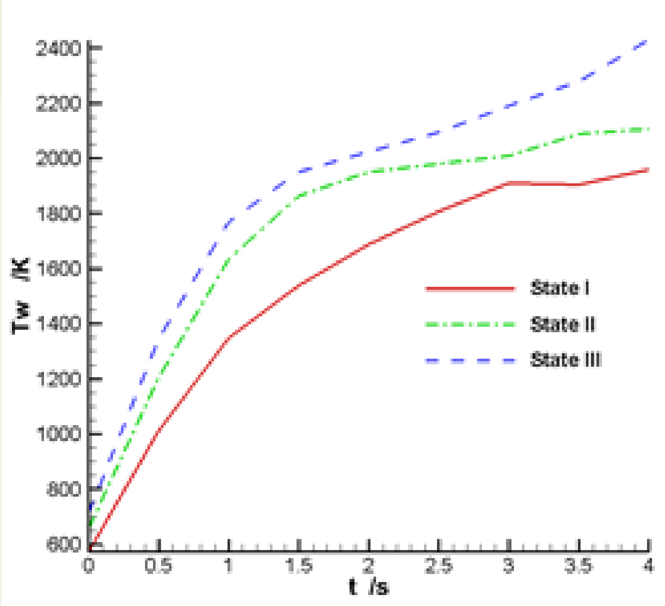
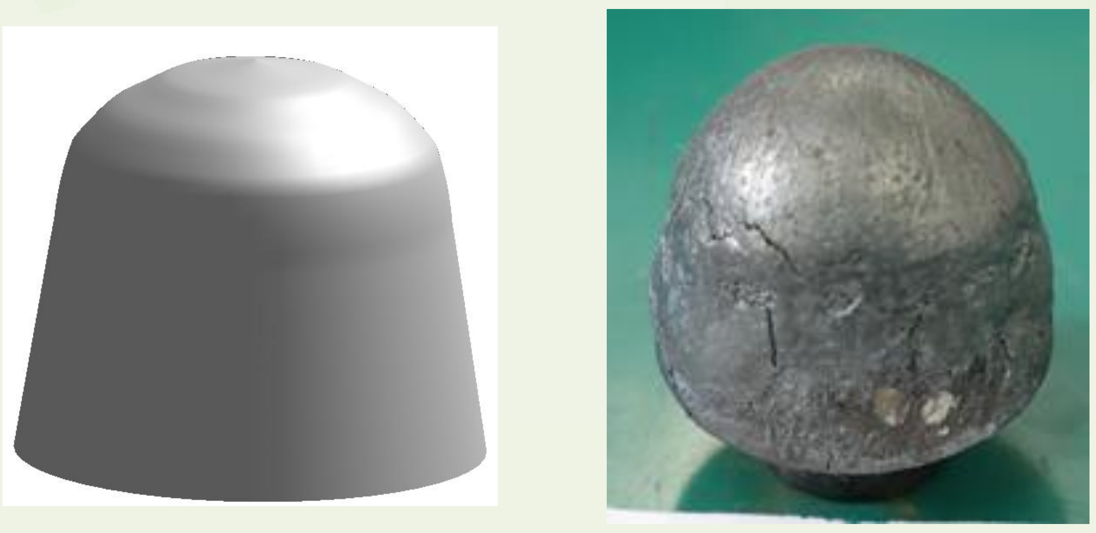


Fig.2 Variation of stagnation temperature with time



a.Calculation shape of iron meteorite ablation

b.Iron meteorite ablation test shape

Fig.5 Comparison between the calculated shape of the melting shear ablation model and the experimental shape of the iron meteorite cone specimen(state Ⅲ）

The experimental conditions of test states I- III are increasing heat flux and decreasing stagnation pressure. The higher the heat flux, the higher the temperature(Figure 2) and the earlier the ablation. The ablation time I-III is 3s,1.5s and 1s,respectively（Figure 3）. After steady ablation, the stagnation point ablation rate increases with the increase of stagnation point pressure（Figure 3). The viscosity coefficient of liquid layer decreases with the increase of wall temperature, so the higher the heat flux and temperature(from states I to III), the thinner the liquid layer（Figure 4）. Table 2 contains the calculation results of melting shear model and melting model without considering shear. Under the melt shear model, the stagnation line ablation rates of states I-III are 1.91mm/s, 1.86mm/s and 1.80mm/s respectively, which are qualitatively consistent with the experiment, while the results obtained by the melt model are contrary to the experiment, which shows that the shear of molten layer is a factor that must be considered in the ablation model. It can also be seen from table 2 that the surface evaporation rate is small compared with the liquid layer loss rate. The above analysis shows that the shear loss of molten layer is the main mechanism of iron meteorite at high temperature.