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Comparison of Crater Behavior of Water Ice by Low and High Density Projectiles under Hypervelocity Impact

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Abstract

Hypervelocity impact tests have been performed on water ice in the velocity range of 3 to 7 km/s, by using low and high density projectiles. The projectile materials included polycarbonate and stainless steel, with diameter of 1.0 mm. The ice targets were solid cylinders at 253K made from pure water. The crater morphology in the solid ice caused by different projectile and different velocity were observed. The crater sizes were measured and compared with previous tests impacted by aluminum projectiles. The results showed that: 1) the crater diameter and crater depth were dominated by different mechanisms, the crater depth was mainly caused by the projectile penetration, while the crater diameter was mainly caused by the ice spallation; 2) the crater depth showed stronger projectile density dependence than crater diameter, while the crater diameter by higher density projectile showed stronger velocity dependence than that by lower density projectile; 3) the crater volume scaled with the impact energy, the crater diameter by high density projectile showed 'energy scaling' behavior, while the crater diameter by lower density projectile showed 'momentum scaling' behavior.

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Keywords: impact crater; water ice; hypervelocity impact; planet

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1. Introduction

Impact craters are one of the most important visible features on the surfaces of most icy bodies in Solar System. It is therefore significant for understanding the formation and evolution of planets in the outer Solar System to study the impact cratering behaviour of water ice. A large amount of laboratory experiments have been performed to study the craters on icy bodies. In early 1980s, Croft (1979, 1981), Kawakami et al (1983), Cintala et al (1985) and Lange (1987) conducted a series of impact cratering tests on water ice [1~5]. They compared the differences of craters in water ice and rocks, and explored the influences of ice strength, projectile densities and impact energies to the crater size. However, most of these works were restricted to lower velocity range (below 1 km/s), which was much lower than the velocities in realistic planetary impact events (from several to dozens of km/s). From the middle 1990s, M J Burchell and his team [6~10] conducted a series of hypervelocity (up to 7 km/s) impact tests on water ice, attempting to construct the scaling laws of the crater size with the impact conditions. All of these works above have greatly enriched the understanding of the cratering behavior in water ice.

One of the main results from these studies is the scaling laws of the crater volume (or mass) with the impact energy. However, it is not sufficient to model the craters just by the combined energy dependence. Other conditions, such as projectile/target properties, impact velocity and incline, ambient temperature, should also be taken into account. Therefore, to better understanding the cratering behavior of water ice under different projectile and different velocities, the hypervelocity impact cratering tests have been performed by using two types of projectiles with different density.

Nomenclature

D	crater diameter
H	crater depth
V	crater volume
E	impact energy
ρ	projectile density

2. Experiment method

2.1. Ice preparation

The ice targets were made by pure water. First, the water was boiled to exclude the dissolved gases. Then it was put into the ice bath. When the water was cooled to about 277K, it was transferred to a special container. The container was consisted of a plastic cylinder shell, a metal bottom and a plastic top. The inner size of the container was Φ200mm×120mm, the height of the water is about 92mm. The container with cold water was then put into a freezer in which the temperature was kept at 253K. During the freezing process, heat sources were mounted on the top plate and the upper portion of the side shell. The ice grew from the bottom to the top. When the water was frozen completely, a clear and solid ice target was formed. Then it was taken out from the container and stored in a freezer with temperature of 253K.

2.2. Experiment facility

The tests were performed at the hypervelocity impact range (Range A) of the China Aerodynamics Research and Development Center (CARDC). Range A consists of a 7.6mm caliber two stage light gas gun (TSLGG) and an impact chamber, as shown in Fig. 1. The TSLGG uses powder as energy source. A piston is accelerated by the powder gas and then presses the hydrogen gas in the pump tube. The hydrogen is pressed to extremely high pressure and entered into the launch tube, driving the projectile to move forward. The projectile then flies into the chamber and impacts on the ice target. A laser velocimeter system was used to measure the projectile velocity.