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Experimental study on collisional destruction of iron bodies: Temperature dependence

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Introduction: Iron meteorites are composed of iron-nickel alloys and most of them have unique crystalline structures known as Widmanstatten patterns. They undergo a transition from ductile to brittle behavior as the temperature is lowered. It is thought that they may have been derived originally from the cores of their parent bodies and so they may tell us the history of planetary formation.If the collisional destruction of cores of parent bodies occurred, fragments of them should be scattered as iron asteroids, but they have not been discovered yet. M-type asteroids may be iron asteroids but it is found that some of them have low density, and might be rubble-piles.We performed impact experiments and examined the temperature dependence of degree of disruption and fragment velocity in order to collect basic data for studying the possibility of formation of iron-rubble-pile asteroids.

Experimental method: We performed impact experiments using two different guns. Impact experiments with velocities of 0.6-1.2 km/s were performed using a powder gun at Kobe University and with velocities of 6.8-7.3 km/s were performed using a two-stage light-gas gun at the Institute of Space and Astronautical Science (ISAS). The projectiles were cylinders 15 mm in diameter machined from stainless steel or nylon spheres 7 mm in diameter. The targets were blocks of Gibeon iron meteorite or cylinders 25 mm and 35 mm in diameter machined from SS400 steel.We used room-temperature targets in the experiments using the two-stage light-gas gun, while we used room-temperature (298K) and low temperature (170-150K) targets in the powder gun-experiments.We compared the velocity distribution of fragments, fragment mass distribution and relationship between energy density and largest fragment mass fraction in low temperature and room temperature to examine the temperature dependence. We measured velocities of fragments using a high-speed camera. Additionally, we performed impact experiments using two targets with different aspect ratios (0.37 and 1) to examine the effect of target shape.

Results: We measured fragments with velocity 20-900 m/s and found that most fragments have velocities lower than the escape velocity of Psyche, i.e., 130 m/s. Temperature dependence is seen in the fragment mass distribution and the relationship between energy density and largest fragment mass fraction. The total mass fraction of SS400 steel fragments with mass less than 1 % of the initial mass accounted for 2.4-25 % of the initial mass at low temperature, whereas 0.12-18 % of the initial mass at room temperature. Energy density for destruction of targets with aspect ratio 0.37 is lower at low temperature than room temperature, which is not seen in previous studies.

Keywords: iron meteorites, impact, rubble-pile