Effects of impact angles on the impact strength of icy and rocky planetesimals for the collision among equal size bodies

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Introduction: There are a lot of impact experiments to simulate planetesimals collisions, and most of them had a large mass difference between a projectile and a target. The impact strength is well known that they are described by the energy density: the ratio of the projectile kinetic energy to the mass of the target and the projectile. So, when the projectile is rather smaller than the target (this is an usual situation in the lab. experiments), the very high speed more than 1 km/s is necessary to disrupt the target. This is an analogy of the present asteroid collisions, but it might be far from the simulation expected in planetesimals collisions. Because we speculate the collisions among the similar size small bodies in the solar nebula, and the relative collisional velocity among them could be several 10 m/s. Therefore, it should be important that the planetesimals were disrupted or not at the impact speed around several 10m/s for the collisions among similar size small bodies, then we must conduct the collisional experiments to derive the impact strength of planetesimals in the similar size collisions. In this study, we carried out the impact experiments using the equal size ball made of ice, gypsum, and gypsum-glass beads mixture. These samples simulate icy planetesimals, planetesimlas for chondrite parent bodies. We also conducted not only head-on collision but also oblique collision and studied the effects of impact angles on the impact disruption.

Experimental methods: We prepared three types of ball sample with the size of 25 mm and 30 mm made of ice, gypsum-glass beads mixture, and gypsum. They were made by putting each solution in a round mold to form spherical sample. The impact experiments were made by using three types of accelerators: they are a spring gun for low velocity collision, a vertical gas gun for ice and a horizontal gas gun for gypsum, and the achieved velocity is from 4 to 160m/s. The oblique impact was also conducted by shifting the impact point from the geometrical center of the target. The impact angle was changed from 0 deg. (normal impact) to 80 deg. (nearly passing away impact). Impact experiments were observed by a high-speed camera and all of the impact fragments were collected to measure the weight and establish the size distribution. We looked for the recovered fragments to identify the same fragment found in the video image, and tried to construct the velocity-mass distribution of the impact fragments.

Results: We used the reduce mass to calculate the impact energy in the center-of-mass system, so the energy density Q_g was defined by the ratio of the kinetic energy of two bodies in the center-of-mass system to the mass of the two equal balls. The impact strength was obtained for the similar size collisions by using this Q_g. As a result, the impact strength $Q_g{}^*$ of ice and gypsum was derived to be almost similar to that obtained for the impact experiments with the mass difference more than 10. However, the $Q_g{}^*$ of glass beads-gypsum mixture was derived to be rather smaller than that obtained in the previous experiments. In the oblique impacts, the mass of the maximum impact fragment was found to decrease with the increase of the impact angle. So, we modify the energy density by using the velocity component normal to the impact surface which effectively work for the disruption, then this modified energy density enabled us to fit all of the data on one line for each target. Finally, we estimated the re-accumulation condition of planetesimals according to the velocity distribution of the impact fragments that obtained in this study. As a result, it is speculated that icy planetesimals could re-accumulate for the bodies larger than 20 km in the diameter, and this threshold size for the planetesimals of ordinary chondrite parent bodies is 5.2km and that for the planetesimals of carbonaceous chondtite parent bodies is 6.7km.

Keywords: Planetesimals, Oblique impact, Impact strength, Energy partition, Re-accretion