Impact disruptin of glass plate: Velocity distribution of fragments

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In a field of planetary science, the impact fragmentation experiments have been conducted for three decades. In particular, the fragment velocity has been extensively studied because it is important to understand the origin of asteroid families and the process of planetesimal accretion. However, there are some arguments. For example, Nakamura and Fujiwara [1991, Icarus 92, 132-146] obtained the results that the fragment velocity is proportional to ~ -1/6 power of the mass while Giblin et al. [1998, Icarus 134, 77-112] found considerable variation in the slope of the fragment velocity-size distribution.

One of the problems is that the measurements of fragment mass and velocity are difficult in the 3-D space when spherical or cubic targets are disrupted. There are several reasons; fragments overlap each other in the line of sight and some fragments are not observed, it is difficult to determine fragment shape and hence volume or mass does not precisely estimated, and at least two cameras are necessary to obtain three components of fragment velocities but the identification of the same fragments in two images recorded by different cameras with different directions is quite difficult. As a result, the number of fragments whose mass and velocity are determined was so small that the statistical discussion was difficult.

Here we consider the impact fragmentations of thin glass plates. Projectiles impact on one side of glass plates. In this case, the displacements of fragments are limited on the plate-plane, and hence we can observe the velocity and mass (area) of most fragments with a high-speed camera. Thin Pyrex glass plate targets (square) with a thickness 1 mm and a side length of 30-200 mm were vertically installed and suspended by two fine threads under an ambient pressure of 1 atom. Cylindrical aluminum projectiles with a diameter of 15 mm and a height of 10 and 15 mm, which were accelerated by an air gun at Institute of Low Temperature Science, impacted against the upper side of the targets. Around the impact point, two brass semicircular projectile stoppers with a radius of 15 mm and a thickness of 10 mm were set to prevent the projectile from penetrating into the target. These stoppers were connected by two thin threads and hooked on the upper side of the target. The projectile initially impacted the target, and its motion was quickly terminated by the stoppers. Fragment motion was observed using a high-speed camera with a rate of 4000 frames per second.

Result 1. The variety of fragment velocity ranges one order of magnitude at the same fragment area (mass) and it seems that there is no one-to-one relation between fragment area and velocity.

Result 2. The averages of the Y-component (parallel to the projectile direction) of fragment velocity are about 20-50 % of the case of elastic collision and do not depend on the largest fragment area normalized by original target areas (the degree of fragmentation).

Result 3. Setting a coordinate with X and Y, which are perpendicular and parallel to the projectile direction, respectively, and an origin to be impact point, we plot Vx and Vy as a function of x0 and y0, respectively, where x0 and y0 are the initial positions of fragments and Vx and Vy are the components of fragment velocity. There are positive correlations; the velocity components increase with the distance from the axes.