The velocity and mass distributions of impact ejecta in the vicinity of the impact point: An application to the material transport from Mars to Phobos

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High-speed ejecta produced by a hypervelocity impact are transported to extremely far from the impact point. The surface of a satellite, Phobos, would contain Martian materials ejected by hypervelocity impacts (Ramsley and Head 2013). For understanding how much the ejecta can be transferred to Phobos, it is necessary to investigate the maximum velocity of impact ejecta and their mass in the vicinity of the impact point.

Although previous studies have been studied about the velocity distribution of impact ejecta from the position beyond the impactor’s radius (e.g. Hermalyn and Schultz 2011, Tsujido et al., 2015), high-speed ejecta from just below the impact point have not been observed well. The ejection behavior has been also investigated using a numerical code in detail (Johnson et al., 2014). The simulation results, however, have not been validated through a comparison with the results of hypervelocity impact experiments.

In this study, we performed impact experiments in order to observe the high-speed ejecta and to investigate the ejection velocity very near from the impact point using ultra-high-speed video camera. While the ejection velocity can be measured from the obtained images, it is difficult to determine the mass of the ejecta from impact experiments. We also performed SPH simulations of the impact ejecta in order to compare with the experimentally-observed ejection behavior under the same impact conditions, and to confirm the validity of the simulations. We investigated mass distribution of both target and projectile components in the ejected material in the simulations.

We used polycarbonate as both projectiles and targets. Impact experiments were conducted using two-stage light gas guns at PERC/Chitech and ISAS/JAXA, Japan. Impact velocities were 3.56-7.04 km s^{-1}. Impact angles were 90 degrees and 45 degrees measured from the target surface. High-speed video cameras (Shimadzu, HPV-X1, HPV-X2) were used, and the frame rate was 0.2 μs $frame^{-1}$, which enables us to observe the high-speed ejecta in the vicinity of the impact point because this time was much shorter than the time for a projectile penetration. The two cameras were used at ISAS/JAXA to observe the impact ejecta from two different directions in a right angle. This allows to reproduce three-dimensional images during impact processes.

Impact simulations were carried out with a three-dimensional SPH code (e.g. Genda 2012). The Tillotson EOS for polycarbonate was adopted (Sugita and Schultz 2003). We used 10^4, 10^5, and 10^6 SPH particles for a projectile to investigate the effects of the spatial resolution on the ejection behavior.

High-speed images show that a pattern of the ejecta curtain in the vertical impacts was almost axial symmetry like an umbrella. On the other hand, it was asymmetry in the oblique impacts, and two components of ejecta in different traveling directions were observed. One moved along the target surface to the downrange of the projectile trajectory. This is considered to be produced due to a jetting process during a projectile penetration (Kurosawa et al., 2015). The other component expands to the upward of the target surface. The boundary of the two component was observed as a kink. We confirmed that the SPH code with the highest spatial resolution, i.e., 10^6 SPH particles, reproduces the ejection behavior, including the travel distance of the outer edge of impact ejecta and the two component in oblique impacts. The edge of the ejecta curtain consists of the target material during a vertical impact, whereas the leading edge of the ejected materials along the target surface is dominated by the projectile material during an oblique impact. We will discuss the application of the results to the problems of a material transport from Mars to Phobos.

Keywords: ejecta, hyper-velocity impact experiment, SPH simulation