**P231-P003** **Room: Poster Session Hall** **Time: May 15**

# Elastic Ejection of Late Fragments Produced in Impact Craterings on Gypsum Targets

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Fragments observed in Onose and Fujiwara (2004), in which impact cratering experiments on gypsum targets were produced using nylon projectiles, 7 mm in diameter at 4 km/sec, were classified into early and late fragments according to their shapes, departure times from the target surface, ejection velocities, and initial positions. Early fragments are ejected earlier during cratering process, and many of them show the same characteristics as spalled fragments described in Melosh (1984). Contrastively, late fragments are newly observed and recognized in our previous study, and their observed nature is difficult to explain with existing theories (eg. Z-Model indicated in Maxwell 1973, 1977). They originate in the crater's pit (13 mm in radius), are ejected vertical to the target's surface at velocities lower than 12 m/s, and leave the target's surface later than 5 msec after the impact.

A sectioned target including a projectile's trajectory indicates a concentric circular structure; a crater is surrounded by a shear-fractured and compacted region, and a shear-fractured region is surrounding them. The outermost region suffers no damage but some radial cracks, and it still is able to support a hoop stress. A center of boundaries of these regions is located 12 mm under the target's surface, and it is assumed to share the same point with that of an isobaric core produced by the impact. Shock wave expands radially and attenuates to the compressive strength of gypsum (10 MPa) on the outer boundary of shear-fractured region (hereafter 'SF-surface'), which lies 20 mm away from the center of the isobaric core.

This paper will propose an ejection mechanism of late fragments as an elastic response of the less damaged part of the target lying outside of the SF-surface. Impact induced compressive wave pushes the SF-surface outwards and stores elastic energy as tensile distortion of circumference direction. As soon as an input of the compressive wave has finished, the SF-surface moves inwards by this hoop-stress, and accelerates the shear-fractured gypsum powder inside of it. Because a shape of the SF-surface produced by an vertical impact indicates axis-symmetry, horizontal components of ejection velocities assumed to be canceled, and vertical components of them supposed to eject gypsum powder as late fragments. The elastic response of a crater's floor to the impact is also suggested in Dence (2004) for the Charlevoix crater.

In this preliminary model, a infinite gypsum with a spherical void, 20 mm in diameter, which represents the less-damaged region of the target outside the SF-surface, was considered with employing the Green's function, and positions and velocities of the SF-surface was monitored. The compressive wave is represented by a rectangular one of 10 MPa in pressure and 3 microseconds in duration. We assumed the SF-surface as a free end in this model. Giving the Young's modulus, Poisson's ratio, and density of the gypsum as 2 GPa, 0.25, and 0.92 g/cc, respectively, the radial velocity of the SF-surface was 1.2 m/s inwards.

A part of the gypsum powder adjacent to the free surface is torn into late fragments and ejected when the motion of the SF-surface is transmitted to their upper surface with the sound velocity of gypsum powder, which was estimated to be 25 m/s by extrapolating the data in Teramoto (2004). It takes 1 msec from the SF-surface to the upper-surface of a layer of gypsum powder. Together with the travel time of fragments from its initial depth to the surface, this can explain the ejection times of late fragments.

References

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