A Theoretical Study on the Dynamic Tensile Strength of Aggregate Dust and Monolithic Dust: Toward a Better Understanding of Ejecta Cloud Formation

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DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) is a mission to flyby (99942) Apophis, (3200) Phaethon, and several other Near-Earth Asteroids (NEAs), equipped with a dust analyzer called DDA (DESTINY$^+$ Dust Analyzer). During each flyby, the DDA will measure the mass, electric charge, velocity, and chemical composition of dust in the so-called ejecta cloud surrounding the NEAs, and during the cruise phase, it will measure those of interplanetary dust and interstellar dust. Since ejecta clouds are formed by continuous bombardments of interplanetary dust onto small airless bodies, one may expect that ejecta clouds are ubiquitously present around NEAs. They are, however, too faint to be observed even by space-borne telescopes and hence in-situ measurements by the DDA will provide an unique opportunity to detect ejecta clouds around NEAs. It is worthwhile noting that the presence of an ejecta cloud has been identified only around Jovian satellites and the Moon by dust detectors onboard Galileo and LADEE to date.

Currently available numerical models of ejecta clouds have been used to predict the detection of ejecta clouds by the DDA, while the models are based on either an empirical law of macroscopic impact experiments or mathematical functions that include numerous variables not governed by physical laws. Therefore, we aim at establishing a theory of ejecta cloud formation that involves mesoscopic physics based on the Johnson–Kendall–Roberts theory of contact mechanics, the Griffith theory of fracture mechanics, and the Weibull theory of flaw statistics. Here, we would like to emphasize that the tensile strength of solid particles is a key physical quantity for a deeper understanding of impact phenomena and ejecta cloud formation. Owing to the hypervelocity impact of interplanetary dust, strain rates have an effect on the tensile strength and hence the formation of ejecta clouds is ruled by the dynamic tensile strength rather than the static tensile strength. In this meeting, we will present a simple theoretical formula that is capable of describing the dynamic tensile strength of solid particles applicable to both aggregates and monoliths with arbitrary porosity, size, composition, and strain rate.