Impact experiments onto heterogeneous targets and their interpretation in relation with formation of the asteroid families

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Results of laboratory impact experiments, when extrapolated to the planetary scale of events, are aimed for better understanding of cratering and/or disruption of asteroids, satellites, and cometary nuclei. There is absolutely no reason to assume that these bodies are uniform rocky or icy monoliths. So, we studied reactions of the heterogeneous targets on the impacts. A series of impact experiments onto solid decimeter-sized cylinders made of porous gypsum mixed with approximately one-centimeter-sized pebbles have been performed. The mean density of the material of the targets was 1867 kg m^{-3}, the mean mass ratio (pebbles / gypsum) = 0.856 / 0.144, and the mean volume ratio (pebbles / gypsum / pores) = 0.585 / 0.116 / 0.299. The target densities and their heterogeneous structures could be representative of those of the asteroids Ida, Eros, and many others, because asteroid sub-surface volumes could be composed of consolidated boulders formed by self-compaction and/or by impact compaction. Impact velocities in the experiments ranged from 2.0 km/s to 6.7 km/s (collision velocity in the asteroid main belt is approximately 5 km/s). By means of weighting and counting the post-impact fragments, their distribution function was found. Let Q [J/kg] be the specific energy of impact per unit of the target mass. Of particular interest is the value of impact strength, that is, the specific energy of disruption Q^*, corresponding to the ratio (mass of the largest fragment) / (mass of the target) = $m_l/M = 0.5$, which is, by convention, the value separating the cratering events from the catastrophic disruption impacts. Mass or size distribution of the post-impact fragments is expressed by the power law

$$N \propto m^{-p} \propto r^{-3p},\ p = p(Q/Q^*) \tag{1}$$

A parameter that can be measured in the laboratory is the exponent p. For the case of a swarm of asteroids forming an asteroid family, the observationally estimated value is not the exponent p but rather the exponent $q = 3p$, since the sizes r of the family members are better known than their masses m (because then the asteroids' densities should be known). We have found that, for the gypsum/pebbles targets, there is $Q^* \approx 270$ J/kg and the exponent q varies linearly with rather high slope:

$$q = (0.705 \pm 0.093)(Q/Q^*) + (2.7 \pm 1.2) \tag{2}$$

for $1 < Q/Q^* < 40$, approximately.

For comparison, this result differs considerably from that for porous water ice targets with porosity equal to 0.37 and specific energy of disruption $Q^* \approx 39$ J/kg (based on the data presented in Fig. 9 of Arakawa et al., 2002). In that case, q has only a slight slope:

$$q = (0.092 \pm 0.020)(Q/Q^*) + (1.30 \pm 0.22) \tag{3}$$

for $1 < Q/Q^* < 20$, approximately.

The presence of pebbles strongly influences the impact strength of the target as well as the size distribution of the post-impact fragments. Formulae (2) and (3) indicate that the increase of specific impact energy delivered to the target leads to more efficient comminuting. Comparison with the experimental size distribution within families of asteroids is in progress.

References: Arakawa, M., Leliwa-Kopystynski, J., Maeno, N., 2002, Icarus, 158, 516.