LOW VELOCITY IMPACT EXPERIMENTS ON ICE AND BASALT

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Collision of solid bodies is an important process during planetary accretion. However, experimental data are sparse, compared with the range of masses and velocities required to understand the accretion process in detail. In order to help correct this situation we performed impact experiments which extend to the previously neglected low-velocity regime (100 m/s \(\leq\) 1000 m/s).

Experiments were performed using a single stage vertical gas gun which has a novel sabot stopper defice (1). The projectiles used are aluminum and poly-carbonate with mass of 0.2 to 20 gram. The targets are commercially produced ice blocks and fine grained basalts from Kitashidara, Japan. Target ice blocks were placed on a thick polyurethane-foam sheet and the basalts were supported by threads in order to reduce the shock wave effects at the boundary of the target and its supporting system.

We studied the energy required for catastrophic failure, size distribution of fragments, and crater morphology for each projectile and target combination.

Figure 1 shows the maximum fragment mass as a function of the projectile kinetic energy per unit target mass. This clearly indicates that the energy required for catastrophic failure of ice is about two orders of magnitude smaller than that for basalts. This fact alone indicates that accretion of icy bodies is more difficult than silicate bodies by high speed impact but the definite answer should wait for the data of the velocity distribution of fragments.

The relationship between the crater diameter, \(D\), in ice and the projectile kinetic energy, \(E\), is consistent with Croft et al. (2) and is expressed by

\[
D (\text{cm}) = 1.0E (\text{joule})^{1/3.4}
\]

which gives about 3.6 times smaller diameter than that in basalts for the same impact energy (3).

Comparison of \(D \propto E\) relation for ices, pyrophyllites, and basalts indicates that the relation between the crater diameter, \(D\), and the strength, \(Y\), of the target is expressed in the following form:

\[
D \propto (\frac{E}{Y})^{1/3.4}
\]

The depth/diameter ratios of craters in ice obtained in the present experiments are \(\sim 0.2\) which are about the same for those in silicate rocks but are significantly smaller than those obtained by Croft et al. (2). The present study indicates that the crater morphology of ice is very dependent on the projectile shape and material property in the velocity range of 0.1 to 1.0 km/sec.

The size distributions of fragments from finite targets of ices and basalts are both expressed by
IMPACT ON ICE AND BASALT

Mizutani, H. et al.

\[ N(m) = A m^{-\alpha} \]

where \( N(m) \) is the number of fragments with mass larger than \( m \).

The exponents \( \alpha \) for both ice targets and basalt targets increase from 0.2 to 2.0 as the kinetic energy per target mass increases. The variation of the size distribution of fragments with the kinetic energy should probably be taken into account in future numerical simulation of the accretion processes in the solar system.

References:


Figure 1. Dependence of crater diameter on impact energy for ice compared to craters in the same energy range in pyrophyllites and basalts. The difference among the three straight lines are thought to be due to the strength effect.