EFFICIENCY OF ANGULAR MOMENTUM TRANSFER IN LOW VELOCITY OBLIQUE IMPACTS;

M. Yanagisawa+, J. Eluszkiewicz, and Thomas J. Ahrens, Division of Geological and Planetary Sciences, California Institute of Technology, 252-21, Pasadena, CA 91125

+) Permanent address: Institute of Space and Astronautical Science, Sagamihara, Japan

The rotational state of planetary bodies is the result of collisions, either during accretion or in the case of the minor objects, such as asteroids, throughout the history of the solar system. Theories of rotational state evolution quantitatively depend on the efficiency of angular momentum transfer during individual collisions. When a large body (target) is obliquely impacted by a smaller object (without complete destruction of the target) a portion of the orbital angular momentum of the incident body, $L_{in} = mv\ell$ results in a change of its spin. Here m and v are mass and velocity of the projectile, and ℓ is the impact parameter. The target spin is $L_t = I\Omega$, where I and Ω are the moment of inertia and angular velocity of the target. The efficiencies of angular momentum transfer upon low velocity impact, that is, L_t/L_{in}, were measured in a series of laboratory experiments.

Spherical targets, 5.1 cm in radius, were constructed of plaster, two types of mortar, designated "1" and "2", and cement (Fig. 1). Also, a granite sphere (3 cm radius) was used in an experiment. Target densities were: 1.5 g/cm^3, plaster; 2.2-2.4 g/cm^3 mortar and cement; and 2.8 g/cm^3, granite. The experiments were conducted such that the targets were in free-fall prior to impact. (The thread shown in Fig. 1 does not affect target rotation). Lead projectiles, 1.9 or 2.6 g, in mass, and 1.0 or 1.3 cm, in length, respectively, are accelerated to 310-390 m/sec using a chemical propellant gun. Resulting impact ejecta and target rotation were obtained by imaging the region of cratering with a 16 mm framing camera (4000 frames/sec). The experiments were conducted at atmospheric pressure.

The craters formed by the impacts were all small (<5% of the target mass) such that we could approximate the moment of inertia of the impacted targets as $I = (2/5)\ MR^2$. Here M is the mass of the target and R is its initial radius. Recovered projectiles demonstrated some mass loss (<5%) and severe distortion for all plaster and mortar-1 targets. The projectiles were almost completely fragmented for the other targets. No crater was formed in the granite target. Angular momentum transfer efficiencies (L_t/L_{in}) are plotted versus normalized penetration depth in Figure 2. For data of Fig. 2, the mass and velocity of projectile are 1.9 g and ~330 m/sec (energy ~100 J) except for the cases of the mortar-2 and one mortar 1 targets. The impact parameter is 0.5R (excluding the case of plaster targets). Projectile energy and impact parameter were varied for the mortar-2 and plaster targets, respectively, as indicated in the Figure. No clear relationship between L_t/L_{in} and these parameters was found.

Figure 2 shows that L_t/L_{in} varies among different target materials. It can be scaled by penetration depth normalized by projectile length. When crater is shallow, the angular momentum is transferred only via frictional shear stresses between the target and projectile. When projectile penetrates into the target, compressional stresses on the crater walls probably play a major role in momentum transfer. Thus, the efficiency of angular momentum transfer appears to be strongly controlled by crater depth.

EFFICIENCY OF ANGULAR MOMENTUM TRANSFER IN LOW VELOCITY OBLIQUE IMPACTS
Yanagisawa, M., Eluszkiewicz, J., and Ahrens, T.J.

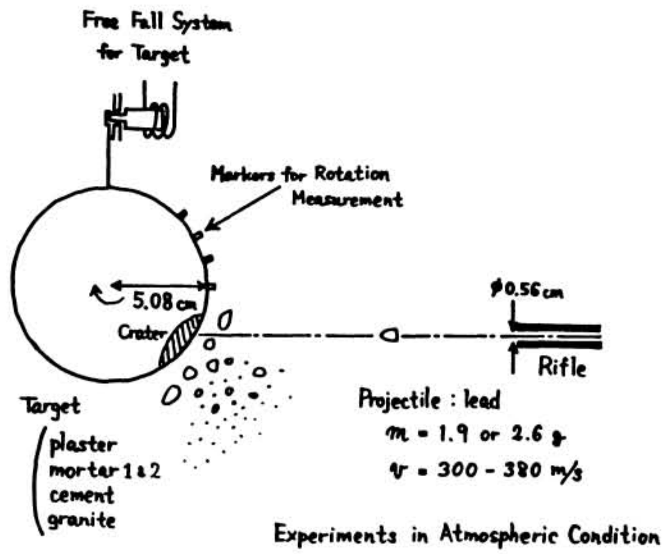

Fig. 1 Sketch of experimental arrangement.

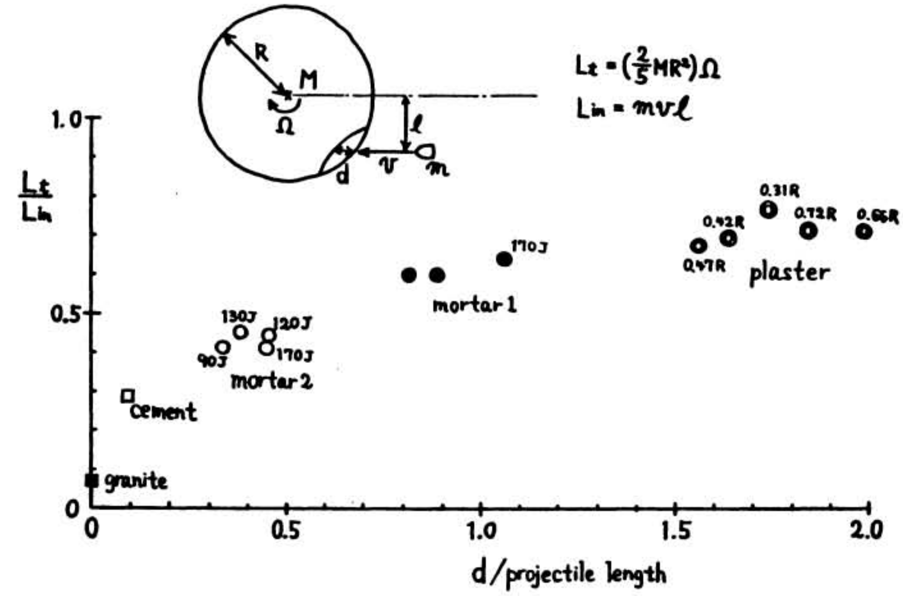

Fig. 2. Angular momentum transfer efficiency, L_t/L_{in} versus normalized crater depth.