LUNAR GRAIN ADHESION: IMPACT AND REBOUND BELOW THE HYPERVELOCITY IMPACT REGION. D.G. Ashworth, D.G. Dixon and J.A.M. McDonnell, Space Sciences Laboratory, University of Kent, Canterbury, Kent, U.K.

The motion of dust particles, such as impact excavated soil and crater ejecta, and the subsequent deposition of this material, is an essential component of lunar regolith development. The adhesion of such particles (1) on exposed surfaces affects solar wind absorption (2) cosmic ray track production (3) and micrometeorite cratering (4). Sticking probabilities for sub-micron sized accreta have been estimated from lunar microcrater accretionary particle analysis by McDonnell (5) and show that smaller particles ($\sim 0.1\mu m$ diameter) have a high probability of being bound firmly at the time of their first contact - this effect will therefore be a significant top surface phenomenon. We present here the commencement of a programme of research in which we seek solutions to the behaviour of solid particle impacts taking into account plastic and elastic deformation. Experimental measurements using a 2MV microparticle accelerator will be offered in support of the theoretical predictions.

The work presented below is an analysis of a simplified system in which a sphere of diameter D travelling with velocity v_i strikes normally a flat unyielding plane (fig. 1). Upon impact, the sphere undergoes elastic and plastic deformation, bonds with the surface over an area A, and rebounds with velocity v_r having broken the bond and leaving a plinth of material from the spherical particle on the target plane.

If a small sphere of a brittle material is considered as a first approximation, there will be a plastic region in compression (6) but not in tension. The force F_p on area A when deformation has just ceased is given by:

$$F_p = A\sigma_c$$

where σ_c is the stress needed to produce plastic flow in compression. Hence the total work done, W, in producing plastic flow when the sphere is compressed by length L is:

$$W = \int_0^L A\sigma_c \, dL$$

or

$$W = \sigma_c V$$

where V is the original volume of the plastically deformed region. Hence, the energy, E, remaining in the particle is:

$$\begin{aligned} E &= \tfrac{1}{2} m_1 v_i^2 - \sigma_c V \\ &= \tfrac{1}{2}\rho V_p v_i^2 - \sigma_c V \end{aligned}$$

where m_1 is the mass of the incident sphere, v_i is the velocity of the sphere, ρ is the density of the sphere and V_p the volume of the sphere. At this point the sphere is considered to have bonded to the target plane with no energy exchange and the remaining energy E is required to break the particle away from the surface and provide kinetic energy for the rebound. The particle must then extend and fracture. The fracture plane is taken to be at the interface between the main body of the particle and the plastically extended volume so a plinth of material will be left behind, although this assumption has not yet been confirmed by measurements. This plinth may be considered as cylindrical, of height (L_1+x) and cross-sectional area A when extended elastically and plastically before fracture (fig. 2) and of height L_1

when the particle has broken free. If the modulus of elasticity of the material is Y and the tensile strength σ_T then the force at fracture F_f is

$$F_f = \sigma_T A$$

and at maximum extension the elastic component, x, is:

$$x = \frac{\sigma_T L_1}{Y}$$

The elastic energy, E_E, contained in the plinth at fracture will then be:

$$E_E = \frac{\sigma_T{}^2 A L_1}{2Y}$$

so the energy, E_r, now remaining in the rebounding particle is:

$$E_r = \tfrac{1}{2} m_1 v_i{}^2 - \sigma_c V - \sigma_T{}^2 \frac{AL_1}{2Y}$$

$$= \tfrac{1}{2} m_2 v_r{}^2$$

where m_2 is the mass of the rebounding particle = $\rho(V_p - V)$ and v_r is the velocity of the rebounding particle.

From these simple considerations it is possible to derive expressions for v_i, v_r, L and e_v, the coefficient of restitution. These may be checked by inserting limiting conditions into the equations or tested experimentally using small spheres accelerated onto a target using the 2MV Van der Graaf accelerator at Kent.

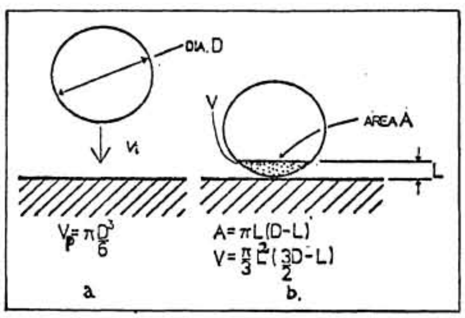

Figure 1(a) A sphere travelling at velocity v_i hits an unyielding surface. (b) The volume V will be plastically deformed.

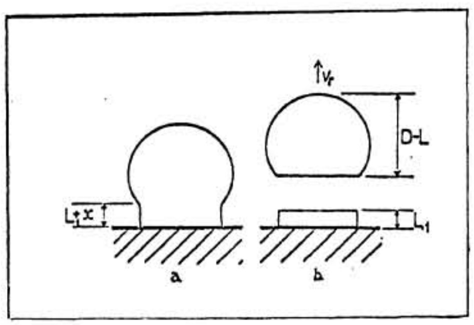

Figure 2. A rebounding sphere (a) about to break away and (b) leaving the surface with velocity v_r with a plinth of material left behind.

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