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Adhesion of rough particles of lunar regolith

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Abstract

The influence of roughness of lunar regolith particles on their adhesive properties is studied. A possibility of dust particle launching over the lunar surface is discussed.

1. Introduction

The future lunar missions Luna-Glob and Luna-Resource are planned to be equipped with instruments for direct detection of dust particles over the surface of the Moon. Dust is usually considered as a part of the dusty plasma system over the Moon [1]. Up to now significant uncertainty exists as to the physical mechanism through which dust particles are released from the surface of the Moon. Adhesion has been identified [2] as a significant force in the dust particle launching process which should be considered in future attempts to understand particle launching methods. However, in Ref. [2] important effects (e.g., roughness of the dust particles) are omitted and very large values for the adhesive force are given. Here, we evaluate the adhesive force for lunar dust particles with taking into account the roughness and adsorbed molecular layers.

2. Adhesive force

To evaluate the adhesive force between two particles the following information is required: geometry of the particles, Hamaker's constant [3], as well as the properties of the surrounding media. Hamaker's constant characterizes the force which arises due to London–van der Waals attraction between two spheres and is estimated usually within the range of 10^{-21} J to 10^{-18} J depending on the chemical and mineral compositions. For lunar regolith Hamaker's constant is $4.3\cdot10^{-20}$ J [4]. Real lunar dust particles are typically of rather complicated geometry. In most cases one can not operate with them as with smooth spherical particles. However, one can model near-the-contact zone as a half-sphere of smaller radius. Since the van der Waals forces are short-range those, the influence of the distant part of the particle is negligible. Rough particles of irregular form putted closely usually have a few points of contact. Without exact knowledge of number of contacts we provide calculation for one contact point. Two particles are modeled as smooth plane with half-spherical asperity and spherical particle of radius *a*. In this case the expression for the adhesive force consists of two parts: the first one determines the influence of the whole plane, and the second one describes the asperity contribution. The basis for our calculations is the Rumpf model [5]. We modify it by taking into account gas adsorption. We use the so-called surface cleanliness $S=\Omega/t$. Here, $\Omega=0.132$ nm characterizes the diameter of oxygen ion while t determines the absorbed layer thickness. Surface cleanliness varies in the range of 1 to 0 and for lunar dayside is calculated as $S=0.88$ [4]. The final expression for the force of adhesion between a plane with an asperity of the radius *r* and a spherical particle is

$$F=\frac{AS^2}{24\Omega^2}\left(\frac{ra}{r+a}+\frac{a}{\left(1+rS/(2\Omega)\right)^2}\right). \quad (1)$$

3. Results

Figure 1 shows the force of adhesion calculated on the basis of Eq. (1). The force is normalized by $F_0=F(r=0)$ which corresponds to the absence of roughness. Three curves in Figure 1 are presented for particles of different sizes *a* (100 nm, 1 μm, 10 μm). We note that the increasing parts of the dependencies given in Figure 1 are not confirmed by experiments. This fact is connected probably with the presence of asperities of the second order. Furthermore, we determine the value of *r* which corresponds to the minimum force and study the dependence of the minimum force versus the size of the particle *a*

(Figure 2). The mass density of the particle is taken to be 2.4 g/cm^3, the gravity acceleration at the surface of the Moon is 1.62 m/s^2. We find that the adhesive force exceeds the lunar gravity for the lunar regolith particles with the sizes less than 50 μm. Comparison of our results with those of Ref. [3] shows that the effect of roughness results in two-three orders of magnitude attenuation of the effect of adhesion.

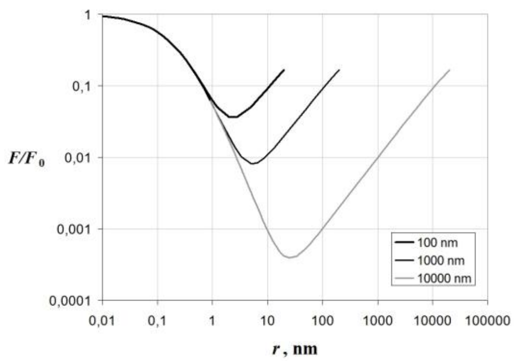

Figure 1: Normalized force of adhesion versus asperity radius for 100 nm, 1 μm, and 10 μm regolith particles.

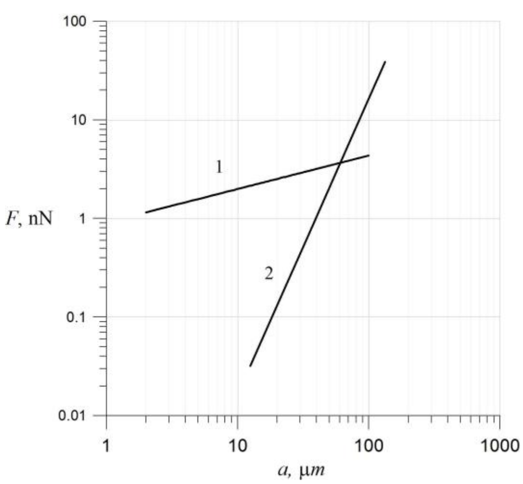

Figure 2: Adhesive (1) and gravity forces (2) for lunar conditions.

4. Discussion

Thus, we have estimated the adhesive force for rough lunar regolith particles. The effect of roughness results in two-three orders of magnitude attenuation of the effect of adhesion. However, even considering the roughness of lunar regolith particles, the electrostatic forces required to launch dust particles from the lunar surface, as a rule, do not exceed the adhesive forces. Dust particle launching can be explained if the dust particles rise at a height of about dozens of nanometers owing to some processes. This is enough for the particles to acquire charges sufficient for the dominance of the electrostatic force over the gravitational and adhesive forces. The reasons for the separation of the dust particles from the surface of the Moon are, in particular, their heating by solar radiation and cooling. The linear sizes of dust particles in the surface layer and, correspondingly, their pressures on each other change. As a result, at a certain arrangement of the particles, forces ejecting them upward appear. This process depends on the linear expansion coefficient, the heat conductivity of rock in the upper layer, and the time of thermal action and can be enhanced in the presence of a volatile adsorbed component in the surface layer.

Acknowledgements

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