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Adhesion of rough natural particles of natural and anthropogenic origin

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Abstract

Adhesive forces for rough dust particles of natural origin are calculated with taking into account roughness of the surface and adsorbed molecular layers.

1. Introduction

In Earth environment nano- and microscale particles are typically attached to larger particles. Figure 1 shows microscale particles containing smaller grains on their surfaces originated from (a) mining, (b) atmospheric brown clouds, (c) rockslides, and (d) chemical explosions. The forces responsible for this interaction are adhesive forces which depend on the origin of the particles, their surface properties, contact area as well as the surrounding media. Forces of adhesion appear due to intermolecular van der Waals forces including permanent dipole–dipole interaction, induced dipole–permanent dipole interaction and dispersion interaction of two induced dipoles. The intensity of the van der Waals interaction is characterized by the Hamaker's constant, which depends on the properties of the two materials and the intervening media. The potential of intermolecular forces decreases with distance s as s^{-6} and the attractive force for two spherical particles [2] is:

$$F = \frac{Aa}{12D^2}\,. \tag{1}$$

Here A is for Hamaker's constant, a is the particle radius, D is the minimum distance between the particles which is usually considered as the molecular diameter. Furthermore, theoretical investigations of adhesion performed by different authors (see, e.g., [1]) have taken into account effects of contact deformations for particles of different elastic properties. The next step is to take into account the effect of rough surfaces of the interacting particles, which exists even for highly polished surfaces at nanometer scales. The first idea is to take half-spherical asperity at the smooth surface of the particle [3] that results in rather realistic results. Interaction of asperity of radius r with spherical particle of larger radius a is described by the following force

$$F = \frac{A}{6D^2}\left(\frac{ra}{r+a} + \frac{a}{\left(1+r/D\right)^2}\right). \tag{2}$$

The first term in (2) is responsible for the interaction of asperity with the particle while the second one characterizes the interaction with the plane separated from the particle by the asperity.

2. Model

Here, we use the Rumpf model of roughness supplemented by adsorption. If Hamaker's constant is calculated for vacuum condition, in the atmosphere of mixture of gases the model should be modified. We use surface cleanliness $S = D/(2t)$ [4] where t characterizes the distance from the center of the outermost mineral molecule to the center of the outermost adsorbate molecule. For Earth's atmosphere the most important is the role of water vapors and S is calculated [3] to be 0.13. Hamaker's constant in vacuum for most cases is within the range of 10^{-20} to 10^{-19} J, for example, for quartz $A = 6\cdot10^{-20}$ J. Figure 2 shows the range for minimum adhesive forces. The lines (1) to (4) correspond to $A = 10^{-20}$ J, $S = 0.1$; $A = 10^{-19}$ J, $S = 0.1$; $A = 10^{-20}$ J, $S = 1$; and $A = 10^{-19}$ J, $S = 1$, respectively. The line (5) characterizes the gravity force. Under natural conditions the line (1) fits the minimum adhesion effect and most situations in nature correspond to the band between the lines (1) and (2).

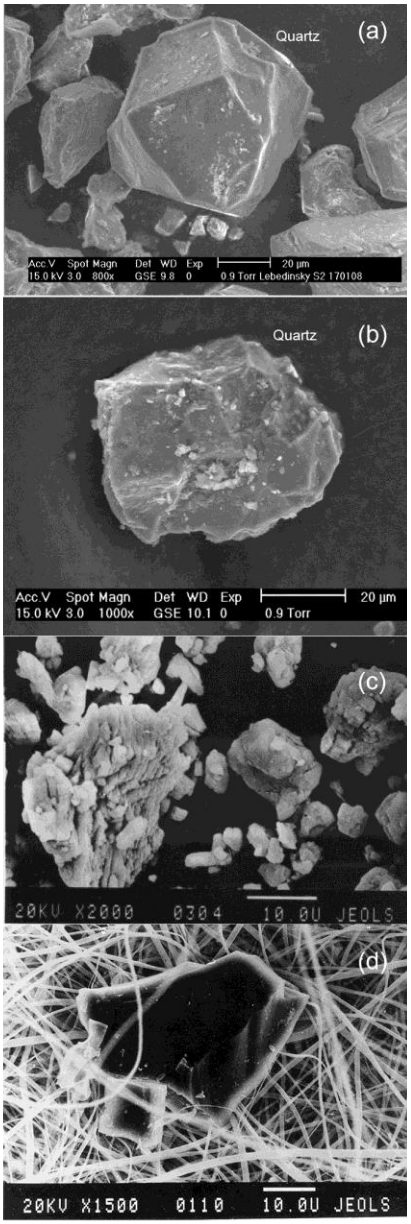

Figure 1: Images of particles from different sources.

Thus the gravity exceeds the adhesion for particles larger than 5-15 μm: the particles with the sizes larger than 5-15 μm cannot be attached to larger particles due to the adhesive forces.

3. Summary

We have studied adhesion of particles originated from rockslides, mining, chemical explosions, and atmospheric brown clouds and found that for the particles smaller than about 5-15 μm the gravity is small in comparison with the adhesive force. This result is in accordance with the observations.

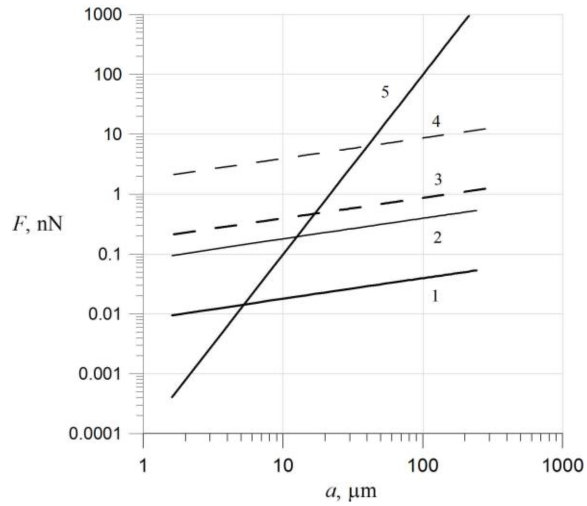

Figure 2: Adhesive (1-4) and gravity (5) forces for different particle sizes *a*.

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References

[1] Hamaker, H.C.: The London-van der Waals attraction between spherical particles, Physica, Vol 4, No. 10, pp. 1058-1072, 1937.

[2] Derjaguin, B.V., Muller,V.M., and Toporov, Yu.P.: Effect of contact deformations on the adhesion of particles, J. Colloid Interface Sci, Vol. 53, pp. 314–326, 1975.

[3] Rabinovich, Y.I., Adler, J.J., Ata, A., Singh, R.K., and Moudgil, B.M.: Adhesion between nanoscale rough surfaces. I. Role of asperity geometry, Journal of Colloid and Interface Science, Vol. 232, pp. 10–16, 2000.

[4] Perko, H.A., Nelson, J.D., and Sadeh, W.Z.: Surface cleanliness effect on lunar soil shear strength, Geotechnical and Geoenvironmental Engeneering, Vol. 127, No 4, 2001.