

Particle-Wall Adhesion in Electropacked Beds

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Abstract—Electric fields applied across loosely packed beds of glass beads or sand induce strong interparticle electrical forces. Reported here is an investigation of the closely related phenomenon of bed particles sticking electrically to walls. The yield locus of a metallic sled sliding over the surface of an electropacked bed is measured as a function of the applied electric field. The yield locus shifts with applied field because greater shear force is required to initiate movement, but the static friction coefficient remains unchanged. The effective electrical stress acting on the sled is estimated from the yield-locus shift, and the results are compared with data from other experiments, including fluidized-bed measurements and the angle-of-repose technique.

INTRODUCTION

ADHESION is the sticking of particles to a plate or a wall. Cohesion is the sticking together of adjacent granules [1]. Electrical adhesion is widely reported in fluidized-bed experiments where low-conductivity particles are used [2]–[6]. Electromechanical effects reported in these works are attributed to either triboelectrification [2]–[4] or electric fields imposed by electrodes [5]–[7]. The use of electrical adhesion for particle separation applications has been suggested [4], [5], [8] and is practiced in electrostatic precipitation [9].

Electric current in a granular material such as the layer of precipitated dust in an electrostatic filter is constrained to flow from particle to particle in the immediate vicinity of interparticle contacts [10]. The electric field across the interparticle gap is intensified greatly by current constriction, making nonlinear charge transport likely (Fig. 1) [10], [11].

Two phenomena thought to be consequences of current constriction are the nonlinearity of the effective bulk resistance of high-resistivity granular materials at moderate applied electric fields [10] and the strong electrical cohesion that varies approximately linearly with the applied field [7], [12]–[14].

The thesis of this work is that current-constriction phenomena and the strong electrostatic attraction are important in electrical adhesion. The fundamental geometry of particle-wall adhesion can be constructed from the particle-particle cohesion geometry shown in Fig. 1. The symmetry plane between the two particles can be replaced by a conducting

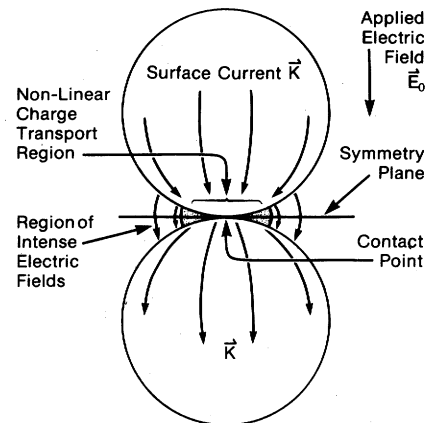


Fig. 1. Electrically enhanced particle-particle cohesion.

plane by using the method of images. Formally, this method does not apply to the region of nonlinear conduction near the contact region. However, the existence of current constriction in particle-wall adhesion is evident from this construction, and an analogous region of intense electric fields and nonlinear charge transport is predicted.

Dietz and Melcher [11] have accounted for the nonlinear charge transport by limiting the magnitude of the electric field in the vicinity of the contact. Using the image argument, their analysis of the interparticle electric force applied equally to particle-wall adhesion. One important difference is the packing arrangement of the particles. Some attempts have been made to account for random packing in estimates of the electric stress acting in the bulk of a granular material [11], [15]. Rigid walls disrupt the packing arrangement [16], so packing effects in particle-wall adhesion are expected to differ from bulk random-packing effects.

In this work, the results of new sled yield-locus experiments are presented in which the electrical adhesion of glass beads and sand to a metallic plate is measured as a function of the average electrostatic field. The results of this work are compared with several measurements of the electrical adhesion of glass beads and sand to rigid walls by other methods.

EXPERIMENTAL APPARATUS

The sled yield-locus experiment is a classical measurement of the static friction coefficient and the yield shear stress between the surface of a packed bed and a movable metallic sled. A shear force is exerted on the sled, tending to pull it across the bed surface. The yield shear, that is, the shear force required to initiate steady motion of the sled, is measured as a function of the weight of the sled and of the applied electric field.

The experimental cell is illustrated in Fig. 2. The apparatus

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