THE EFFECTS OF ELECTRIC FIELDS ON WIND DRIVEN PARTICULATE DETACHMENT

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Introduction:

The generation of electric fields close to the surface during sand/dust transport events is well-documented and attributed to the electrification of sand/dust particulates during contact (collision) i.e. the processes of contact electrification or triboelectrification (Farrell et al 2004, Renno et al. 2004, Schmidt et al 1998). Electrification leaves larger grains electrified positive compared to smaller grains, and subsequent gravitational separation of these particulates, especially Aeolian suspension of dust then leads to the generation of electric fields in ranges of 30-170 kV/m in terrestrial dust devils (Kok and Lacks 2009, Forward et al. 2009, Jackson and Farrell 2006).

Studies of terrestrial wind driven transport rates from a sand bed with an applied external electric field have shown increased transport rates for electric fields above 250 kV/m. However for electric fields in the range 150-250 kV/m, the transport rate was suppressed. This is attributed to poor electrical conductivity of the sand bed or possible dielectric effects of the sand particulates (Rasmussen et al. 2009).

Electric field induced levitation of sand particles (63 µm to 2 mm) from a conductive surface has been demonstrated and reduction in the wind driven threshold for sand transport over a conductive surface is expected (Kok and Renno 2006).

However, it is not clear that in nature a surface is necessarily conductive, as in environments with low absolute humidity the surface would be better modeled as a (poorly) insulating surface. In reality a sand bed typically consists of a complex network of electric conductive chains grains, making the electric conductivity of the surface to the sub-surface spatially non-uniform.

One example of low humidity environments is the planet Mars and though experiments with charging of Martian soil simulants suggest that triboelectric charging and electric field generation occurs in Martian dust and sand events (Anderson et al. 2009, Krauss et al. 2003, Sickafoose et al. 2001, Eden and Vonnegut 1973) there exists no direct evidence from Mars.

However observations of dust accumulation on the Sojourner rover wheels and on electronics on the Mars Exploration Rovers (MERs) suggest electrification of surface dust (Anderson et al. 2009, Ferguson et al. 1999), while razorbacks seen by MERs suggest the presence of chain formation in charged surface materials (Shinbrot et al. 2006).

This study aims to examine the effect of conductive and insulating surfaces on the detachment threshold wind speed of sand sized particles under the influence of electric fields.

Detachment Theory:

A simple model of wind driven grain detachment is constructed from the application of force balancing (Merrison et al. 2006), modified with the application of electric field induced component. All forces are expressed as stresses.

The stress applied to a surface particle by wind can be expressed with two components, a vertical lift stress (τ_L) and a horizontal torque (τ_T). Particle detachment is prevented by two stresses, the first being gravity (τ_G) and the second being surface adhesion (τ_A). The application of a vertical electric field results in a vertical stress on the particle (τ_E) which can either hinder or aid detachment. For this experiment only the vertical component of adhesion ($\tau_{A\perp}$) is of interest and the horizontal torque is not considered as horizontal movement, *i.e.* rolling, has been inhibited.

The condition for detachment is that the combination of the wind shear (lift) and electric field induced stress is balanced by the adhesion and gravitational stress terms:

$$\tau_L + \tau_E + \tau_{A\perp} + \tau_G = 0$$

Experiment and Analysis:

Small circular deposits of granular materials were deposited upon a surface within a parallel plate electrode system such that an electric field could be applied. The electrode system was placed inside an environmental wind tunnel and the circular deposits were imaged using a camera while the wind speed within the wind tunnel was increased until the deposits were seen to be removed.

Both conducting (copper) and insulating (polycarbonate) surfaces were used in conjunction with three types of particles: soda lime glass spheres, irregular quartz particles and copper particles. The glass spheres were chose due to their well characterized geometry and composition, thus being well suited for theoretical treatment with regard to electrical properties and wind detachment (Stoy 1995, Jones et al. 2002, Merrison et al. 2007). The quartz particles were chosen in order to study morphological effects and the copper particles were chosen to represent conductive material.

Fig.1: The three materials used in the study: glass spheres, quartz particles and copper particles. All particles were in the size range ~ 100-125 µm after being sorted through sieving.

Analysis of the images determined the relative color index in each color filter (red, green, blue) between a rectangle enclosing one circular deposit and a corresponding background value. The wind speed required for Aeolian detachment, or the threshold detachment wind speed, $U_{1/2}$, was defined as the wind speed corresponding to the frame where the relative color index had fallen halfway between the maximum (full coverage) and minimum (removed) value.

Results and Discussion:

Absolute determination of the stresses involved is inaccurate given their empirical nature and the final representation of the results uses the following determined dependencies for the stresses: $\tau_L \propto U^2$ and $\tau_E \propto E^2$, where U is the wind speed and E is the electric field.

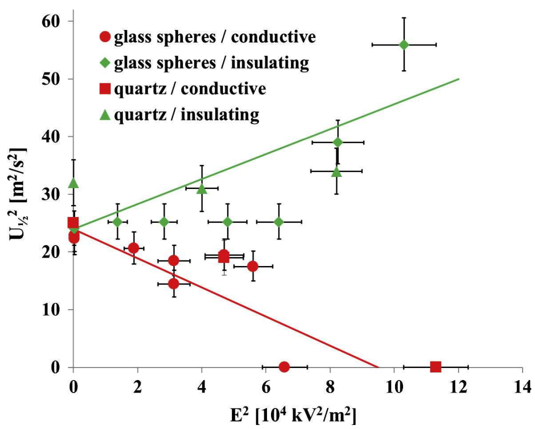

Fig.2: The detachment threshold wind stress (square of the detachment wind speed) plotted as a function of the applied electric field stress (square of the electric field) for sand sized glass spheres and quartz particles on both conductive and insulating surfaces.

Fig. 2 shows the detachment threshold wind stress versus the applied electric field stress for glass spheres and quartz particles on both conducting and insulating surfaces. There is clearly a qualitative difference between the two types of surfaces. Conductive surface reduce the wind shear stress needed for detachment, while insulating surfaces increases the necessary wind shear stress. There does seem to be a more complex behavior at low field strengths leading to a suppression of the effect.

This study has demonstrated a qualitative difference in the behavior of a conductive and an insulating surface with regards to electric field assisted Aeolian transport. Models of electric fields in Martian dust devils suggest that they can reach up to a few kV/m (Barth et al. 2012) indicating that this effect can be of relevance to Martian sand (and dust) movement.

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