APPROACH FOR MODELING OF DUST CONTACT ELECTRIFICATION ON THE MOON.

Y. Zhang[1] and C. M. Hartzell[1]. [1]Dept. of Aerospace Engineering, Univ. of Maryland, College Park, MD, USA.

Introduction: Understanding dust transportation on the Moon is important for deciphering the geologic history of lunar surface and planning human/robotic exploration activities. This problem is further complicated when considering the charging effects of dust grains and their interaction with time-variable lunar surface electric fields [1]. Lunar dust grains can acquire charge when grains collide or roll against each other. Evaluating the amount of charge transfer during contact electrification is needed for understanding dust transportation.

Numerous experiments have observed contact electrification between identical dielectric materials, yet the underlying mechanism of this process remains poorly understood [2]. Here we propose a general model based on the donor-acceptor mechanism for predicting the amount and polarity of charge transferred between dust grains during contact, and we apply this model to study dust charging in lander plumes on the Moon.

Donor-acceptor model of contact electrification between same-material dielectric grains: Experimental and statistical analyses suggested that same-material insulator contact electrification may arise from the microscopic fluctuation and misalignment of the donor/acceptor sites between the two contact surfaces, where a unit charge e is transferred from a donor site to an acceptor site [3–5].

Based on these analyses, we design two parameters to characterize the charge exchange ability of an insulator grain, i.e., the surface donor/acceptor density, σ_d and σ_a. Figure 1 presents two particles as examples whose donor regions were generated using the grow and nucleate procedure given in [5]. Upon contact, each donor site has a transfer probability, α, to lose its charge carrier to the other surface if the facing site is an acceptor.

By randomly choosing the contact area on two mosaic-like grains, we carried out 1000 Monte-Carlo tests to evaluate the exchanged charge, $\Delta q_{i\to j}$ and $\Delta q_{j\to i}$, as a function of contact number. The results show that the mean exchanged charge at each contact can be simply derived from the donor and acceptor densities before the contact, i.e., $\Delta q_{i\to j} = \alpha\sigma_{d,i}\ \sigma_{a,j}\ l_0^2\Delta A$, $\Delta q_{j\to i} = \alpha\sigma_{a,i}\ \sigma_{d,j}\ l_0^2\Delta A$, where l_0 is the size of a donor/acceptor site and ΔA is the contact area increment.

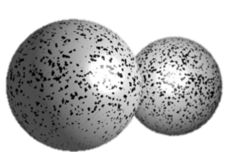

Figure 1 Donor-acceptor mosaic model of dust grains. The black/gray patches denote donor/acceptor sites.

Model implementation in the Open-Source DEM code LIGGGHTS: The simplicity of the proposed charge exchange model allows us to effectively implement it in a discrete-element modeling (DEM) code. To take the effect of local electric field into account, the transfer probability, α, is reduced accordingly if the direction of the electric field at the contact point retards the movement of the charge carrier. In addition, the charges of two grains in contact are adjusted if the local electric field exceeds the breakdown strength E_{bd}. After each timestep, the donor/acceptor density is updated by reducing the exchanged amount, e.g., $\sigma_{d,i} = \sigma_{d,i} - \Delta q_{i\to j}/(4\pi r_i^2)$. The total exchanged charge, $\Delta Q_i = e(\Delta q_{j\to i} - \Delta q_{i\to j})$. Note that there are not any assumptions being made on the unit charge. Therefore, this model can be used to describe different charge carrier species.

Model validation tests. We validate the proposed donor-acceptor model against in-vacuum granular vibration experiments [6]. The results show that the overall charge distribution and the mean charges of both small and large grains, as well as the size-dependent bipolar charging feature, are quantitatively consistent with the experimental data, supporting model validity.

Application to study dust charging in lander plumes: We simulate the dust dynamical evolution in lander plumes using a periodic box in the x-y plane. The gas drag is calculated from the assumed gas density and speed along the x axis. Figure 2 presents a snapshot of a simulation. Intensive collisions between dust particles in the plume lead to substantial charge accumulation on them. The result implies that contact electrification could be a dominate charging mechanism near the surface during spacecraft descending/ascending and can profoundly influence the dust transportation.

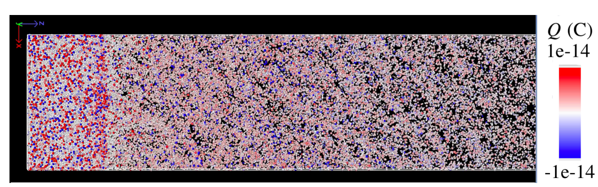

Figure 2 Modeling of dust contact charging in plumes.

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