EFFECT OF POROSITY ON ACCESS OF SOLAR WIND TO LUNAR REGOLITH. A. V. Kulchitsky[1], D. M. Hurly[2], J. B. Johnson[1], P. Duvoy[1], [1]University of Alaska Fairbanks, Institute of Northern Engineering, P.O. Box 755910-5910, Alaska 755910, USA, anton.kulchitsky@alaska.edu, [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723.

Introduction: The solar wind consists of ions and electrons that are accelerated through the solar corona to flow outward from the Sun at several hundred km/s in the ecliptic plane. As the solar wind ions are predominantly protons, the solar wind is a significant source of protons to the Moon. It is still uncertain if the solar wind delivered hydrogen is converted into water through chemical reactions once in the lunar environment. It has been suggested that water could be created via micrometeoroid bombardment. The implanted solar wind H would act as a reducing agent converting FeO to nanophase iron. The oxygen may combine with the hydrogen and be released as water. Because the solar wind is a steady, continual source of hydrogen to the Moon, this process is of great interest to exploration. If occurring, it represents an ongoing mechanism for creating water on the Moon.

The solar wind has access to the extreme surface of the Moon because the Moon lacks a global magnetosphere or substantial atmosphere that would deflect the incident flow. Solar wind ions mainly neutralize on contact with the surface and penetrate ~10 nm into the regolith. However, owing to the porosity of regolith on the Moon, the ions have access through pore space to grains that are partially buried. This work quantifies the relationship between regolith porosity and solar wind access as a function of grain depth.

The Approach: To study how far protons can reach into the upper layers of lunar regolith, we used a discrete element method model COUPi [1]. First, we created different particle beds representing regolith of different porosity using polyhedral particles. The particles are put into the grid above the bottom of the box so they do not overlap. Then, they fall under the gravity 10 m/s^2 and settle. The different porosity is achieved by varying friction and adhesion between the particles. The range of porosities achieved, while the homogeneity of the regolith bed is preserved, vary from 0.43 to as high as 0.61.

After the regolith particles are settled, the protons, represented by point particles of infinitely small size, are generated randomly above the regolith bed. Then protons are fired with constant velocity into the regolith. The angle of incidence is varied to find the dependence of the penetration depth with incidence angle. As soon as a proton hits a regolith particle, it stops. After all protons stop, they are counted and the distribution function of protons is built depending on the depth measured in mean size of the particles. The maximum of the distribution function is assigned to the surface level.

Fig. 1 shows the regolith bed before and after the protons are fired with 0 angle of incidence measured from the normal to the surface. The protons are generated above ½ of the regolith bed to allow different angles of incidence.

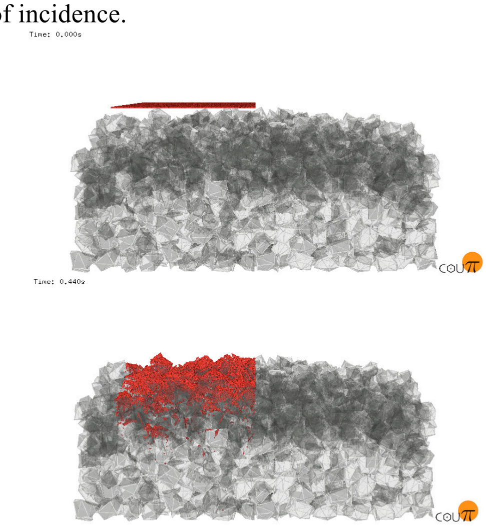

Figure 1 Regolith particles (gray, semi-transparent) and protons (red) before and after the simulation.

Results: We found that penetration depth depends on the angle of incidence. Fig. 2 shows the proton distribution as a function of depth for different angle of incidence.

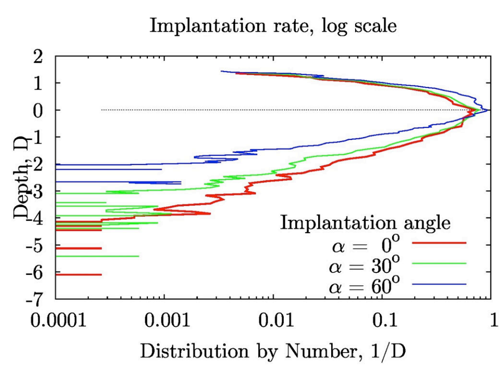

Figure 2 Proton implantation rate depending on incidence angle for average porosity

We also found that proton distribution in upper layers of regolith is well described by the Gamma distribution function as shown in Fig. 3.

$$f_\Gamma(x; k, \theta) = \frac{1}{\Gamma(k)\theta^k} x^{k-1} e^{-x/\theta}$$

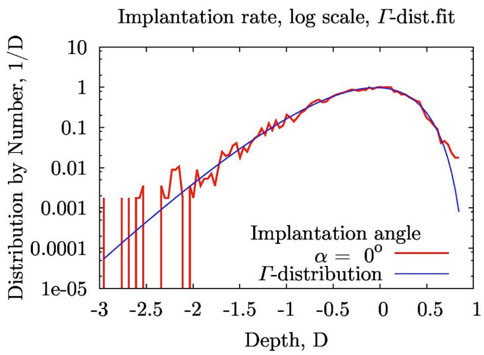

Figure 3 Proton distribution in regolith fit with Gamma-distribution function example.

The porosity influence of proton distribution shows that more porous material allows deeper penetration of protons.

The implantation rate as a function of depth, porosity and the angle of incidence will be presented. The future work will include a study of regolith particle size distribution influence on the proton implantation depth distribution function as well as more numerical characteristics of porosity influence on proton implantation.

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References:

[1] Nye, B., Kulchitsky, A. V. and Johnson, J. B. (2014), Intersecting dilated convex polyhedra method for modeling complex particles in discrete element method. *Int. J. Numer. Anal. Meth. Geomech.*, 38: 978–990. doi: 10.1002/nag.2299