ISRU Research at Imperial College London, A Status Update. J. J. Cilliers[1] and K. Hadler[1], S. Starr[1], J. N. Rasera[1], R. D. Cruise[1], Y. Yu[1], V. Schein[1], Earth Science and Engineering, Imperial College London, Exhibition Road, S. Kensington, London, SW7 2AZ, United Kingdom j.j.cilliers@imperial.ac.uk, k.hadler@imperial.ac.uk, s.starr@imperial.ac.uk, j.rasera@imperial.ac.uk, r.cruise19@imperial.ac.uk, y.yu20@imperial.ac.uk, victoria.schein18@imperial.ac.uk.

Introduction:

A range of processes to extract oxygen and water from lunar regolith have been proposed such as hydrogen reduction and molten salt electrolysis. At the proof-of-concept stage, the nature of the material fed into the reactor does not need to be controlled or optimised. For larger scale and continuous operation, reliable production requires there to be control over the reactor feedstock characteristics. Controlling the size range of regolith, for example removing coarse and fine particles, and/or concentrating specific minerals or particle types, has the potential to improve the operation of any reactor handling naturally variable materials. This step, beneficiation, is often overlooked in the ISRU flowsheet, in part due to a lack of understanding of the effects of feedstock variability on downstream operations. Beneficiation will also have a significant effect on the overall mine scale and process flowsheets [1,2].

The challenges of handling and manipulating lunar regolith in situ are numerous – on Earth, separating mineral particles by size at 50 µm without water is difficult. On the Moon, the environmental conditions and particle characteristics increase the complexity significantly.

At Imperial College London, we are addressing the challenges of the beneficiation of lunar regolith by combining our terrestrial mineral processing expertise with the specific needs of ISRU. There is a focus on the classification of regolith by size and type, exploiting electrostatic properties of particles in the lunar atmosphere. In this talk, we will give an update on our ongoing projects. At a fundamental level, we are investigating the saturation charge of particles under ideal (terrestrial) conditions [3]. The data will provide a valuable input into the design of effective contact, or tribo-, chargers for use in electrostatic separators. The charge acquired on particles in a tribocharger has been modelled using Discrete Element Method (DEM) and testing in a tribocharger/electrostatic separator testbed [4]. Subsequent simulations allow for the testing of conceptual tribocharger designs, in order to provide clear design guidelines for effective electrostatic separation.

We are also investigating the use of electrostatic standing wave systems for particle transport and separation. Significant progress has been made in developing highly efficient codes for the calculation of electric fields of arrays of parallel electrodes. A testbed system is in development that will allow testing of this concept in air and vacuum.
We will also present preliminary results from a novel vibratory size classification system which has been tested on lunar simulants and an Apollo soil sample.

The research presented in this talk will showcase the progress being made in the beneficiation of lunar regolith in our group, however it will also highlight the gaps in knowledge that must be addressed in order to constrain further this often overlooked stage of the ISRU value chain.

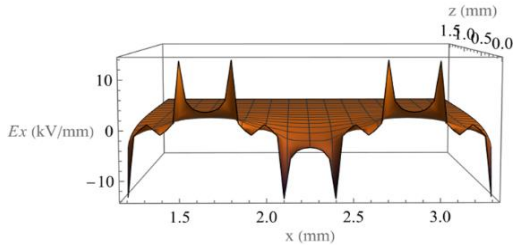

Figure 1. Calculated electric field of an array of electrodes.

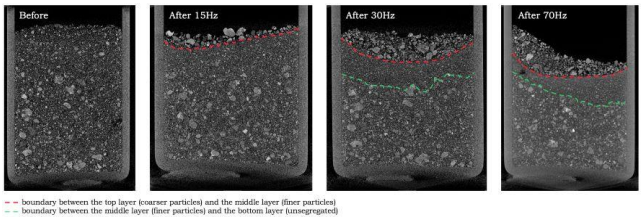

Figure 2. Micro-CT of Apollo 15 soil sample showing segregation due to vibration.

References:

[1] J.J. Cilliers, J.N. Rasera, K. Hadler, 2020. Estimating the Scale of Space Resource Utilisation (Sru) Operations to Satisfy Lunar Oxygen Demand, Planetary and Space Science, Volume 180, article id. 104749, 2020., [2] J. N. Rasera, J.J. Cilliers, J.A. Lamay, K. Hadler, The beneficiation of lunar regolith for space resource utilisation: A review, Planetary and Space Science, Vol. 186, July 2020, 104879 [3] R. Cruise, The effect of particle size and relative humidity on triboelectric charge saturation, Journal of Physics D: Applied Physics, forthcoming. [4] J.N. Rasera, J. N., Cilliers, J. J., Lamamy, J.-A., & Hadler, K. (2021). XXX International Mineral Processing Congress. In *Proceedings of the XXX International Mineral Processing Congress*. Cape Town, South Africa; International Mineral Processing Council.