VACCUM SINTERING OF HIGHLAND SIMULANT CSM-LHT-1G

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Introduction: Sintering of lunar regolith is a process of interest to consolidate the ubiquitous granular material in durable structures on the lunar surface such as platforms, landing/launch pads, roads, and foundations for long-term robotic and human activities. In principle, the sintering of the lunar mixtures of minerals largely dominated by silicates only requires controlled heat input into the material without the need for a binding compound. The demonstration of controlled sintering under vacuum conditions is therefore important and previous published works on the topic have investigated the processing parameters needed to obtain satisfactory results with different simulants. Many publications do not report quantitative assessment of the effects of processing conditions on the strength properties of the sintered products.

The work presented is an investigation into such effects on a carefully selected simulant, CSM-LHT-1G prepared for high temperature processing to eliminate undesired components that would not be present from lunar materials. The experimental work was performed in support of a larger project that aims to perform a small-scale demonstration of sintered structure on the lunar surface using the capabilities of a CLPS program lander.

Project Description: Previous studies have discussed several methods for heating the lunar regolith to obtain sintering ranging from metal combustion and resistive crucible heating to directed radiative heating like solar, microwave, and laser beam irradiation [1]. Very few of these techniques have been tested in vacuum conditions with identical simulants but several of these investigations have reported significant changes in the results with those obtained in atmospheric conditions. The variability of the mineralogy of the simulants used in these investigations and the presence of weathering products they contain are important factors to measure and document to understand the variations in outcomes [2,3]. Several heating techniques proposed aim at transferring heat to the regolith in a localized and direct manner to maximize energy usage efficiency on the luanr surface. This concept of direct heat input is attractive for lunar operations but the internal heating rates of the regolith are difficult to measure in-situ and the properties of each simulants involved are not always known such as dielectric properties, emissivity, optical absorption. Consequently, the results vary with the experimental conditions dictated by the performance characteristics of the heat source and the nature and preparation of the regolith simulants that make it difficult to assess quantitatively the working heat in the material, a concept used to control ceramic production instead of targeting a specific processing temperature.

Our contribution is centered on quantitatively assessing the results of known heat input in prepared simulants through microstructure imagery and strength measurements of the obtained materials under controlled conditions. The thermal environment is created with a vacuum tube furnace with in-tube temperature measurement by thermocouple. The comparison between data from the reference thermocouple outside the furnace tube, used for furnace programming and the in-tube thermocouple placed in close proximity to the regolith enabled precise targeting of specific conditions at the sample.

The selection and preparation of the CSM-LHT-1G simulant was driven by several factors: 1. The need for high degree of fidelity in representing the mineralogy and major oxides compositions of lunar polar terranes for high-temperature processing, 2. The cost and availability of the simulant in quantities of hundreds of kg, and 3. The need for low concentrations of weathered products. This simulant is a variant of the CSM-LHT-1 lunar highland simulant produced by Colorado School of Mines. The original mineralogical composition of CSM-LHT-1 (70 wt.% Greenspar, 30 wt.% Merriam Crater basalt) was modified to obtain a 30 wt.% glass content with the addition of NU-LHT-5M glass balanced with pyroxene (augite) to yield CSM-LHT-1G.

Initial heating experiments on low volume samples identified the conditions that yield materials ranging from brittle material to highly densified material. These processing conditions (heat rate, dwell time, final temperature, and pressure) were used to produce large samples in a sequence generated by a randomized factorial design of experiments. The large volume of samples,some compacted and others non-compacted enabled the machining of several ASTM standard test articles for flexural and compression strength measurements. The presented work provides reference data to quantify the relation between known heat input and relevant strength properties of sintered regolith to help understand the internal conditions seen by the same material under high heat input rates created by rapid sintering techniques.

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