Paper ID: 39183
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SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations (IP)

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CHARACTERIZING THE MATERIAL RESPONSE OF BIOPOLYMER-STABILIZED REGOLITH TO PREDICT MICROMETEORITE DAMAGE OF ISRU HABITAT SYSTEMS

Abstract

Transforming in-situ materials, such as Martian or lunar regolith, into useful structural elements is a powerful way to reduce the launch mass needed for establishing long-term surface operations. A novel material, termed Regolith Biocomposite (RBC), embraces this concept. RBC consists of regolith mixed with a small amount of biopolymer binding agent. The biopolymer stabilizes the regolith to form a brick-like material with strength approaching that of conventional concrete. RBC has been proposed as material for building stable landing pads, pavements that prevent dust levitation, radiation shielding, and habitats. In principle, the use of this material could enable far-term capabilities by reducing mission reliance on materials and structures that would otherwise be fabricated on Earth. Given that RBC may be used for the construction of critical surface systems, it is essential to understand its performance against micrometeorite impacts. Due to their stochastic nature, micrometeorite impacts pose a great risk for sudden, catastrophic failures such as depressurization. Understanding the performance of RBC as a construction material for space in a micrometeorite environment is necessary to ensure crewmember safety and surface system reliability for long-duration missions. A total of nine hypervelocity impact (HVI) experiments were conducted to characterize the relationship between the intensity of a hypervelocity impact and the incurred damage of RBC. A light-gas gun (LGG) at the Ames Vertical Gun Range (AVGR) at NASA Ames Research Center in Moffett Field, CA was used. Spherical aluminum projectiles, ranging in diameter from 1.6mm to 6.4mm, were launched at a 90 impact angle at velocities ranging from 3.63 km/s to 6.20 km/s. Resulting craters were 3D scanned and transient crater dimensions were calculated from cross sections. A material constitutive model using the Drucker-Prager yield criterion and the P- equation of state is also pursued for eventual computational modeling using mesh-free methods. Uniaxial compression and tension tests are conducted, as well as split-Hopkinson pressure bar (SHPB) experiments. An analytical power-law relationship between impact velocity and transient crater volume is derived using Holsapple's pi-group scaling laws to extrapolate impact velocities past what is experimentally achievable, ultimately allowing damage prediction in the velocity regime relevant to micrometeorites. This demonstrates that RBC's behavior follows well-established literature. Uniaxial compression and tension tests indicate strengths of 14 MPa and 2 MPa, respectively. SHPB results will be used to calculate a dynamic increase factor, which will be incorporated into the constitutive model to capture strain rate effects.