Abstract #1672

English

Combustion Joining of Regolith Tiles for the In-Situ Fabrication of Launch/Landing Pads on the Moon and Mars

To mitigate dust problems during launch/landing operations in lunar and Mars missions, it is desired to build solid pads on the surface. Recently, strong tiles have been fabricated from lunar regilith simulants using high-temperature sintering. The present work investigates combustion joining of these tiles through the use of exothermic reactions. Based on thermodynamic calculations, it is hypothesized that combustion of a stoichiometric nickel/aluminum mixture in the gap between the tiles will weld the regolith tiles together. The objective is to experimentally determine the minimum distance between two regolith tiles that is needed for the formation of a strong weld through a self-propagating combustion of the intermetallic mixture. The mixture, placed in the gap between tiles fabricated from JSC-1A lunar regolith simulant, is ignited by a CO2 laser in an argon environment. The combustion front propagation over the mixture is studied using video recording.

French

No abstract title in French

No French resume

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Robert Ferguson graduated wit a B.S. in Mechanical Engineering from the University of Texas at El Paso in May 2016. Having previously worked on propulsion techniques at the the University's Center for Space Exploration and Technology Research, he was awarded a NASA Harriet G. Jenkins Graduate Fellowship to pursue his current research of combustion joining of lunar regolith tiles.

Biography in the user profile

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Combustion Joining of Regolith Tiles for *In-Situ* Fabrication of Launch and Landing Pads

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Agenda

- Background
- Objectives
- Experimental
- Results
- Future work

Background

- During the Apollo lunar landings, dust concerns were repeatedly noted.
  - Obstructed visibility during landing
  - Affect on nearby equipment
  - Lunar and command module contamination
  - Health issues affecting the astronauts during return

Dust Mitigation Techniques

- NASA's Granular Mechanics and Regolith Operations Lab at Kennedy Space Center has produced tiles by high-temperature sintering of lunar regolith simulant.

- *In-situ* resource utilization reduces costs of missions to the Moon and Mars.

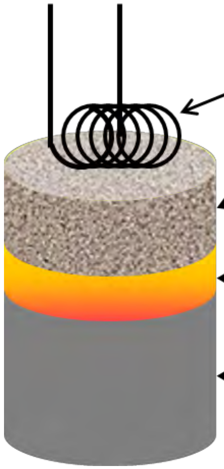
Joining the Tiles

- A method to join these tiles is desirable.
- By joining the tiles, launch and landing pads could be constructed using *in-situ* resources.
- Combustion joining, a technique based on self-propagating high-temperature synthesis (SHS), shows promise as a joining operation.

A rover built a prototype launch-and-landing pad on Hawaii's Big Island in late 2015. *Credit: PISCES*

SHS

- Reactive powders are mixed and ignited by an external energy source.
- The released chemical energy provides heat to propagate the combustion front.
- The reaction generates high temperatures and desired products.
- SHS is used to synthesize ceramics and other materials.



Schematic of SHS process

Combustion Joining

- Powders are mixed and placed into a gap between two parts.
  - Thermites or intermetallics
- The powders are ignited, and a self-sustained combustion propagates along the gap.
- This process welds the two parts together *via* the reaction product.

Present Work

- Apply combustion joining techniques to sintered regolith tiles.
- Powders are mixed and placed between the tiles.
- The mixture is ignited and combustion propagates along the tile gap.
- The reaction heat partially melts the edges of the tiles while forming a new material and welding the tiles together.

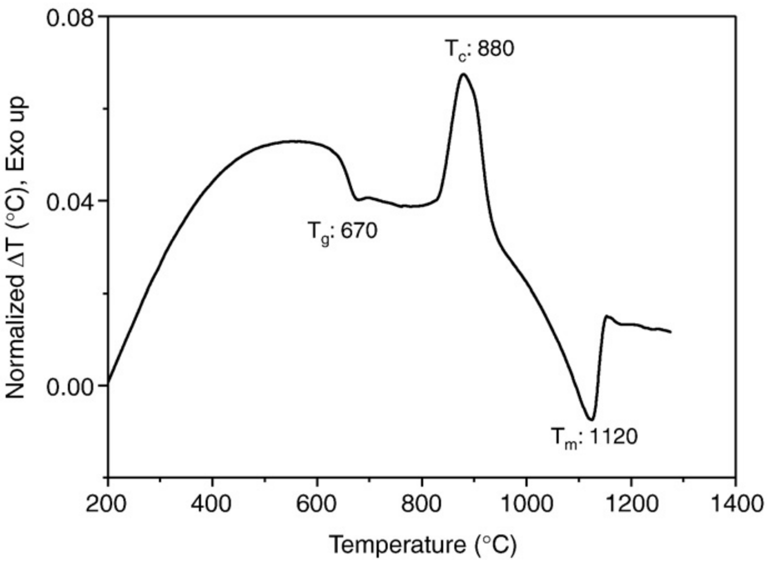
Objectives

- Verify the feasibility of combustion joining of regolith tiles.
- Determine the optimal distance between the tiles.
- Identify an effective mixture for combustion joining of regolith tiles.

Nickel-Aluminum System

- NI + Al → NiAl
  - Adiabatic flame temperature: 1639 °C
  - 58 % solid NiAl
  - 42 % liquid NiAl

- JSC-1A Lunar Regolith Simulant
  - Partially melts at 1120 °C

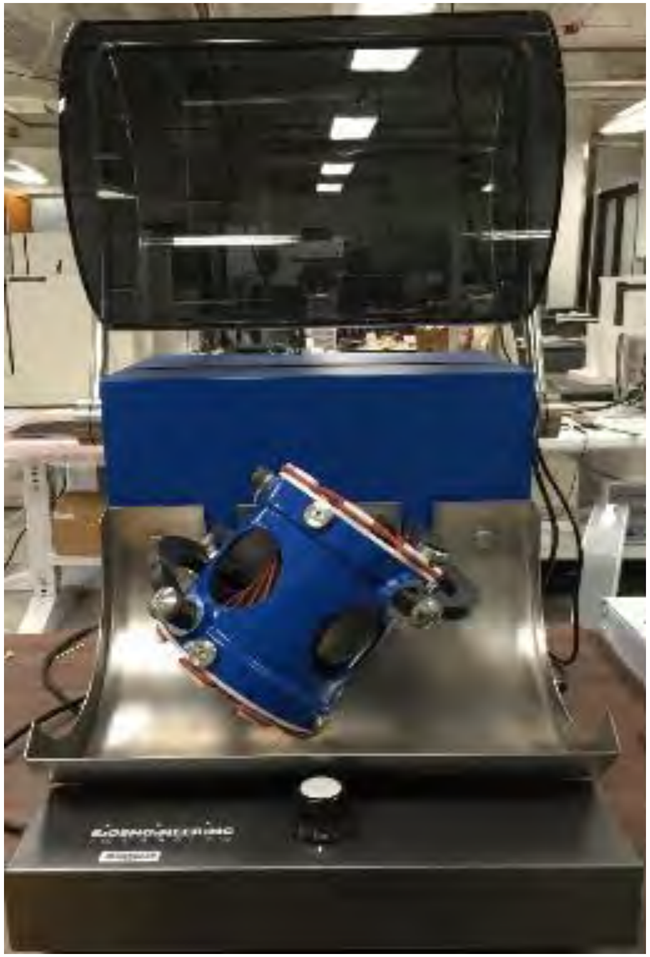


DTA curve for the JSC-1A lunar simulant

Ray et al., *Journal of Non-Crystalline Solids* 356 (2010) 2369–2374

Powders

- Nickel
  - 3-7 µm, 99.9% pure, Alfa Aesar
- Aluminum
  - 3.0-4.5 µm, 97.5% pure, Alfa Aesar
- Al:Ni 1:1 mole ratio
- Mixed in a 3D inversion kinematics mixer (Inversina 2L) for 60 min in a N_2 environment

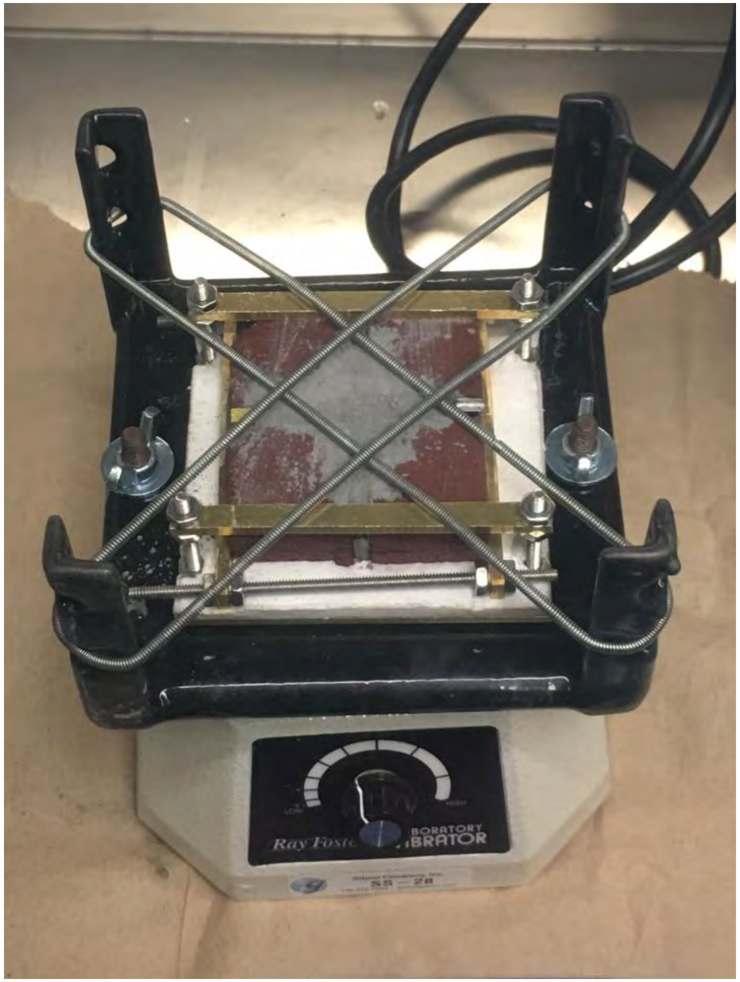


Tiles

- Tiles made at KSC are cut into 32-mm square segments using a saw.
- The tiles retain their original thicknesses:
  - 6.3 mm
  - 12.7 mm
  - 25.4 mm

Tile Holder

- Tiles loaded into holder and locked into place with a preset gap (2, 4, 6 mm).
- Powders are placed into the gaps and settled with a shaker (Gilson SS-28 Vibra-Pad).
- Additional powder is added as necessary.

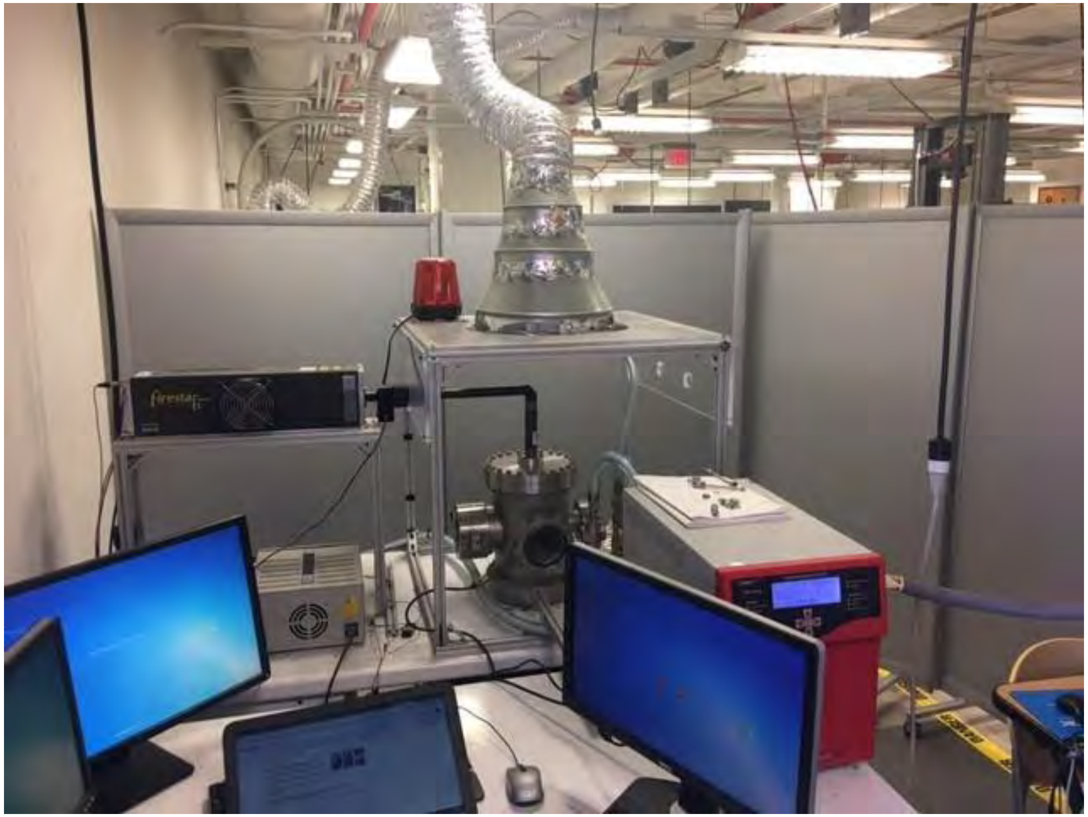


Laser Ignition Facility

- 11.35-L stainless steel vacuum chamber
- Two door ports, two window ports
- Top-mounted ZnSe window for laser ignition
- Pressure transducer
- Connected to compressed gas cylinders (Ar, CO_2) and vacuum pump

Laser

- 60-W CO_2 laser (Synrad Firestar ti-60)
- Controlled from LabView software

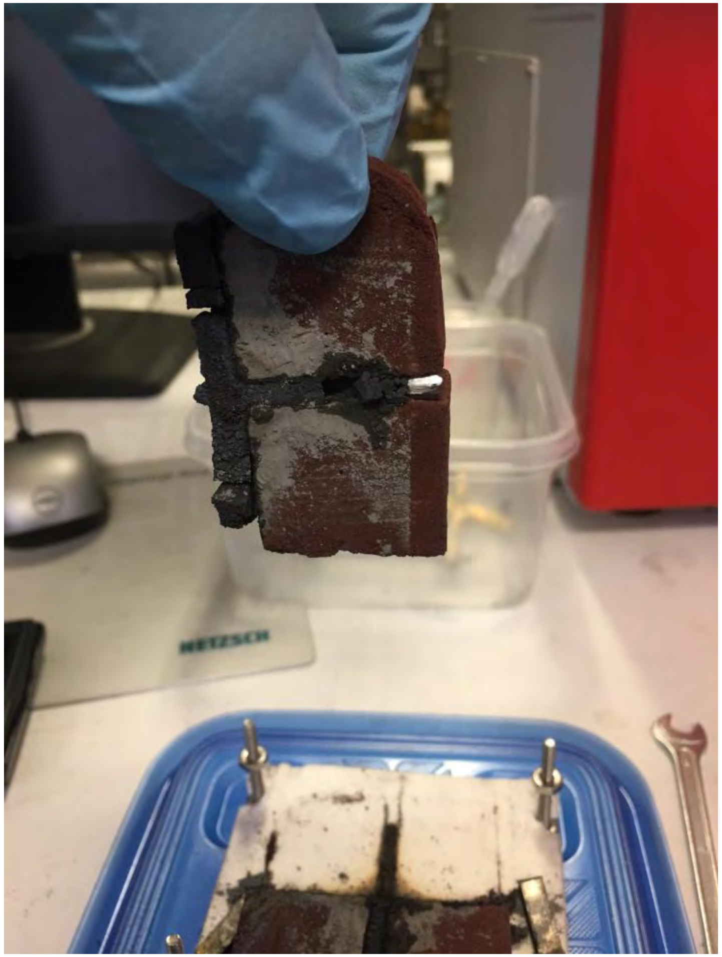


Experimental Procedure

- Tile holder is placed into chamber.
- CO_2 laser is aligned with the target using laser diode pointer.
- Chamber is evacuated and refilled with:
  - Argon for Moon
  - CO_2 for Mars
- Pressure is reduced to 10–100 mbar.
- Laser is pre-programmed for 10-s pulse.
- Photosensor turns off laser upon ignition.

Initial Results

Initial Results



Future Work

- Vary tile thicknesses and gaps.
- Measure strength of the welds.
- Determine thermal diffusivity and specific heat of tiles.
  - Differential scanning calorimetry
  - Laser flash analysis
- Develop a model for combustion propagation along the gap, which can be used to scale up the experimental results.

Thank you!