

Cold Welding in Suborbital Flight

Mya Morgan¹, Erik Eastman¹, Cameron Foland¹, Kate Shirley², Diana Baker¹, Andrew Zeller¹, Xander Lees¹, Andy Zollinger², Sydney Kennett¹, Yashvi Mehta¹, Angel Castaneda²
 ACC Space Grant, RRCC Space Grant, Dr. Lynne Albert², Jacob Wikowsky¹
 [1]Arapahoe Community College [2]Red Rocks Community College

Introduction

This experiment evaluates the probability of cold welding and the strength of resulting bonds between both similar and dissimilar metal pairs under three different contact conditions in the vacuum of space. It also investigates the use of lightweight, accessible insulation materials for protecting data collection components in low-orbit (LEO) rocket experiments.

Cold Welding

- A solid-state joining process in which two intimately joined metal surfaces form continuous bond without use of heat. [1]
- Surface contaminants such as oxides, gases, or oils must be fully removed before welding will occur. [1]
- When separation between surfaces becomes sufficiently small, distinction between the two materials diminishes. [1]

Research Question: *How do material properties and contact modalities affect formation and strength of cold-welded bonds in a spaceflight environment?*

Data Protection

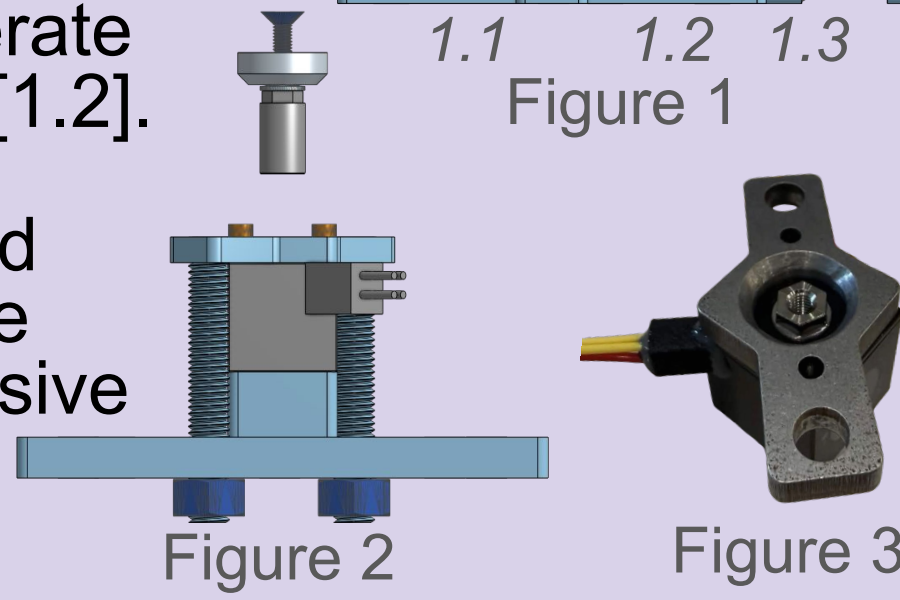
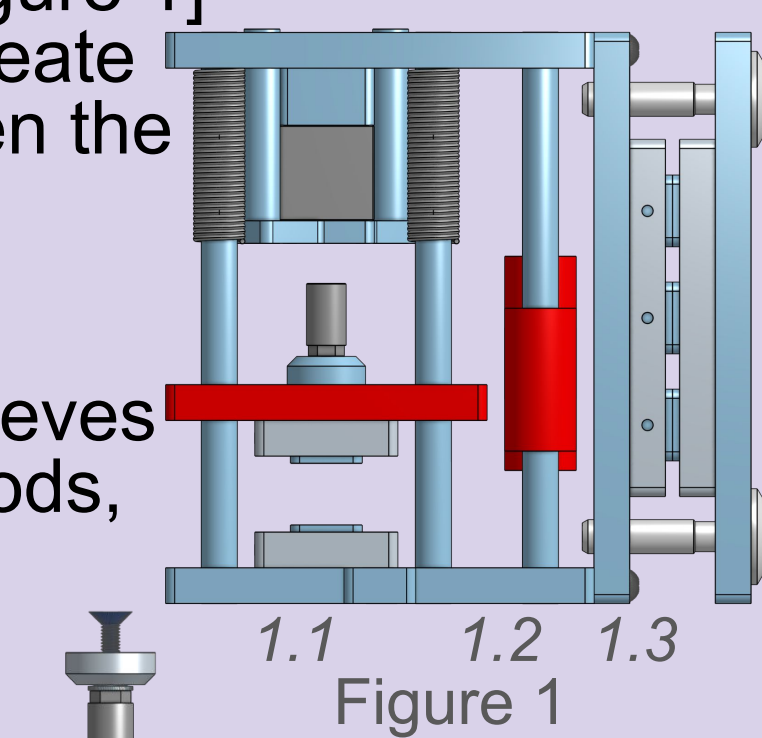
- Two test insulative materials
 - Aerogel-based padding, approximation of proprietary ablative material Starlite [2]
- Accessibility
 - Budget-friendly, ingredients locally sourced
 - Ease of replication for future spaceflight applications

Research Question: *Can low-cost, low-mass protection strategies ensure reliable data recovery in a suborbital spaceflight environment characterized by thermal stress and water exposure?*

Methodology

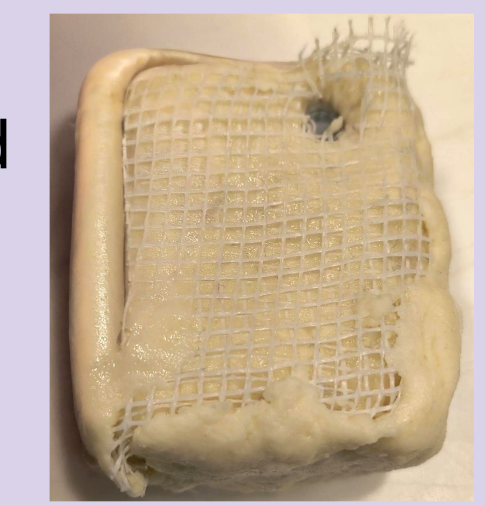
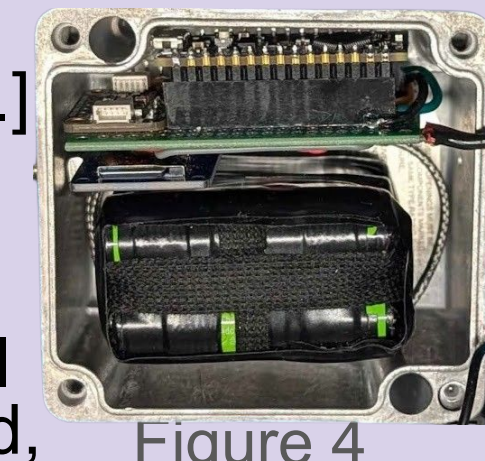
Cold Welding:

- 3 Contact Modalities [Figure 1]
 - **Impact** - designed to create an impact force between the metal samples [1.1].
 - Dcubed assembly [Figures 2,3]
 - **Friction** - cylindrical sleeves slide along stationary rods, using launch-induced vibrations to generate surface abrasion [1.2].
 - **Pressure** - paired samples are bolted together to provide constant compressive force. [1.3]



Data Protection:

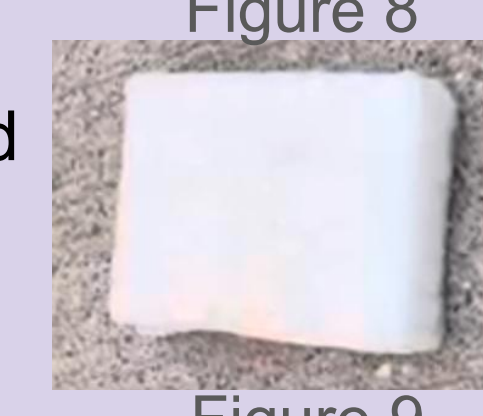
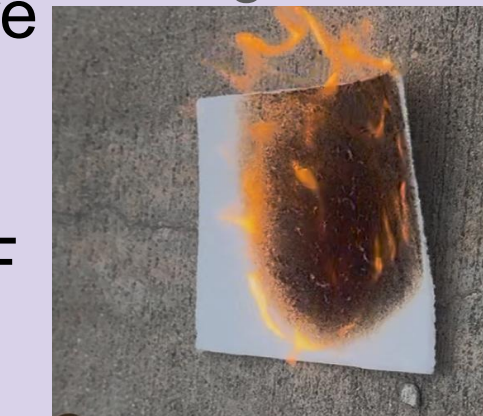
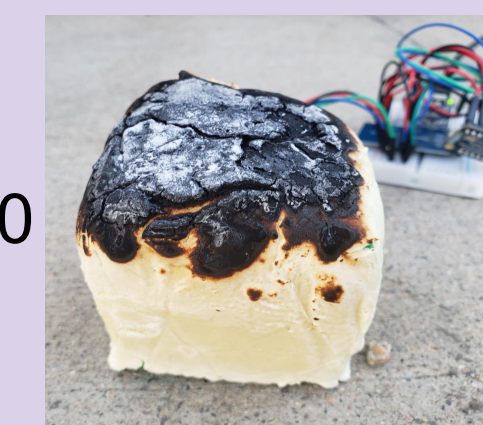
- An Arduino Nano Every is housed in a hammond box to ensure collection of internal and external sensor data [Figure 4.]
- External temperature data is collected for validation of cold welding experiment.
- A gyroscope/altimeter will track all general movement of the payload, allowing for improved post-flight data.
- Aerogel insulation padding is folded over the left cube and sewn on the four corners with a denim needle and kevlar thread.
- Starlite, a home-developed blend consisting of borax, powdered sugar, cornstarch, baking soda, all-purpose flour, and water is layered over the right cube in two stages, sandwiching a sheet of fiberglass meshing in between. [Figure 5]
- A second Arduino is housed in 1 of 2 test cubes to collect internal temperature sensor data for comparison of the insulative materials against reentry heat.



Results

Data Protection:

- Starlite Iterative Testing
 - Formula v1.0 withstood temperatures of over 1000 F, but its durability was inadequate [Figure 6].
 - Formula v2.0 withstood similar temperature and vibration test with minimal damage [Figure 7].
- Aerogel Iterative Testing
 - Aerogel v1.0 performed poorly in heat tests [Figure 8].
 - Aerogel v2.0 withstood temperatures over 1000 F [Figure 9].
- Data will be collected for better understanding of the rocket flight atmosphere and the capabilities of Aerogel and Starlite.



Cold Welding- Expected:

- **Gold/Gold-** positive control
 - All contact forms show evidence of cold welding.
- **Aluminum/Aluminum-** more limited
 - Most likely to bond in friction test
- **Gold/Aluminum-** unpredictable
 - Little existing literature
 - Most likely to bond in friction test
- Cold welding will be evaluated using a combination of microscopic surface analysis and quantitative measurements with a tensometer.

Discussion

Several limitations of this study should be considered given the constraints of a suborbital platform and the pre-flight nature of the experiment.

- Friction mechanism relies on passive motion induced by launch vibration/acceleration.
 - No precise control over magnitude and timing.
 - Orientation of rod-sleeve assemblies may cause sleeves to be driven toward one end of rods during ascent.
 - Most frictional interaction is expected to occur during ascent, prior to exposure to vacuum conditions.
 - A motorized friction mechanism would allow for more precise timing and surface interaction, representing a preferred design for future iterations.
- Pressure and impact tests rely on theoretical force values.
 - Variations and constraints in manufacturing may result in non-uniform contact pressures.
- Thickness and uniformity of electroplated gold layer is not precisely quantified and may influence bonding behavior.
- Experiment is based on a pre-flight design, all results remain hypothetical until validated through post-flight analysis.

Future post-flight analysis will provide opportunity to validate hypotheses and refine both experimental methods and design approaches for future spaceflight missions.

References

- [1] F. P. Bowden, A. J. W. Moore, and D. Tabor, "The Ploughing and Adhesion of Sliding Metals," *Journal of Applied Physics*, vol. 14, no. 2, pp. 80–91, Feb. 1943, doi: <https://doi.org/10.1063/1.1714954>
- [2] O. Fabián, "Wish upon a Starlite," *MRS Bulletin*, vol. 44, no. 4, pp. 316–316, Apr. 2019, doi: <https://doi.org/10.1557/mrs.2019.92>