Spreading Behavior of Powder-Fiber Composite for Refractory Panels

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Abstract: Morgan Thermal Ceramics creates flexible ceramic insulation panels for specialty applications. The ceramic powder-fiber mixture used within these panels needs to be spread evenly to achieve a consistent and quality end-product. Spreading the powder manually has proven to be difficult, requiring highly skilled, trained professionals to accomplish. The goal of this project is to investigate methods that can spread the powder more efficiently.

This work is sponsored by Morgan Thermal Ceramics, Elkhart, IN

Morgan

Project Background

The ceramic mixture is a blend of powders and fibers that come together to form a highly porous and cohesive network, allowing for the structure to be lightweight, flexible, and incredibly heat resistant.

Project Objectives

1. Gain an understanding of the powder-fiber mixture's geometry.
2. Investigate the flow behavior of the mixture.
3. Analyze the compaction behavior of the mixture.
4. Develop a prototype spreading solution based on these findings.

Methods

Properties

- Geometrical Properties
  - Canty SolidSizer
  - RO-TAP Sieve Shaker
- Flow-Based Properties
  - GranuDrum powder cohesion analysis
  - FT4 powder rheometer
  - Schulze Ring Shear Tester

Processing

- Spreading behavior trials with RO-TAP Sieve Shaker
- GranuPack tapped bulk density analysis
- MTS C43 50kN loadframe compaction testing

Performance

- Thermal conductivity verification with ASTM C1114-06

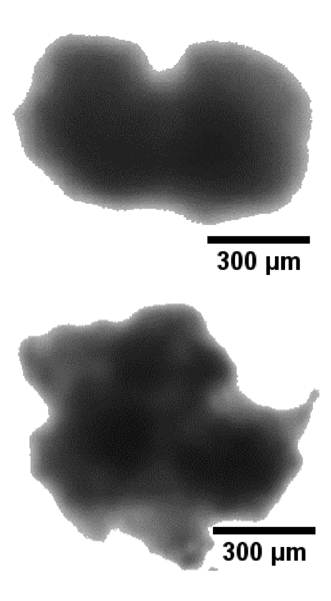
Prototyping

- Custom-built prototype solution using vibration

Properties

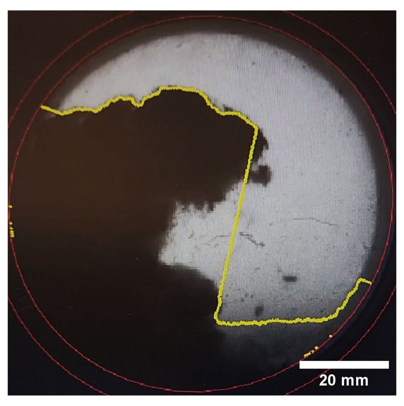
Geometry

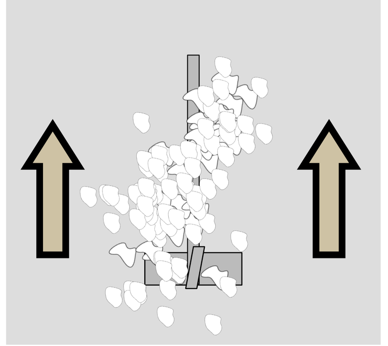
The mixture was put through a sieve shaker with holes of 300 um. Upon application of vibrations the fine particles segregated themselves from the larger fibers almost immediately, falling through the screen. Upon analysis, it was determined that the mean particle size of the material in the bottom of the sieve was over three times larger than the 300um opening. This indicated significant clustering of the powder occurred during vibration.



Flow

The mixture is extremely cohesive and exceeded the cohesivity limit for many tests' quantitative analysis. Qualitative information was still able to be obtained. To the right is an image from the GranuDrum test that shows the powder forming structures that can extend out to the side, unsupported.

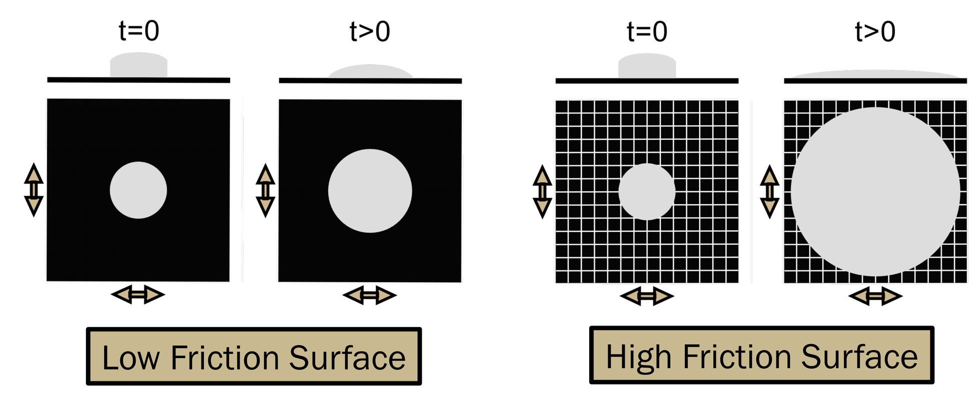




A phenomena visually similar to the Weissenburg effect was observed when analyzing the mixture in the FT4 rheometer. The mixture climbed up the propeller in a manner reminiscent of a sheared viscoelastic fluid. This is hypothesized to highlight two aspects of the blend: an "elastic" network of fibers and "viscous" powder component.

Processing

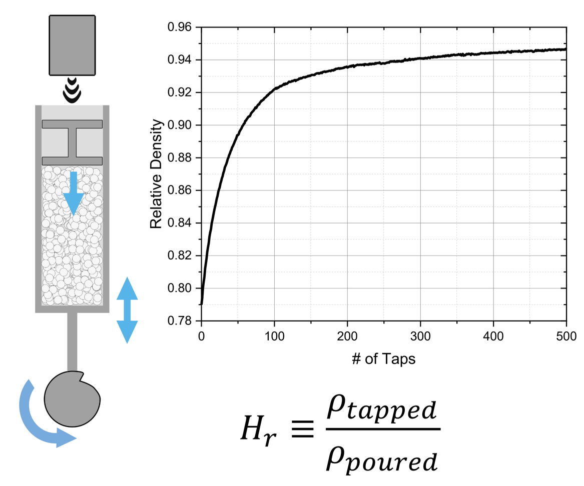
Vibration Induced Spreading



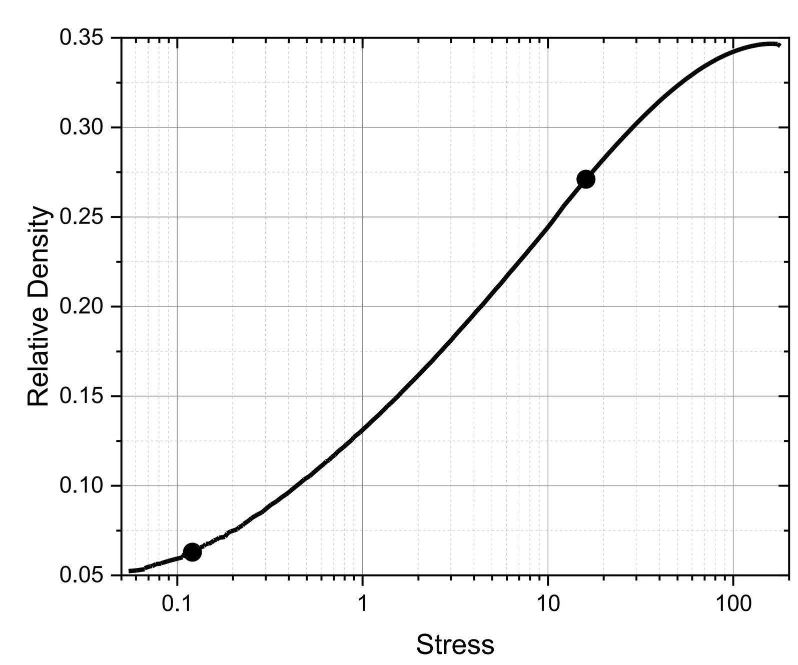
- On a low friction, vibrating surface, a pile of the mixture will flatten out to some degree and circulate but does not effectively spread.
- On a high friction surface such as the fabric used by Morgan Thermal Ceramics, vibration induces fast and effective spreading, as well as some circulation.
- Although the mixture is cohesive, consistent spreading can be achieved with the combination of vibration and wall friction.

Compaction

A tapped bulk density experiment resulted in a Hausner Ratio (H_r) that indicates a cohesive powder. Powders such as these tend to create a low-density, three-dimensional structure when poured freely.



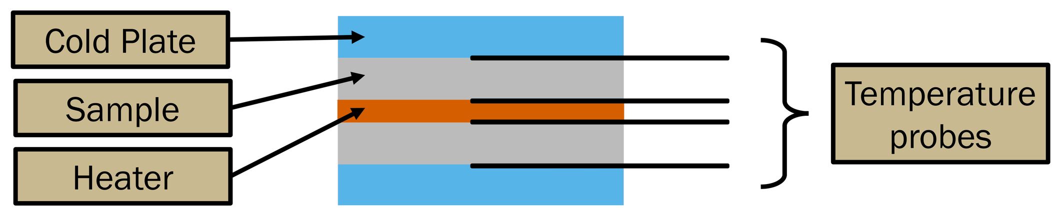
$$H_r \equiv \frac{\rho_{tapped}}{\rho_{poured}}$$



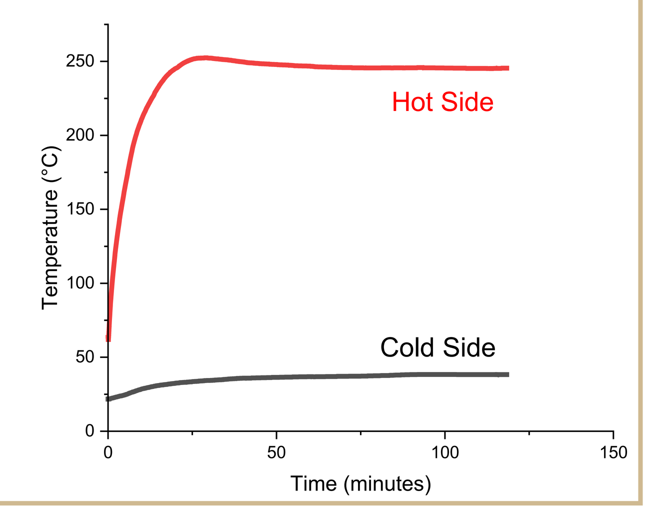
The powder-fiber blend exhibits a compaction curve like that of granules. The 2 points correspond to a theoretical yield point, and the maximum in the rate of densification of the mixture. Past the yield point, the composite network will deform into a solid structure.

Performance

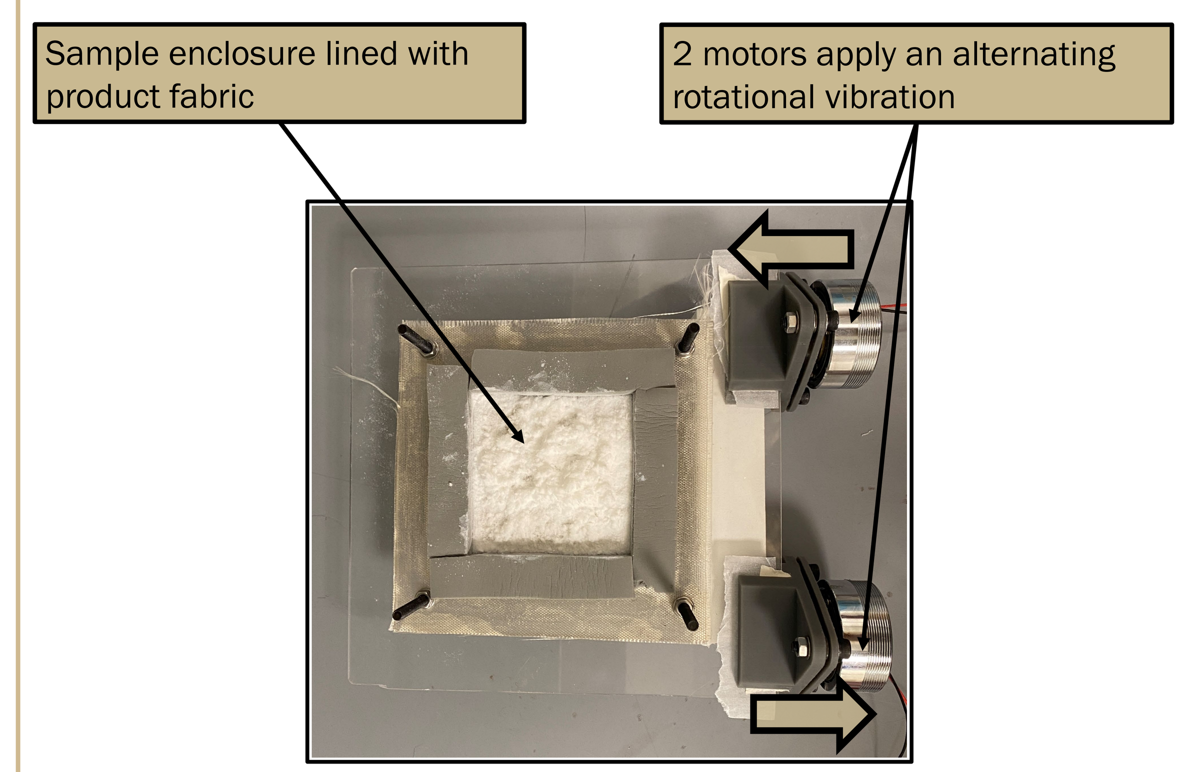
Thermal



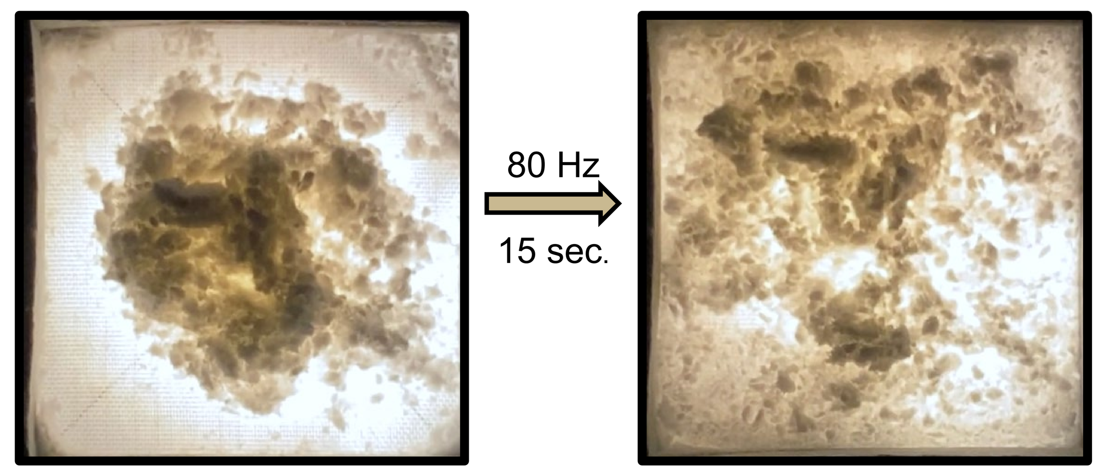
ASTM C1114 – 06 was utilized to design and implement a thermal testing rig. This was able to demonstrate thermal performance of the product that aligns with manufacturer specifications. Such testing procedures can also be used to evaluate panels made with vibrational spreading.



Prototyping



Can be lit from below to monitor and quantify mixture distribution



Early testing shows modest success. The spreading seems to be limited by the power of the motors we are using, one of which broke due to extreme forces on one of its components. Further prototypes and implementation should use motors that can deliver more powerful rotational vibration.

Recommendations & Future Work

Recommendations:

- Implement a rotational vibration agitator to enhance efficiency and consistency of mixture spreading.
- A combination of manual spreading to get the material spread out and vibration to fill in gaps and corners may be beneficial.

Future Work:

- Experiment with different frequencies and amplitudes of vibration to optimize the spreading process.
- Investigate the effect of closing the powder in with another layer of fabric on the top.
- Analyze the effect of even spreading by vibration on the final thermal properties of the product.

Acknowledgements

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