Virtual Research Presentation Conference

AM of High Permeability Magnetic Shielding Alloy (HIPERMASH)

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Program: Topic
Assigned Presentation # R20124

Jet Propulsion Laboratory
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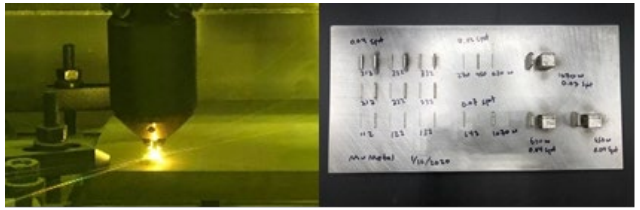
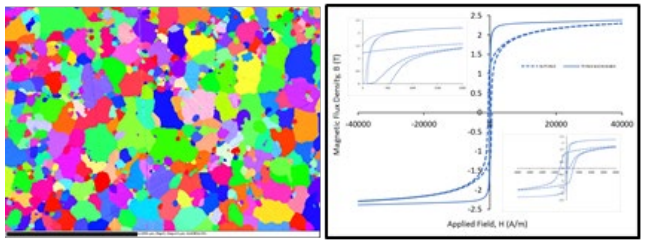
Tutorial Introduction

- High permeability magnetic materials (mumetal) used for magnetic shielding in JPL spacecraft can be challenging to fabricate and iteratively design and can be time consuming and costly

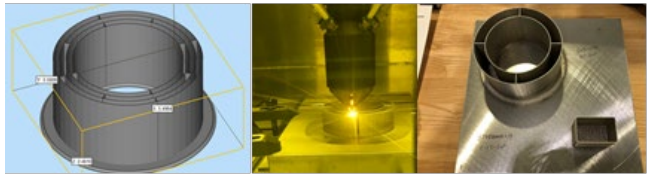
- We propose to develop a metal additive manufacturing process and post process for a high permeability mumetal alloy (Fe-80Ni-5Mo) which will offer several benefits compared to the current state of the art method of manufacture:
  - Reduced schedule via rapid prototyping and near net fabrication
  - Geometric freedom for more efficient shield designs and integration



Print parameter and post process development

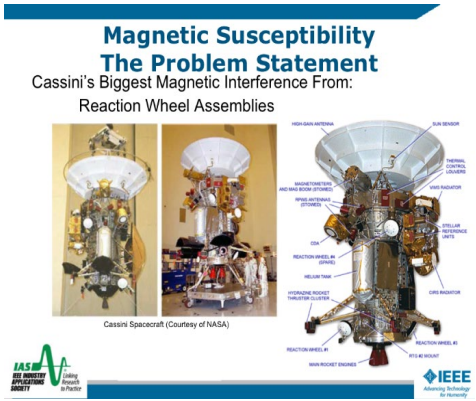


Material / magnetic properties

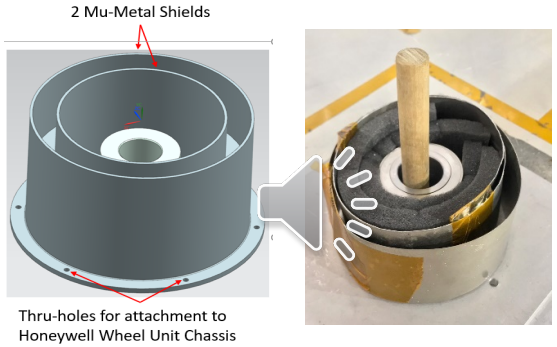


Rapid Build / test prototype

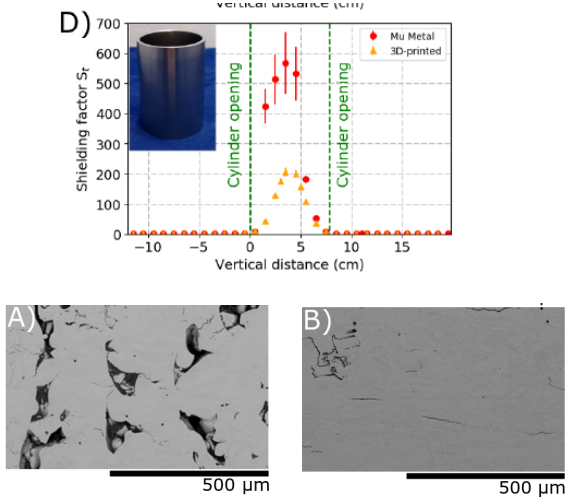
Problem Description



High permeability magnetic materials are used for magnetic shielding in JPL spacecraft



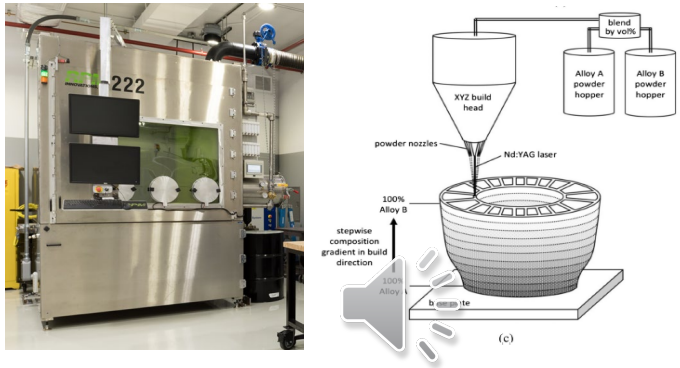
Limitations is material availability, traditional fabrications and current methods of prototyping can result in significant schedule and project risk



Recent developments [1-2] in additive manufacturing of "mumetal" shows promise but further development and improvement is required!

[1]Vovrosh et al. "Additive manufacturing of magnetic shielding and ultra-high vacuum flange for cold atom sensors", Scientific Reports, 8 (1), 2018; https://doi.org/10.1038/s41598-018-20352-x
[2] Mikler ety al. "Laser additive manufacturing of magnetic materials", JOM, 69 (1), 2017

Methodology



DED facility of at JPL and process schematic

- The blown powder directed energy deposition (DED) process will be used for feasibility assessment for printing mumetal and developing a deep understanding of process-structure-property relationships in high permeability mumetal
- The multi-material capability of with DED will allow for development of future concepts where alloy composition may be varied to impart different properties in different locations to optimize function (e.g. mumetal/high strength steel, high permeability/high saturation alloys)
- Lessons learned may be translated to development of parameters for laser powder fusion AM to take advantage of additional geometric freedom and fine feature capability

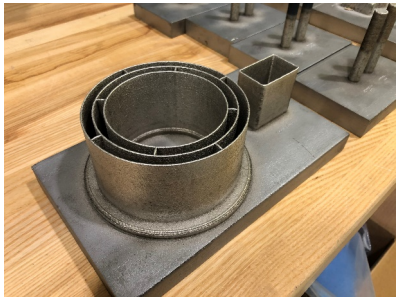
[1] A. Reichardt *et al.*, "Advances in additive manufacturing of metal-based functionally graded materials," *Int. Mater. Rev.*, vol. 0, no. 0, pp. 1–29, 2020, doi: 10.1080/09506608.2019.1709354.

Results

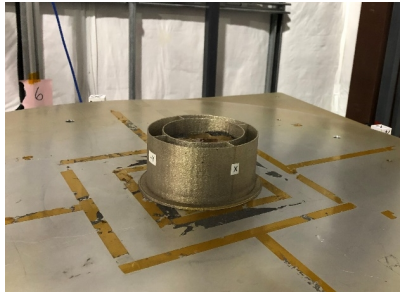
Measured magnetic properties of printed test coupons with a variety of post print thermal treatments

Established process for chemical surface finish enhancement after printing (vendor)

Developed printing parameters with >99% density as-printed



Printed several shield prototypes based on EUROPA Clipper RWA shield concepts



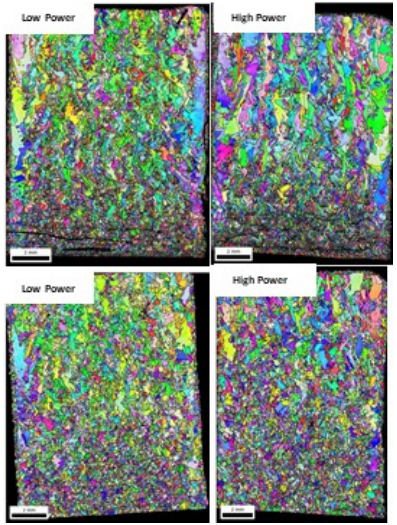
Completed shield attenuation test in JPL EMC lab. Measured 28 db attenuation with printed and annealed prototype

Results Cont'd

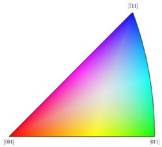
Build Parameter	Thermal Treatment	Max Relative Permeability	B Max Saturation (G)	Hc (Oe)
Low power 1	As-print	6203	7024	0.259
	Stress relief + anneal	51596	7387	0.052
	Anneal	45225	7272	0.053
	HIP + Anneal	49783	7380	0.054
	HIP	40185	7484	0.070
Low power 2	Anneal	51948	7387	0.050
High power	Anneal	59198	7289	0.043
Wrought Alloy (ASTM A753 Alloy 4)	Anneal	200000	-	0.025

As-print

Post anneal



EBSD maps of both as-printed and annealed mumetal printed with high and low power parameter sets



- With post process annealing, max permeability up to 59,000 with coercivity as low as 0.043 was observed
- Achieved lowest coercivity for mumetal produced by AM based on survey of recent published literature. No published values for max permeability of AM produced mumetal are available for comparison. Permeability may be improved with further print and post process anneal development
- Columnar grains are observed in as-print condition with some texture in <101> direction. Post anneal appear to less columnar in morphology while some <101> direction texture remains (although less so than in the as-print condition)
- Appears to be some correlation between build parameters, microstructure and annealed magnetic properties. To be explored in future work towards improvement of magnetic properties

References