Laser Powder Bed Fusion of Rare Earth Permanent Magnets

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Permanent Magnets and their Applications

- Types of Permanent Magnets
- Hysteresis Loop
- MS scans
- Relative Magnet Sizes
- [BH]_{max} and volume of the magnetic material are reciprocally related

Rare earth and Electric vehicles

- Permanent magnet synchronous motor
- Over 90% of electric vehicles manufactured to date utilize traction motors equipped with neodymium-iron-boron ("NdFeB") magnets.
- Adamas intelligence forecasts that global annual electric vehicle sales will increase from 4.6 million units last year to 14 million units in 2025.

Limitations of Conventional Processing

- Complex shapes involve significant cutting and machining resulting in materials waste of about 30%.
- China’s dominance in rare earth elements has significant influence over supply and pricing which increases the production cost.
- Longer lead times

Approach

- Alloy Design
- Fabrication
- Characterization

Alloy Design by Melt Spinning

- Alloying additions such as Ti & C would mitigate these effects by refining the microstructure, and increase the processing window.
- A bimodal microstructure, a fine microstructure on the wheel contact side transitioning into the dendritic structure on the free side, was observed.

Materials and Method

- The crushed powder had a non-spherical morphology. Powder was hand-spread in modified powder bed build plates.
- Melt spun ribbons are manually crushed with alumina mortar and pestle with size selection via sieves (~75 µm).
- Samples were printed using a Lumex Avance - 25 metal 3D printer under ultra-high purity Argon to prevent oxidation.

Fabrication and Characterization

- Circular scan performed with Nikon XT H 225 ST, an industrial X-ray computed tomography (XCT) system, revealed a generally low porosity except for some surface cracks.
- Shallow melt pool is desired for optimal magnetic properties.

Conclusions

- Alloy modifications with Ti and C led to a homogenous microstructure with smaller grain sizes.
- Parts with high density were fabricated.
- Further parameter optimization is underway to improve the magnetic properties.
- Various other compositions and alloying additions are also tested.

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