MSE-7: Additive Manufacturing of Soft Magnetic Composites

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Problem Statement:

Can Additive Manufacturing (AM) methods be used to create functional Soft Magnetic Composites (SMCs)? How will AM methods affect the insulating coating on the iron particles, and will a "next generation" coating outperform current SMCs?

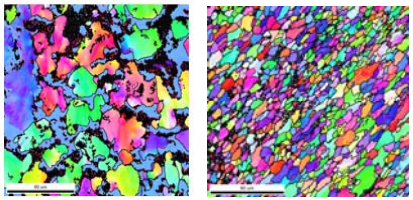
- SMCs (a magnetic core with an insulating coating) are a possible alternative to traditional laminated Si-steels, but AM is needed in order for SMCs to be produced in complex shapes.
- AM powder bed fusion methods used were DMLS and Binder Jet printing.

Approach:

- Electron dispersive x-ray spectroscopy (EDS) and electron backscatter diffraction (EBSD) techniques were used to characterize coating integrity and grain orientation of post-processed rectangular parts.
- Toroids were used to evaluate magnetic properties and mechanical strength.

Results:

Binder Jet Sample DMLS Sample



Element	*Weight % 600°F*	*Weight % 800°F*	*Weight % 1000°F*	*Weight % 1200°F*	*Weight % 1400°F*
O	5.63	4.93	10.76	11.92	15.03
Mg	-	-	0.13	-	-
Si	-	0.1	0.13	0.14	0.13
P	**0.13**	**0.17**	**0.04**	**0.04**	**0.01**
S	0.11	0.12	0.13	0.14	-
Ca	-	-	0.1	1.08	-
Cr	0.19	0.48	0.91	0.78	0.45
Mn	0.87	0.68	0.87	0.58	0.65
Fe	**93.08**	**93.53**	**85.99**	**85.05**	**83.61**
Ni	-	-	0.75	-	-
Br	-	-	0.19	-	-
Mo	-	-	-	0.27	0.13
Total	100	100	100	100	100

- SEM/EBSD: Elongated grain structure due to thermal diffusion in the DMLS sample, and high porosity in the binder jet sample.
- EDS: Phosphorus level dropped between 800 °F and 1,000 °F, as well as diffusion.

Discussion & Conclusions:

- Binder jet printing preserved the particle coating better than DMLS, but DMLS resulted in a higher build density without the need for post-processing.
- Phosphorus coating in a known SMC sample diffused into the iron particles and was completely burned off at sintering temperatures above 800 °F.
- A NiCuZn ferrite coating exhibited a gradual decrease between 600 °F and 1,400 °F but agglomerated during mixing.
- Future work: magnetic testing *via* hysteresis loop and mechanical testing to measure yield strength.

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