Additive Manufacturing of Silicon Steel Ferromagnetic Cores for High-Frequency Loss Reduction in Electrical Machines

Ahmed Selema[a,c,d], Thomas Kairet[b], Setareh Gorji Ghalamestani[b], Peter Sergeant[a,c]

[a] *Department of Electromechanical, Systems, and Metal Engineering, Ghent University, 9000 Ghent, Belgium.*
[b] *Sirris, Rue Bois Saint-Jean 12, 4102 Seraing, Belgium.*
[c] *FlandersMake@UGent, Core Lab MIRO, 3001 Leuven, Belgium.*
[d] *Innovation and Technology Centre, USP3D NV, Ghent Belgium.*

Additive manufacturing (AM) enables the fabrication of complex 3D ferromagnetic cores using silicon steel, offering greater design flexibility compared to conventional laminated Fe-Si. The study evaluates L-PBF method with Fe-6.5 wt%Si, showing comparable magnetic properties with reduced eddy current losses, making them suitable for high-performance electrical machines.

Keywords: additive manufacturing, silicon steel, electrical machines, Hilbert structure

The increasing demand for sustainable and efficient electromobility has driven the need for advanced manufacturing techniques in electrified powertrains. Conventional electrical machines rely on 2D laminated electrical steel, limiting design flexibility and performance optimization. Additive manufacturing (AM) presents a transformative approach by enabling the fabrication of complex 3D structures with optimized material properties [1,2]. This study explores the AM-based production of ferromagnetic cores using silicon steel (Fe-6.5 wt%Si) powder and investigates their magnetic performance in comparison to conventional Fe-Si laminations. Using AM technology and L-PBF method, test samples are fabricate, and their magnetic properties, including core losses and eddy current suppression, are systematically evaluated. The results demonstrate that 3D-printed silicon steel cores achieve comparable magnetic properties while providing enhanced geometric flexibility. Moreover, advanced shape-profiled cores with a Hilbert shape (see Figure 1) are designed and printed to further assess their high-frequency performance. Findings indicate that AM-enabled cores effectively mitigate eddy current losses, making them promising candidates for next-generation high-performance electrical machines. The ability to tailor core geometries at a microscale level opens new possibilities for optimizing electromagnetic performance, weight reduction, and material efficiency. This study underscores the potential of AM in revolutionizing electrical machine design and manufacturing for future energy-efficient applications.

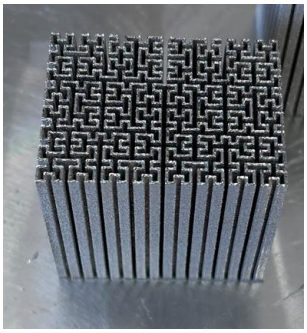

Figure 1: 4rth order Hibert structure printed with L-PBF method, Fe-6.5 wt%Si, 0.32mm wall thickness

References

[1] Stornelli, G., Faba, A., Di Schino, A., Folgarait, P., Ridolfi, M. R., Cardelli, E., & Montanari, R. (2021). Properties of additively manufactured electric steel powder cores with increased si content. *Materials*, *14*(6), 1489-. https://doi.org/10.3390/ma14061489

[2] Selema, A., Beretta, M., Ibrahim, M. N., Verwimp, J., Rombouts, M., Vleugels, J., Kestens, L. A., & Sergeant, P. (2023). Material Engineering of 3D-Printed Silicon Steel Alloys for the Next Generation of Electrical Machines and Sustainable Electromobility.