Correlation between the mesostructure and magnetic properties of FeCoV processed by L-PBF: Reducing eddy current losses with air gaps

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Bulk Fe49Co2V processed by Laser Powder Bed Fusion (L-PBF) shows high eddy current losses, 15 times higher, compared to conventional stack of laminations [1]. The flexibility of the L-PBF process enables the production of new designs allowing the reduction of these losses. Positioning thin air gaps to make harder the current circulation while keeping a constant section for the magnetic flux can reduce by a factor of ten the eddy current losses [1]. For this purpose, a geometry based on the Peano space filling curve was chosen to build Fe49Co2V torus by L-PBF. This structure allowing to optimize the filling rate of ferromagnetic material is composed of 350 µm thick walls separated by 250 µm thick air gaps. After a heat treatment to optimize the microstructure, magnetic losses are compared to the ones of bulk torus and laminated sheets torus to estimate the benefit of this new architecture.

Keywords: Additive manufacturing; Laser Powder Bed Fusion; FeCoV; Soft Magnetic Materials; Air Gaps; Eddy Current Losses

1. Introduction

Rotors and stators in electrical machines are traditionally manufactured by stacking insulated ferromagnetic sheets to limit power losses. However, the conventional lamination imposes design constraints that limit the emergence of optimal motor topologies. Additive manufacturing, particularly the Laser Powder Bed Fusion (L-PBF) process, offers a promising alternative by enabling greater design freedom. Nevertheless, bulk components produced via L-PBF exhibit high magnetic losses, which increase with frequency [2]. For this reason, it is crucial to design printed parts including a 2D or 3D internal network of non-conductive phase.

Magnetic losses, especially eddy current losses, play a critical role in determining the efficiency of ferromagnetic materials. Optimizing the geometry of thin-walled structures fabricated via L-PBF can significantly contribute to minimizing these losses [1,2]. Although the insertion of insulating layers helps reduce eddy currents, optimizing the microstructure remains crucial for further improving magnetic performance [3].

2. Results and discussion

This study investigates an innovative strategy to mitigate these losses by integrating air gaps directly into the L-PBF-manufactured structures. The investigated alloy is Fe-49Co-2V (wt.%), which allows to enhance the power density of electric motors due to its large saturation magnetization (J_{sat} = 2.4 T). By fine-tuning the thickness and distribution of these walls, it is possible to control eddy currents losses. There will be compared to those in laminated sheet components.

This approach brings L-PBF-processed materials closer to conventional laminated solutions in terms of efficiency while preserving the design flexibility offered by additive manufacturing. In this work, different heat treatments have been performed on architectural torus (Figure 1.a) to optimize their magnetic properties and, at the same time, investigate the relationship between the alloy's microstructure and its magnetic properties. Magneto-electrical properties, including electrical resistivity, magnetic permeability, and magnetic losses have been measured. Microstructures are analysed by Scanning Electron Microscopy (SEM), Electron Backscatter Diffraction (EBSD) (Figure 1.b), and Transmission Electron Microscopy (TEM). These investigations allow to correlate the evolution of the mesostructure and microstructure (grain structure, crystallographic texture and phases) with the overall magnetic performances, providing valuable insights into the processing-structure-property relationships of L-PBF-manufactured ferromagnetic

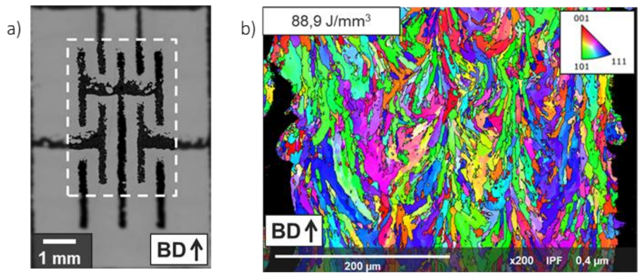

Figure 1: Metallography of a Peano toroid section (a); and IPF map of a characteristic wall in Fe-49Co-2V (350 µm thick).

References

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