Comparison of soft magnetic properties of iron-silicon based additively manufactured electrical steels.

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Additive manufacturing (AM) of soft magnetic materials (SMMs) opens up new possibilities for designing complex-shaped components with tailored magnetic properties. In this study, toroidal samples were fabricated by selective laser melting (SLM) from three different metal powders: Fe-6.5wt%Si, FeSiB and FeSiAl. The printed samples were examined using optical and scanning electron microscopy to characterise their microstructure and to assess the effect of the printing process on material integrity.

Magnetic characterisation included the measurement of complex magnetic permeability spectra and DC hysteresis loops to assess the soft magnetic performance of each composition. The Fe-6.5wt%Si composition was determined to be the most suitable for additive manufacturing in terms of printability, despite its extremely high silicon content, which renders the material highly brittle. In an attempt to reduce the thermal gradient during processing, with the objective of mitigating the formation of internal stresses responsible for macroscopic cracking, this composition was also printed on a preheated build platform at 300 °C. However, this approach did not lead to improved structural integrity; in fact, the resulting samples exhibited increased brittleness, indicating that reducing the thermal gradient was not an effective strategy for minimizing internal structural defects.

Keywords: selective laser melting; soft magnetic materials; iron-silicon; additive manufacturing

1. Introduction

The additive processing of iron-silicon-based electrical steels is a popular and emerging direction in the field of additive manufacturing [1,2]. Due to the specific characteristics of the manufacturing technology, several challenges have arisen during the printing of these materials [3].

2. Results and discussion

The internal stresses generated during the cyclic laser melting of high-silicon steels are responsible for the formation of macroscopic structural defects in the printed parts. As a result, the reproducibility of the magnetic properties of electromagnetic components produced this way is limited. These structural defects may be caused by the high thermal gradient and the formation of ordered phases and precipitates during repeated melting cycles.

Figure 1: Optical microscopy image of Fe-6.5wt%Si (left) and FeSiB (right).

In my work, I attempted to reduce the thermal gradient by printing Fe-6.5wt%Si samples on a home-built, elevated-temperature build platform. Additionally, I explored microalloying the brittle Fe-Si alloy with boron and compared the results with the well-known Sendust (Fe-Si-Al) alloy. To mitigate printing defects and achieve reproducible magnetic properties, I developed a customized set of printing parameters.

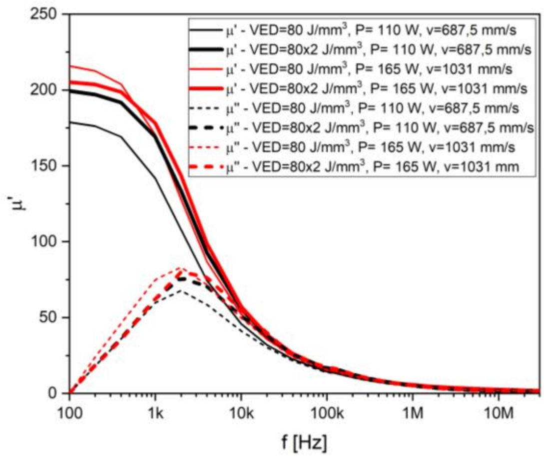

Figure 2: Complex permeability spectra of Fe-6.5wt%Si with different printing parameters.

References

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