The importance of secondary properties in magnetic filaments for additive manufacturing

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Additive manufacturing, particularly fused deposition modelling (FDM), enhances the ability to create complex designs, transforming manufacturing across various sectors, including automotive and bioengineering. The introduction of magnetic filaments expands the functionality of FDM to include applications in sensing, actuation, and magnetocaloric devices. The consistency of magnetic properties in 3D-printed magnetic parts is significantly influenced by factors such as particle agglomeration and the quality of filaments, including those commercially available options. Our recently developed methodology made significant advances, obtaining precise control over homogeneous lab-scale soft magnetic filaments as well as magnetocaloric $La(Fe,Si)_{13}H$ composites, which maintain essential properties necessary for solid-state magnetic refrigeration. In this work, soft magnetic behaviour is optimized by using amorphous Finemet-type alloy powders, with the notable discovery of enhanced magnetic softness after filament manufacturing and printing. We broaden the range of material options by applying the methodology to a wider selection of polymer bases, analyzing printability and mechanical properties to enhance applicability.

Keywords: soft magnetic properties; additive manufacturing; fused deposition modelling; 3D printing; mechanical studies.

1. Introduction

Additive manufacturing, notably fused deposition modelling (FDM), has evolved beyond basic fabrication, enabling complex designs. Its accessibility democratizes manufacturing, impacting the automotive and bio- engineering sectors. Magnetic filaments further expand the functionality of FDM, enabling sensing, actuation, and magnetocaloric devices.

While achieving consistent magnetic properties in 3D printing of magnetic parts is a challenge due to particle agglomeration and inhomogeneities, recent advances demonstrate precise control over homogeneous soft magnetic filaments [1]. A customized methodology enables fabrication with 5-60 wt.% magnetic particle loading, crucial for complex magnetic circuits. This methodology was extended to magnetocaloric filaments, specifically $La(Fe,Si)_{13}H$ composites, retaining pristine first-order thermomagnetic behaviour and hydrogenation, a significant advancement for solid-state magnetic refrigeration [2].

However, the limited selection of polymer matrices restricts applications. This work addresses this by extending the controlled methodology to diverse polymer bases, including PLA (polylactic acid), PETG (polyethylene terephthalate glycolmodified), and TPU (thermoplastic polyurethane). This novel approach broadens material options, showing that lower EOS Maraging powder percentages are needed for continuous filaments with PLA and TPU. We also extended to working with Finemet-type magnetic filaments, further enhancing magnetic filaments for FDM applications.

2. Results and discussion

A good homogeneity and distribution of powder particles embedded in the polymer matrices were studied with the aid of Scanning Electron Microscopy. As an example, the backscattered electron micrograph of PETG+EOS maraging steel is shown in Figure 1 (a). From the magnetic point of view, a good correlation between nominal filler concentration and experimental magnetization values demonstrates the reproducibility of the procedure, even for different types of polymers (Figure 1 (b)). It was determined that the use of PETG provided the most homogenous and best extruded composite filament to be used in 3D printing.

To improve magnetic softness, a filament with gas-atomized Finemet-type alloy powders as fillers and PETG as matrix was fabricated. Due to stress relaxation during the filament fabrication process, the coercivity of the filament is lower than that of the starting alloy powders, enhancing applicability [3].

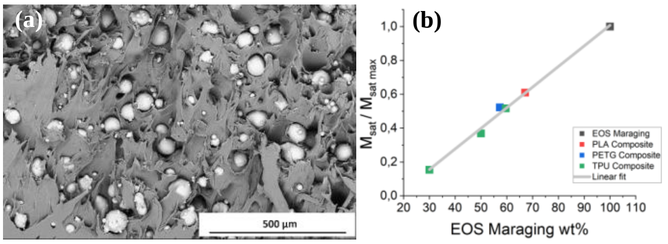

Figure 1: (a) Backscattered electron micrograph of PETG + EOS Maraging filament. (b) Magnetization versus the content of EOS Maraging powder.

References

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