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Magnetic Properties of Printed Pet-G Structures Containing Iron Oxides as a Function of Infill Density

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Introduction

With regard to their potential processing with the additive technology of Fused Filament Fabrication, this work aims to characterize printing structures made of a thermoplastic material with various infill densities and magnetic particles primarily composed of Iron(III) oxides. A structural thermoplastic made of polyethylene terephthalate glycol (PET-G) with Iron(III) oxides has been chosen, and the right processing temperatures have been determined through thermal analysis. A variety of printed products with varying filling densities were tested for their paramagnetic properties. Relative porousness has been recognized to be unequivocally reliant upon the printed inside designs of tried items. When compared to the sample printed with the least dense structure, the samples with the densest structure had a relative permeability that was 18% higher. Magnetic field distributions and the holding forces of all printed samples have been calculated using FEM (Finite Element Modelling) simulations. The results of the simulations showed that produced composites could be used as advanced components for homogenizing electric motors' magnetic fields or as magnetic switches and sensors. In addition, the printing structure's magnetic properties can be adjusted to meet the required density. Additive manufacturing is used extensively in a variety of industrial fields, including medicine, research, engineering, civil engineering, the food industry, and others. It is a well-known method for processing various materials. Fused Filament Fabrication Crump in, which processes thermoplastic or elastomeric filament materials, is one of the most common technologies used in industry and hobby.

A wide range of advantages are provided by FFF additive technology, including affordability, suitability for both commercial and hobby applications, accessibility of processing materials, and usability for products that require shape. Currently, there is an endless supply of thermoplastics and elastomers that can be processed. The most common thermoplastics that are suitable for processing include polylactic acid, polyethylene terephthalate, polyethylene terephthalate glycol, acrylonitrile butadiene styrene, polypropylene (PP), polycarbonate, and polyvinylchloride. Different kinds of additives, such as UV stabilizers, a variety of fillers, flame retardants, or pigments, are frequently used to modify the properties of polymeric materials based on the particular requirements of the application. Last but not least, certain additives are utilized to enhance the material's magnetic properties. Particles or fibers are two common applications for fillers. When the fundamental characteristics that describe magnetic properties include magnetic induction, the intensity of the magnetic field, and the material's relative permeability, magnetic particles impart conductance, shielding, and magnetic properties to the polymer composite.

PET-G was utilized in this work because it offered products with superior mechanical properties, ease of use, and sufficient temperature resistance (in comparison to thermoplastics ABS and PLA). Additionally, PET-G typically provides excellent layer adhesion. Furthermore, it can be recycled and has a low risk of twisting and shrinking. Because PET-G is not magnetic, it can only be used in certain applications, like components that guide and concentrate magnetic flux or magnetic force. Iron oxide-based products are used to make magnetically detectable thermoplastic (MDT) PET-G, which is used to make sensors and smart packaging. The goal of this work was to improve the filling density of printed structures made of PET-G-containing iron oxides in order to maintain the necessary magnetic properties (values of sufficient permeability) and the material requirements for processing. After that, Finite Element Modelling (FEM) was used to evaluate the developed materials' magnetic behavior as well. The emergence of a particular force effect on the finished material upon its exposure to an external magnetic field is related to the fundamental potential application of printed magnetic plastics. There are certain applications in both common and technical practice where securing a general plastic structure to a magnet or other source of a magnetic field is necessary. On the other hand, securing the magnetic components to the plastic base might also be advantageous. Simply put, it could be an alternative to a magnetic board made of sheet metal. The greatest possible force is the most important question for any subsequent practical applications. This subchapter presents the results of the magnetic field simulation and force effects calculation on the model of the selected type configuration of a permanent magnet and type plastic plate corresponding to printed PET-G variants with various levels of filling to answer this question. The purpose of this work was to ascertain the magnetic properties of a PET-G additive containing an iron(III) and titanium(II) oxide magnetic additive. The purpose of the thermal analysis measurements was to identify the ideal processing temperatures and to characterize the thermal behavior of the applied polyethylene-based filaments. Fused Filament Fabrication technology was used to create the products with various internal architectures and infill densities [1-5].

Conclusion

The relative magnetic permeability of samples 100F and 100A was found to be up to 40% higher when compared, and it was determined that the paramagnetic properties were influenced by the various densities of printed products. The holding forces were calculated and the magnetic field simulations were simulated using Finite Element Modelling. The creation of a force of approximately 5 N at zero air gap was observed during FEM model simulations on a typical configuration of a magnet and a plate with magnetic filler. This can guarantee the stable attachment of objects with smaller dimensions or lightweight constructions. From the perspective of 3D printing itself, it can be summarized that less dense structures can significantly reduce production costs by reducing materials and printing time. Last but not least, the presented results demonstrated that produced samples' properties could be tailored to their intended uses, such as magnetic sensors and switches. As previously stated, it is possible to ensure the production of shape-demanding samples at a lower cost and in a shorter amount of time using inexpensive FFF technology by selecting the appropriate infill density of the product filling while maintaining the necessary properties. The fact that this technology can be used for small-scale production without the need for costly molds is its primary advantage.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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