THERMAL CHARACTERIZATION OF PLA, ABS, PETG, AND NYLON FILAMENTS FOR 3D PRINTING APPLICATIONS

CARACTERIZAÇÃO TÉRMICA DE FILAMENTOS DE PLA, ABS, PETG E NÁILON PARA APLICAÇÕES DE IMPRESSÃO 3D

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ABSTRACT
This study investigates the thermal characterization of PLA, ABS, PETG, and Nylon filaments, widely used in 3D printing, to understand their behavior during additive manufacturing processes. Thermogravimetry (TGA) and differential scanning calorimetry (DSC) were employed to assess key thermal properties, including thermal stability, glass transition temperatures, and melting points. The research also examined how printing temperature affects the mechanical and dimensional stability of fabricated parts. Experiments involved 23 polymer samples, including virgin and recycled PLA, to evaluate sustainability and material performance. A 3D printer equipped with precise thermal control and calibrated analytical instruments ensured accurate evaluations. Results highlighted correlations between thermal properties and the quality of printed components, providing data to optimize print settings and minimize defects. The findings contribute to advancing sustainable 3D printing practices by identifying efficient material usage and reducing waste. This project addresses industrial needs for high-quality additive manufacturing, emphasizing eco-friendly material development and the importance of standardizing thermophysical data for improved processes and products.

Keywords: PLA. ABS. PETG. Nylon. Thermal characterization. Additive manufacturing.

RESUMO
Este estudo investiga a caracterização térmica dos filamentos de PLA, ABS, PETG e Nylon, amplamente utilizados na impressão 3D, para entender seu comportamento durante

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os processos de manufatura aditiva. A termogravimetria (TGA) e a calorimetria diferencial de varredura (DSC) foram empregadas para avaliar as principais propriedades térmicas, incluindo estabilidade térmica, temperaturas de transição vítrea e pontos de fusão. A pesquisa também examinou como a temperatura de impressão afeta a estabilidade mecânica e dimensional das peças fabricadas. Os experimentos envolveram 23 amostras de polímeros, incluindo PLA virgem e reciclado, para avaliar a sustentabilidade e o desempenho do material. Uma impressora 3D equipada com controle térmico preciso e instrumentos analíticos calibrados garantiu avaliações precisas. Os resultados destacaram as correlações entre as propriedades térmicas e a qualidade dos componentes impressos, fornecendo dados para otimizar as configurações de impressão e minimizar os defeitos. As descobertas contribuem para o avanço das práticas sustentáveis de impressão 3D, identificando o uso eficiente de materiais e reduzindo o desperdício. Esse projeto atende às necessidades industriais de manufatura aditiva de alta qualidade, enfatizando o desenvolvimento de materiais ecologicamente corretos e a importância da padronização de dados termofísicos para processos e produtos aprimorados.

Palavras-chave: PLA. ABS. PETG. Nylon. Caracterização térmica. Manufatura aditiva.

RESUMEN

Este estudio investiga la caracterización térmica de los filamentos PLA, ABS, PETG y Nylon, ampliamente utilizados en la impresión 3D, para comprender su comportamiento durante los procesos de fabricación aditiva. Se emplearon la termogravimetría (TGA) y la calorimetría diferencial de barrido (DSC) para evaluar las propiedades térmicas clave, como la estabilidad térmica, las temperaturas de transición vítrea y los puntos de fusión. La investigación también examinó cómo afecta la temperatura de impresión a la estabilidad mecánica y dimensional de las piezas fabricadas. En los experimentos se utilizaron 23 muestras de polímeros, entre ellos PLA virgen y reciclado, para evaluar la sostenibilidad y el rendimiento de los materiales. Una impresora 3D equipada con un control térmico preciso e instrumentos analíticos calibrados garantizó la precisión de las evaluaciones. Los resultados pusieron de relieve las correlaciones entre las propiedades térmicas y la calidad de los componentes impresos, proporcionando datos para optimizar los ajustes de impresión y minimizar los defectos. Los hallazgos contribuyen al avance de las prácticas de impresión 3D sostenibles mediante la identificación del uso eficiente de materiales y la reducción de residuos. Este proyecto aborda las necesidades industriales de fabricación aditiva de alta calidad, haciendo hincapié en el desarrollo de materiales ecológicos y en la importancia de normalizar los datos termofísicos para mejorar los procesos y los productos.

Palabras clave: PLA. ABS. PETG. Nylon. Caracterización térmica. Fabricación aditiva.

INTRODUCTION

Additive manufacturing (AM), commonly known as 3D printing, has revolutionized how objects are fabricated, offering unparalleled design flexibility and material efficiency (AMBROSI; PUMERA, 2016) (ATAKOK et al., 2022; PAKKANEN et al., 2017). Among AM techniques, Fused Deposition Modeling (FDM) is widely used due to its simplicity, cost-effectiveness, and versatility (WOJTYŁA et al., 2017). However, optimizing material performance requires understanding the thermal properties of the polymers involved, particularly during processing (SONG et al., 2016).

This study focuses on four commonly used thermoplastics—PLA, ABS, PETG, and Nylon—analyzing their thermal stability and transitions using TGA and DSC. These analyses aim to provide insights into material suitability for various industrial applications, with additional emphasis on sustainability through recycled PLA studies.

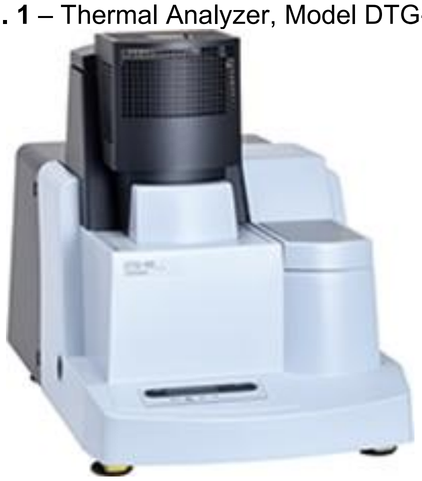
METHODS

Experiments were conducted using 23 polymer samples, comprising 14 PLA, 7 ABS, 1 PETG, and 1 Nylon. Sample preparation included standard extrusion into filaments followed by thermal characterization.

EQUIPMENT

TGA analysis was performed using a Shimadzu DTG-60 instrument, figure 1, measuring mass changes and thermal degradation.

Fig. 1 – Thermal Analyzer, Model DTG-60



Fonte: da Imagem

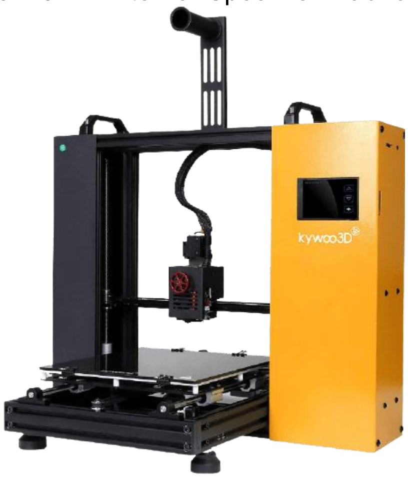
DSC analysis utilized a PerkinElmer DSC 8000, figure 2, calorimeter to evaluate thermal transitions.

Fig. 2 – Differential Scanning Calorimeter (DSC 8000)

Fonte: da Imagem

3D printing trials employed a Kywood3D Tycoon Max, figure 3, printer to produce test specimens under varying temperature settings.

Fig. 3 – 3D Printer for Specimen Fabrication



Fonte: da Imagem

PROCEDURE

Thermal analyses were conducted to assess:

- Thermal stability: Onset and peak degradation temperatures using TGA.
- Transitions: Melting and glass transition temperatures via DSC.

Printing trials: Parts were printed at controlled temperatures, and quality was evaluated for dimensional accuracy, rigidity, and mechanical integrity.

RESULTS AND DISCUSSION

Preliminary results demonstrated that PLA exhibits excellent printability but is sensitive to thermal fluctuations, whereas ABS offers higher impact resistance but requires precise temperature control due to its higher thermal expansion. PETG and Nylon showed intermediate characteristics, with PETG excelling in chemical resistance and Nylon offering superior flexibility.

Recycled PLA presented comparable performance to virgin PLA, though with slight reductions in mechanical properties, emphasizing its potential for sustainable applications. Numerical analyses confirmed that optimal temperature ranges for each material improved dimensional stability and minimized warping.

CONCLUSION

This study highlights the importance of thermal characterization in optimizing 3D printing processes. By correlating material properties with print performance, this research provides valuable data for selecting and processing polymers in additive manufacturing. The insights gained support the development of eco-friendly and cost-effective fabrication methods, contributing to the advancement of sustainable manufacturing practices.

Future work will focus on expanding the dataset to include additional materials and exploring the effects of hybrid material blends on performance metrics.

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