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Effect of Carbon Nanotube Reinforcement and Porosity on Mechanical and Viscoelastic Properties of Polylactic Acid in Material Extrusion Additive Manufacturing

Kamil Feratoğlu[1]✉, İlyas İstif[2]

[1]Kırklareli University, Faculty of Engineering, Kırklareli/TÜRKİYE

[2]Yıldız Technical University, Faculty of Engineering, İstanbul/TÜRKİYE

✉***Correspondence***: kamilferatoglu@klu.edu.tr

Abstract: This study investigates the production of Polylactic Acid-Carbon Nanotube (PLA-CNT) nanocomposite filaments intended for use in fused deposition modeling (FDM). The research delves into the comprehensive analysis of the nanocomposite's thermal degradation behavior, mechanical characteristics, viscoelastic-viscoplastic properties, and porosity. The weight percentages of Carbon Nanotubes (CNTs) within the filaments were accurately determined through advanced thermogravimetric analysis (TGA), indicating a uniform and well-dispersed CNT reinforcement within the PLA matrix. Scanning Electron Microscopy (SEM) analysis provided valuable insights, revealing an enhanced interfilament adhesion, and a notable reduction in porosity with the augmentation of CNT reinforcement. Notably, the incorporation of CNTs yielded a significant improvement in the mechanical properties of the nanocomposite materials, resulting in heightened tensile strength and elastic modulus. Nevertheless, it was observed that higher CNT contents contributed to a reduction in fracture strain, suggesting an increase in material brittleness. In-depth loading-unloading tests showcased a linear viscoelastic behavior, with increased strain rates yielding higher material strength. Furthermore, the investigation of energy consumption during deformation unveiled that at a strain rate of 1E-3, energy consumption was notably higher compared to the rate of 1E-4. Additionally, creep tests conducted demonstrated a decrease in creep compliances with CNT reinforcement, highlighting the nanocomposite's heightened resistance to deformation over time. However, certain exceptions were identified, attributed to CNT agglomerations and insufficient interfacial adhesion. In a broader context, the incorporation of CNT reinforcement yielded a positive impact on the nanocomposite material's thermal, mechanical, and viscoelastic properties. Notably, this study underscores the feasibility of producing PLA-CNT nanocomposite filaments for FDM applications, thereby presenting potential avenues in diverse fields. The comprehensive findings of this research enrich the understanding of the influence of CNT reinforcement on PLA-based materials, while also providing valuable insights for refining the fabrication process and optimizing material properties.

Keywords: Additive manufacturing, Nano-composite polymers, Carbon nanotube, Viscoelastic properties.