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Abstract

Multiple Recycling Cycle Analysis of 3D-Printed Recycled Polycarbonate Using Fused Granulate Fabrication †

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This study explores the degradation behaviours and mechanical performance of 3D-printed recycled polycarbonate (rPC) over multiple recycling cycles using fused granulate fabrication (FGF), a sustainable and scalable 3D printing technique. rPC flakes were subjected to ten recycling cycles, and their thermal, chemical, and mechanical properties were characterised using differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), and mechanical testing. The results reveal that their thermal stability gradually decreases with repeated processing; the glass transition temperature dropped from 110.2 °C to 96.4 °C after ten cycles, while the degradation onset temperature reduced slightly, indicating progressive thermal degradation. FTIR analysis showed transient structural improvements in early cycles, followed by a loss of key functional groups due to chain scission and oxidative degradation. Mechanical testing demonstrated a temporary enhancement in tensile strength and flexural strength—peaking at 68.59 MPa and 76.4 MPa, respectively—linked to improved chain alignment. However, these gains were reversed after the fifth cycle, with significant declines in strength, modulus, and impact strength. Fractography confirmed a transition from ductile to brittle failure beyond five cycles. FGF printing also reduced manufacturing time by up to 84% compared to fused filament fabrication, emphasising its viability for circular manufacturing. The findings offer critical insights into the recyclability feasibility of engineering polymers and support the broader application of FGF in polymer sustainability.

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