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SUSTAINABLE CIRCULAR ECONOMY APPROACH TO UTILIZE BIODEGRADABLE WOOD FIBERS REINFORCED BIOCOMPOSITES IN ENVIRONMENTALLY-BENIGN ARCHITECTED MATERIALS

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ABSTRACT

Integrating wood fibers as a recycled additive into polylactic acid (PLA) opens new frontiers in sustainable materials for additive manufacturing. This work investigates the development and optimization of wood-PLA composites for complex part fabrication via 3D printing. By incorporating wood fibers into biodegradable PLA, this research aims to create materials with enhanced mechanical properties, reduced weight, and minimized environmental impact. The PLA and wood fibers are mixed using twin-screw extrusion to ensure a homogeneous dispersion of the filler within the polymer matrix. Additionally, the compatibilization of the system is studied by grafting maleic anhydride to PLA, enhancing the interfacial bonding between the polymer and the wood fibers. Fused deposition modeling is employed as the 3D printing technique to shape these composite materials into cellular structures, inspired by natural designs such as honeycombs, trabecular bone, and plant cell walls, architectures renowned for their exceptional strength-to-weight ratios. Computational simulations are used to predict the mechanical behavior of the cellular structures and guide the iterative design process. Machine learning algorithms play a pivotal role, processing empirical and simulation data to optimize material composition and structural designs, ensuring continuous improvement in performance. Mechanical testing of the 3D-printed samples is used to assess key properties such as tensile strength, stiffness, and energy absorption. These experimental results serve to validate the computational models and inform further refinements in material formulation and structural design. Overall, this research contributes to advancing the field of sustainable manufacturing by demonstrating the viability of recycling wood fibers into high-performance, biodegradable composites suitable for additive manufacturing. The findings have potential implications for diverse applications, including lightweight construction, packaging, and consumer goods. The integration of natural materials, innovative design methodologies, and cutting-edge computational tools underscores the transformative potential of this study in addressing critical challenges at the intersection of material science and environmental sustainability.