Development of Sustainable Wool-PLA Composite Filament for Additive Manufacturing Applications

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Abstract

The growing demand for sustainable materials and circular manufacturing solutions has increased interest in biodegradable composites reinforced with natural fibres. Poly(lactic acid) (PLA) is among the most widely used polymers in additive manufacturing due to its renewable origin, biodegradability, and ease of processing. However, its brittleness and limited thermal performance restrict broader engineering applications. This study presents the development of a novel Wool–PLA composite for additive manufacturing applications, utilizing both virgin and recycled wool fibres as reinforcement. The novelty of the developed material and manufacturing route has been recognized through a published international patent application (WO2025163342A1).

The research was carried out within the Horizon Europe Twinning project SustDesignTex (2022-2025). The Wool–PLA filament technology originated from a research micro-project conducted at the University of Borås, Sweden.

The study focused on developing a reliable processing route capable of ensuring homogeneous fibre distribution and stable filament production. Several manufacturing approaches were investigated, including direct fibre-pellet blending, mechanical homogenisation, extrusion from PLA and wool nonwoven structures, thermally consolidated composite preforms, and a novel PLA film-wool nonwoven sandwich technology. The influence of feedstock preparation on fibre dispersion, extrusion stability, and filament quality was systematically evaluated.

The results demonstrated that conventional blending techniques produced heterogeneous feedstocks, unstable extrusion behaviour, and frequent filament breakage. In contrast, fibre

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pre-consolidation methods significantly improved composite homogeneity and processing stability. The most effective solution was the sandwich-based technology, in which a PLA film was thermally bonded with wool nonwoven layers prior to pelletisation and extrusion. This method enabled improved fibre impregnation, uniform material distribution, and continuous filament production suitable for fused deposition modelling (FDM).

Mechanical characterisation confirmed the technical feasibility of the developed Wool–PLA composites and their suitability for producing structurally stable additively manufactured components. The developed material combines renewable and recycled resources with advanced manufacturing technologies, supporting circular economy objectives and creating new opportunities for the valorisation of wool waste streams. The proposed manufacturing route represents a promising pathway for the production of biodegradable natural-fibre-reinforced materials for additive manufacturing and injection moulding applications.

Keywords: PLA, wool fibre, recycled wool, biocomposite, filament extrusion, additive manufacturing, FDM, FFF, sustainable materials, circular economy