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Development of eco-friendly basalt filler reinforced poly (lactic acid) composites using an additive manufacturing: An experimental insights

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ABSTRACT

This research work investigates the use of environmentally friendly basalt filler as a reinforcement with polylactic acid (PLA) polymer for lightweight 3D printing applications. The 3D printing filaments were manufactured with a single screw extruder with different weight ratios of basalt filler (0, 1, 3, and 5 wt%) by maintaining the mean diameter of 1.75 mm, followed by 3D printing using fused deposition modeling technique. The results reveal that the tensile strength was insignificantly reduced with the addition of basalt filler, whereas a slight increment is observed in flexural and impact strengths for the 3 wt% filler reinforced composite. However, by preventing deformation under stress, the fillers significantly increased both tensile and flexural modulus. It conferred with the hardness test that the addition of fillers has significantly improved the Shore D hardness value in the ascending order of filler ratios. The thermogravimetric analysis results show that the neat PLA dramatically lost weight as the temperature rose because of a decreased thermal barrier, fast hydrolysis, and chain scission, whereas the basalt fillers act as a thermal barrier and prevent the early degradation of the PLA matrix in the composites. Additionally, the glass transition temperature, viscoelastic properties, and dimensional stability of the 3D-printed basalt-reinforced composites at higher temperatures were all significantly improved. According to the water absorption studies, the 5 wt% basalt-loaded composite has shown more water absorption than other composites. Overall, both 1 and 3 wt% basalt composites could be suggested for developing components like plastic gears, drone chassis, forming boards, sealing strips, and deflector strips of paper processing machines.

1. Introduction

Polylactic acid (PLA) polymer is one of the most popular and preferred industrial raw materials for the production of lightweight structural products due to its biodegradability, recyclability, and environmentally friendly aspects. This versatile material is usually derived from renewable sources via the fermentation process of sugarcane and starch materials. Hence it has emerged as a potential replacement in place of synthetic polymers for sustainable product development [1]. The PLA's biodegradability and recyclability process occurs through the hydrolysis process of supportive ester functional groups and microorganisms attack. However, the degradation rate is oriented on the material characteristics such as molecular mass, isomeric ratio, moisture diffusion rate, and surface morphology. In a general point of view, PLA possesses a slow degradation rate which is beneficial for biomedical products and causes disposal problems for packaging film products [2]. The initial step of PLA degradation begins with hydrolysis by losing the molecular weight of about below 10 kDa followed by degradability [3]. The tensile strength and modulus values of PLA are comparable to other bioplastics, especially with polyethylene terephthalate (PET), however, it shows higher brittleness, toughness, and < 10 % elongation value. This elongation behavior restricts the usage of PLA in high-performance applications under excessive stress values. Moreover, the lower glass transition temperature value also limits the application in hot packaging

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Consent to participate

Not applicable.

Consent for publication

All authors have read and agreed to publish the manuscript.

Ethics approval

The authors hereby state that the present work complies with the ethical standards.

Code availability

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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