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PARAMETER INFLUENCE ON THE TENSILE PROPERTIES OF FDM PRINTED PLA/COCONUT WOOD

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Abstract—Due to its adaptability in allowing for individualized production, 3D printing technology has quickly become a viable option in the fabrication of parts. Recent years have seen a plethora of research devoted to enhancing the quality of 3D printed components. However, the performance of the printed part depends heavily on the correct selection of process parameters for Fused deposition modeling (FDM), making it a significant task.

Deposition Modeling, Tensile Properties, PLA, Coconut Wood, Infill Density	Therefore, studying how different process parameters affect the final product's quality characteristics is essential. So, it's helpful if there's a good option for customizing the mechanical properties of 3D-printed components. This study aims to determine how factors affect the tensile properties of a composite made from PLA and coconut wood. The material in the form of a filament, such as thermoplastic polymers, was used. Coconut wood has been prized for centuries for its durability, beauty, and ecological friendliness. This research aims to create and compare the tensile properties of specimens featuring different infill patterns (concentric, cubic, gyroid, and triangle) and infill percentages (25%, 50%, 75%). Ultimate tensile strength of 37.21 MPa and elastic modulus of 1.12 GPa were achieved with the concentric infill pattern at 75% infill.

I. Introduction

The field of additive manufacturing (AM) holds great promise for the future of the component manufacturing industry [1]. In addition, they make it possible to produce a wide variety of complex prototypes or functional components, such as those resulting from a topology optimization procedure [2]. Sheet lamination (laminated object manufacturing), material extrusion (fused deposition modeling), material jetting (polyjet), binder jetting, powder bed fusion (selective laser sintering, direct metal laser sintering, selective laser melting, electron beam melting), and directed energy deposition (laser sintering) are the most common types of AM technologies [3],

[4]. The maximum amount of space, price, number of building layers, and types of materials required by these systems are all different [5]. Rapid prototyped parts produced using SLA showed significantly inferior mechanical properties compared to other parts made of other traditional manufacturing methods when it was first introduced in the mid-1980s [6].

Stratasys Inc., based in the United States, first began commercializing the FDM process in the early 1990s, after it had been developed in the 1980s [7]. Because of its dependability, cost-effectiveness in producing 3D objects with good resolution, dimensional stability, comprehensive material customization, simple fabrication process, and ability to fabricate complicated geometrical parts safely in a favourable environment, FDM has recently seen widespread use in AM technology in producing various products across various manufacturing sectors [8, 9]. Understanding the optimal combination of the many parameters affecting FDM's product quality and material properties are very challenging. In FDM, polymers such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) are typically used (ABS) [10,11]. Additionally, metals and alloys are utilized in the aerospace and medical industries to create cutting-edge technology. To improve the mechanical properties of composite materials, scientists have developed filaments in recent years. The quality and performance of FDM printed parts are significantly impacted by printing parameters like build orientation, layer thickness, raster angle, raster width, air gap, infill density and pattern, and the feed rate [12–14]. Understanding how various process parameters affect mechanical performance is crucial because mechanical properties are essential for functional parts. Since the literature on the mechanical properties of parts processed by low-cost 3D printers is somewhat scarce, more investigation is needed to determine printer parameters like build orientation, layer thickness, and feed rate. Since coconut wood is biodegradable, compatible, and resistant to corrosion, it is used in various contexts. The malleability of coconut wood is mainly responsible for the qualities mentioned above. Farah's review study shows that researchers today concentrate on PLA-based nanocomposites and modified products [15]. Important printing variables like mass, mass fluctuation, printing duration, and porosity were studied using a prediction model developed by Pires et al. [16] They found that the infill percentage changed depending on the size, the infill pattern, and the print temperature. In contrast, the printing time changed depending on the size, the printing speed, and the layer height [17].

Even though there is some data on how different printing settings affect the mechanical properties of coconut wood particles, this data is limited. Print settings strongly influence mechanical properties, including print speed, layer thickness, printing pattern, melting temperature, and fill density. The strength of the printed parts is proportional to the infill percentage, which is the total amount of material deposited on each surface layer, and inversely proportional to the printing time and amount of material used. A few research efforts have examined how infill pattern affects the mechanical behaviour of the FDM process. As a result, the mechanical properties of printed coconut wood using various printing parameters have been the focus of this study. Concentric, cuboid, gyroid, and triangle infill patterns were used with percentages of 25%, 50%, and 75%, respectively.

II. Materials & Methods

The material used for this study is coconut wood reinforced PLA. The concentration of the coconut wood is 40 %, and the PLA is 60%. Wanhao duplicator i3 FDM printer is used for the printing process. ASTM D638 standard is used for the tensile analysis, and the samples are tested using the Instron 3500 series. Initially, the samples are designed using solid works, and the G-codes are exported to the FDM machine. The optimum parameters for the printing process are set to the layer thickness of 0.3mm, speed of 30 mm/sec, and printing temperature of 210°C. For each variation, n=5 samples, and a total of 60 samples were printed and the average was taken out. Figure 1 shows the schematic of the FDM printer.

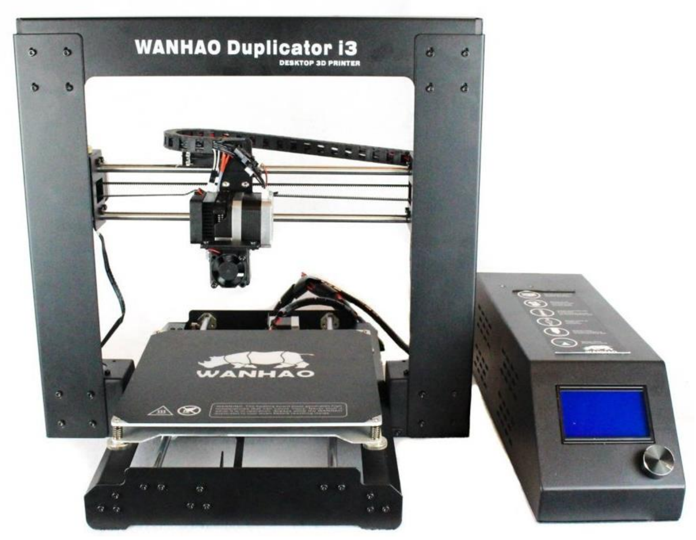

Figure 1: Wanhao duplicator i3 FDM printer

III. Results & Discussion

The primary properties analyzed in the tensile test results were the ultimate tensile strength (*UTS*) and the elastic modulus (*E*). The ultimate tensile strength (*UTS*) of a material is the maximum amount of force that can withstand before breaking. The elastic modulus also referred to Young's modulus is primarily utilized in determining the stiffness of a material.

A. Ultimate Tensile Strength (UTS)

Table 1 and Figure 2 shows the avearage tensile properties of various infill pattern and infill percentage. From that the maximum ultimate tensile strength achieved at concentric pattern of 37.21 MPa at 75 % infill density. The lowest UTS achieved at cubic pattern at 25% infill density of 23.18 Mpa. The results shows that all the patterns are achieved maximum properties at 75% infill density.

Table 1: Average tensile properties of Various infill pattern and infill percentage of PLA/ Coconut wood.

Infill pattern	Infill percentage	Ultimate tensile strength (Mpa)	Elastic Modulus (GPa)
Concentric	25%	28.57	0.8426
	50%	32.87	0.9256
	75%	37.21	1.2015
Cubic	25%	23.18	0.7526
	50%	26.36	0.8426
	75%	29.47	1.0425
Gyroid	25%	24.12	0.8105
	50%	27.52	0.9025
	75%	30.32	1.1025
Lines	25%	25.98	0.7859
	50%	28.18	0.8125
	75%	30.76	1.0025

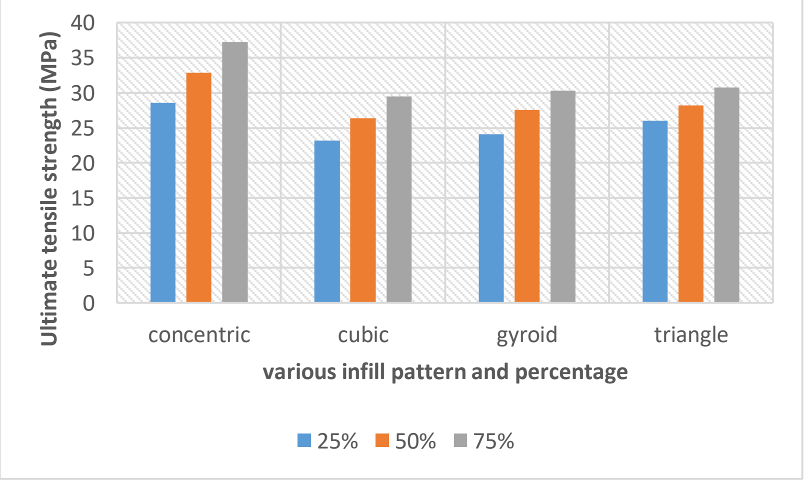

Figure 2: Average ultimate tensile strength of the various infill pattern and infill percentage

B. Elastic Modulus

From the Table 1 and Figure 3, the maximum elastic modulus achieved at concentric pattern at 75% infill density of 1.2015 GPa. The lowest modulus value at cubic pattern at 25% infill density of 0.7526 GPa. All the patterns achieved maximum properties at 75% infill density and the lowest at 25% infill density. The maximum properties achieved at both UTS and modulus at concentric pattern due to its linear structure. The triangle, gyroid and cubic patterns as follows.

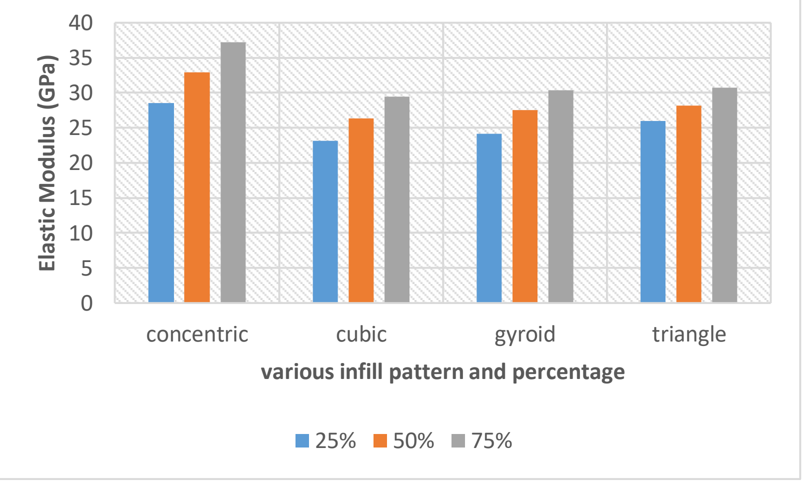

Figure 3: Average elastic modulus of the various infill pattern and infill percentage

IV. Conclusion

The tensile properties of the PLA/ coconut wood were obtained using various infill pattern and infill density. The results shows that both the ultimate tensile strength and elastic modulus achieved maximum properties at concentric pattern at 75% infill density, and 50% and 25% as follows. This study shows that the concentric pattern is highly suitable for the tensile strength of the product. Also increase the infill percentage will increase the strength of the product.

V. Acknowledgement

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