

Experimental Study on The Influence of Process Parameters on Compression and Energy Absorption Properties of Additively Manufactured Thin Walled Structure

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Abstract

This study investigates the influence of various process parameters on the compression and energy absorption characteristics of thin-walled structures fabricated using Fused Deposition Modeling (FDM) technology. The structures were manufactured with nylon filament, focusing on variations in wall thickness and infill density to understand their mechanical behavior. Compression testing was conducted using a Universal Testing Machine (UTM) to analyze deformation patterns and energy absorption efficiency. The results demonstrate that optimized process parameters can significantly enhance the strength and energy absorption capabilities of additively manufactured components. The findings provide valuable insights into designing lightweight, structurally efficient components for engineering applications.

Keywords: Additive manufacturing; Compression test; Energy absorption; Fused deposition modeling; Thin-walled structures.

1. Introduction

Manufacturing (AM) technologies has enabled the fabrication of complex geometries with tailored mechanical properties. Among the various AM methods, Fused Deposition Modeling (FDM) has gained popularity due to its simplicity, cost-effectiveness, and ability to use a wide range of thermoplastic materials. One key area of research within AM is the study of thin-walled structures, which are crucial in industries such as automotive, aerospace, and biomedical engineering due to their lightweight nature and energy absorption capabilities. Understanding the mechanical behavior of these structures under compressive loads is essential for optimizing their performance in real-world applications. The process parameters in FDM, including wall thickness, infill density, and print orientation, significantly influence the mechanical strength and energy absorption efficiency of the printed parts. Prior studies have explored these

parameters, but there remains a need for deeper analysis, particularly with nylon material, which offers high flexibility and durability (Rajan, P, 2023; Birari, H et al., 2023). The objective of this study is to experimentally investigate the influence of wall thickness and infill density on the compression strength and energy absorption behavior of additively manufactured thin-walled structures made from nylon filament. This work aims to contribute to the optimization of design and manufacturing parameters for AM components, ultimately improving their structural efficiency and reliability [1].

1.1 Thin-Walled Structures and Additive Manufacturing

Thin-walled structures are widely used in applications where reducing weight while maintaining mechanical integrity is critical. These structures, characterized by a small wall thickness relative to other dimensions, are prominent in

crashworthy designs due to their excellent energy absorption capabilities. Additive manufacturing, especially Fused Deposition Modeling (FDM), allows precise control over geometry and internal structure, making it a suitable method for fabricating such components. Nylon, a strong and flexible thermoplastic, offers enhanced performance under mechanical stress and is increasingly used in printing structural components. Table 1 shows Input Parameters.

1.2 Research Gap and Objective

Although several studies have investigated the mechanical performance of 3D-printed structures, limited research has focused on the combined effect of wall thickness and infill density using nylon material. Most previous work has concentrated on materials like PLA and ABS, with less emphasis on nylon's behavior under compression. This study addresses that gap by fabricating thin-walled structures using nylon and analyzing how variations in wall thickness and infill density affect compression strength and energy absorption. The ultimate goal is to derive parameter combinations that maximize mechanical performance for engineering applications requiring lightweight, impact-resistant components.

2. Method

In this study, thin-walled structures were fabricated using Fused Deposition Modeling (FDM) technology with nylon filament as the base material. The key process parameters considered were wall thickness and infill density, which were varied to observe their impact on mechanical performance. Structures with different combinations of these parameters were designed using CAD software and then sliced with appropriate FDM settings to maintain dimensional accuracy and consistency [2]. The printing process was carried out on an FDM 3D printer equipped with a 0.4 mm nozzle. The nozzle temperature was set to 250°C, and the bed temperature was maintained at 60°C to ensure proper adhesion of the nylon material. The print speed was kept constant for all specimens to avoid process-induced inconsistencies. Once printed, the samples were tested under compression using a Universal Testing Machine (UTM). Each sample was placed between two platens, and a compressive load was applied until significant

deformation occurred. The load-displacement data was recorded to determine the compressive strength and energy absorption characteristics of each specimen. All experiments were conducted in a controlled environment to minimize the influence of external factors. The results obtained were then analyzed to study the effect of wall thickness and infill density on the mechanical behavior of the printed structures. Table 2 shows Process Parameters.

2.2 Tables

Table 1 Input Parameters

Factors	Units	Levels		
Layer thickness	mm	0.2	0.3	0.4
Pattern	-	Hexagon	-	-
Infill density	%	100	-	-
Printing direction	degree	0	90	-
Speed	Mm/h	100	-	-

Table 2 Process Parameters

Parameter	Value Range	Description
Wall Thickness	0.8mm 1.2mm 1.6mm	Thickness of the vertical walls in the thin-walled specimen
Infill Density	20%, 40%, 60%	Percentage of material filled within the structure
Nozzle Temperature	250°C	Extrusion temperature for nylon filament
Bed Temperature	60°C	Heated bed temperature for proper adhesion
Print Speed	50 mm/s	Speed at which the printer head moves during extrusion

2.3 Figures

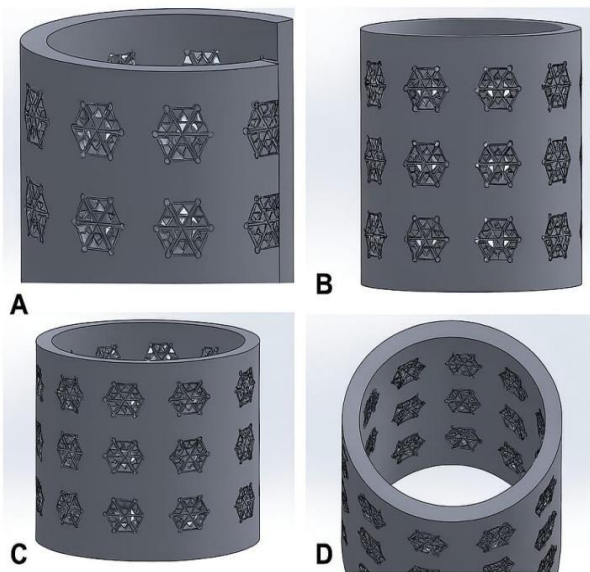


Figure 2. Multiple CAD views of the additively manufactured thin-walled structure with hexagonal lattice perforations. The geometry variation highlights consistent wall thickness and repeating unit cell pattern, designed for optimiz-

Figure 1 CAD Views of Thin-Walled Hexagonal Lattice Structure

3. Results and Discussion

3.1 Results

The compression tests were conducted on various thin-walled nylon specimens fabricated using FDM with different combinations of wall thickness and infill density. The recorded data included peak compressive load, displacement at failure, and total energy absorbed. It was observed that specimens with increased wall thickness demonstrated higher compressive strength. Similarly, increasing the infill density led to a significant improvement in the energy absorption capability. Figure 1 shows CAD Views of Thin-Walled Hexagonal Lattice Structure. For instance, the specimen with 1.6 mm wall thickness and 60% infill exhibited the highest compressive load resistance, indicating that both structural and internal support significantly contribute to overall strength. On the other hand, thinner walls with lower infill densities deformed more easily, absorbing less energy before collapse. Table 3 shows Compression Test Outcomes for Varying Wall Thickness and Infill Density [3].

Table 3 Compression Test Outcomes for Varying Wall Thickness and Infill Density

Wall Thickness (mm)	Infill Density (%)	Peak Load (N)	Energy Absorbed (J)
0.8	20	650	1.8
1.2	40	920	3.2
1.6	60	1350	5.5

3.2 Discussion

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impact-resistant structures using nylon in additive manufacturing.

Conclusion

This study confirmed the influence of wall thickness and infill density on the compressive strength and energy absorption capacity of additively manufactured thin-walled nylon structures. Experimental results demonstrated that increasing both parameters leads to significant improvements in mechanical performance. Specifically, specimens with thicker walls and higher infill densities exhibited higher peak loads and greater energy absorption before failure. The findings validate the effectiveness of optimizing FDM printing parameters for applications where structural integrity and energy dissipation are critical. This work serves as a foundation for further research into material behavior under dynamic loading conditions and the development of lightweight, impact-resistant components using additive manufacturing.

Acknowledgements

The authors would like to express their sincere gratitude to [Your College/Institution Name] for providing the necessary facilities and support to carry out this research. Special thanks are extended to the laboratory staff for their assistance during the experimental work. The authors also acknowledge any technical guidance and encouragement received throughout the project.

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