6th INTERNATIONAL CANKAYA SCIENTIFIC STUDIES CONGRESS
June 15-16, 2026 / Ankara-TÜRKİYE
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3B BASKI İLE ÜRETİLEN SNOWBOARD APARATLARINDA DESTEK GEOMETRİSİ VE DOLULUK ORANININ BASMA DAYANIMINA ETKİSİ

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Özet

Bu çalışma, snowboard kullanıcılarının sürüş performansını artırmak ve dönüş ile frenleme kabiliyetlerini geliştirmek amacıyla farklı geometrilerde tasarlanan aparatların mekanik dayanımlarını incelemektedir. Araştırma kapsamında dört farklı destek geometrisi tasarlanmış, her biri %15 ve %50 doluluk oranlarında üretilerek toplam sekiz numune elde edilmiştir. İlk aşamada T ve O geometrilerine sahip numuneler üretilmiş, ardından elde edilen bulgular doğrultusunda Üçgen ve 3-O geometrileri geliştirilerek aynı doluluk oranlarında test edilmiştir. Tüm numuneler basma testine tabi tutulmuş ve sonuçlar karşılaştırmalı olarak değerlendirilmiştir. Elde edilen veriler, doluluk oranı ve destek geometrisinin mekanik performans üzerinde belirleyici olduğunu göstermiştir. Genel olarak %50 doluluk oranına sahip numuneler daha yüksek basma dayanımı sergilemiştir. En yüksek dayanım, %50 doluluk oranına sahip T geometrili numunede 5702 N maksimum kuvvet (Fmax) değeri ile elde edilmiştir. Bu değeri sırasıyla Üçgen (3727,1 N) ve 3-O (2823,3 N) geometrilerine sahip %50 doluluk oranlı numuneler izlemiştir. %15 doluluk oranlı numunelerde ise Üçgen (1489,9 N), 3-O (1448,8 N) ve O (997,6 N) geometrileri daha düşük dayanım değerleri göstermiştir. Bununla birlikte, %15 doluluk oranına sahip T geometrili numune 2484,5 N maksimum kuvvet değerine ulaşarak aynı doluluk oranındaki diğer tüm numunelerden daha yüksek basma dayanımı göstermiştir. Ayrıca bu değer, %50 doluluk oranına sahip O geometrili numunenin (1759,7 N) dayanım değerini de aşmıştır. Bu durum, destek geometrisinin mekanik performans üzerindeki etkisinin doluluk oranından bağımsız olarak önemli olabileceğini göstermektedir.

Anahtar Kelimeler: 3B Baskı, Basma dayanımı, Doluluk oranı, Destek geometrisi

EFFECT OF SUPPORT GEOMETRY AND INFILL DENSITY ON THE MECHANICAL STRENGTH OF A SNOWBOARD ATTACHMENT MANUFACTURED BY 3D PRINTING

Abstract

This study investigates the mechanical strength of apparatuses designed with different support geometries to enhance the riding performance of snowboard users and improve their turning and braking capabilities. Within the scope of the research, four different support geometries were designed, and a total of eight specimens were produced with infill densities of 15% and 50% for each geometry. In the initial stage, specimens with T and O support geometries were manufactured. Based on the findings obtained from these tests, two additional geometries, namely Triangle and 3-O, were developed and fabricated using the same infill densities. All specimens were subjected to compression testing, and the results were comparatively evaluated.

The findings revealed that both infill density and support geometry significantly influenced the mechanical performance of the specimens. In general, specimens with a 50% infill density exhibited higher compressive strength than those with a 15% infill density. The highest strength was achieved by the specimen with a T-shaped support geometry and 50% infill density, reaching a maximum force (Fmax) of 5702 N. This was followed by the Triangle (3727.1 N) and 3-O (2823.3 N) geometries at the same infill density. Among the specimens with 15% infill density, the Triangle (1489.9 N), 3-O (1448.8 N), and O (997.6 N) geometries exhibited comparatively lower strength values. Notably, the T-shaped specimen with a 15% infill density reached a maximum force of 2484.5 N, outperforming all other specimens with the same infill density. Furthermore, this value exceeded the compressive strength of the O-shaped specimen with a 50% infill density (1759.7 N). These results indicate that support geometry can have a substantial effect on mechanical performance, independent of infill density. Overall, the findings suggest that modifications in support geometry have a more pronounced influence on compressive strength than variations in infill density.
Keywords: 3D Printing, Compressive strength, Infill density, Support geometry

1. INTRODUCTION

Additive manufacturing (AM) technologies, particularly fused deposition modeling (FDM), have gained considerable attention in recent years due to their capability to fabricate lightweight and geometrically complex structures with reduced material waste. Unlike conventional manufacturing methods, FDM enables the layer-by-layer production of components directly from digital models, thereby offering advantages such as rapid prototyping, design flexibility, customization capability and cost-effective manufacturing. Owing to these benefits, FDM technology has been extensively utilized in various engineering sectors, including aerospace, automotive, biomedical, defense and sports equipment manufacturing.

The mechanical performance of FDM-manufactured components is strongly dependent on several process parameters, including infill density, infill pattern, build orientation, layer thickness and internal structural geometry. Previous studies have shown that increasing infill density generally improves the mechanical strength and load-bearing capacity of printed parts due to enhanced internal material continuity. Tanveer et al. [1] reported that both infill density and infill pattern significantly influence the mechanical behavior of FDM-printed structures, particularly in applications subjected to external loading. Similarly, Serrano-Cinchilla et al. [2] demonstrated that higher infill densities substantially improve the compressive properties of PLA specimens manufactured using FDM technology.

In addition to infill density, several studies have emphasized the importance of internal structural architecture and build orientation on the overall mechanical response of FDM-manufactured components. Birosz and Andó [3] reported that optimized internal infill configurations can significantly improve load distribution and structural efficiency while simultaneously reducing material consumption. Likewise, Rajkumar [4] demonstrated that build orientation and infill pattern considerably affect the stiffness and deformation behavior of FDM-printed structures under external loading conditions. These findings indicate that geometrical design parameters should be carefully considered when optimizing the mechanical performance of additively manufactured components.

Recent studies have further emphasized that the mechanical behavior of FDM-manufactured PLA components is strongly governed by internal architecture and process parameters. Chacón et al. [5] demonstrated that build orientation, layer thickness and feed rate significantly affect the tensile and flexural properties of PLA structures, highlighting the importance of parameter optimization.

Tymrak et al. [6] investigated the mechanical properties of open-source FDM printed components and reported that manufacturing conditions have a substantial influence on strength and stiffness. Moreover, Afshar et al. [7] developed a nonlinear material model for PLA specimens with different infill densities and showed that variations in infill density alter stress distribution and deformation behavior. Recent experimental studies have also confirmed that increasing infill density generally improves the compressive performance of PLA structures due to reduced void content and enhanced material continuity [8]. In addition, studies focusing on infill architecture revealed that topology and load-transfer paths may have a dominant effect on mechanical response, indicating that geometrical optimization can provide significant improvements without increasing material consumption [9]. These findings suggest that not only infill density but also internal geometry should be considered simultaneously when designing functional FDM components subjected to compressive loading.

In snowboarding applications, carving performance and rider stability are directly associated with pressure distribution and effective edge control. Uneven load transfer during turning and braking maneuvers may lead to reduced maneuverability, increased vibration and loss of control, thereby negatively affecting both riding performance and user safety. Therefore, the structural configuration and mechanical durability of snowboard attachments are critical design factors for improving rider comfort and operational performance.

Although numerous studies have investigated the influence of infill density and infill patterns on the mechanical behavior of FDM-produced structures, limited research has focused on customized support geometries specifically developed for sports applications. Therefore, the present study experimentally investigates the effects of support geometry and infill density on the compressive performance of additively manufactured snowboard attachments. Four different support geometries were evaluated at two different infill densities (15% and 50%), and the resulting compressive strengths were comparatively analyzed to determine the most mechanically efficient configuration.

2. MATERIALS AND METHOD

A total of eight specimens were manufactured to investigate the influence of support geometry and infill density on compressive performance. Four different support geometries, namely T, O, Triangle and 3-O, were considered, and each geometry was produced with infill densities of 15% and 50%. Polylactic acid (PLA), one of the most commonly used thermoplastic materials in FDM applications, was selected as the printing material due to its ease of processing, dimensional stability and favorable mechanical properties.

The fabricated specimens are presented in Figure 1 and Figure 2. The specimens were designed using SolidWorks 2025 software and exported in STL format prior to manufacturing. All specimens were produced using a Bambu Lab P2S FDM printer with a gyroid infill pattern to ensure a consistent internal structure. The modeled geometries are illustrated in Figure 3.



Figure 1. Specimens featuring Triangle and 3-O support geometries

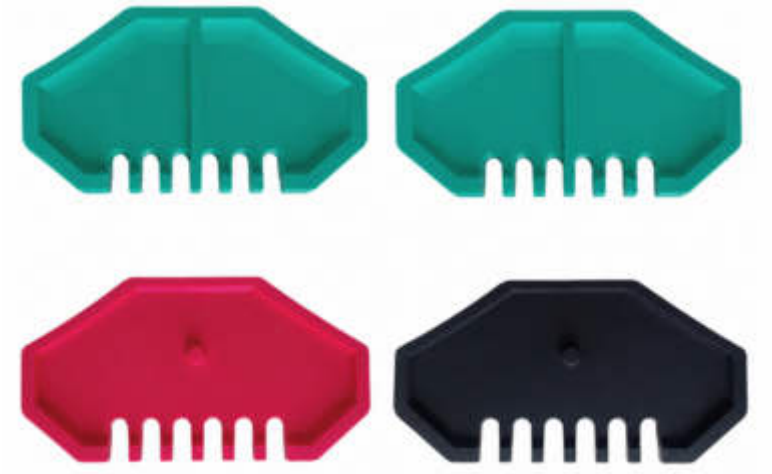


Figure 2. Specimens featuring O and T support geometries

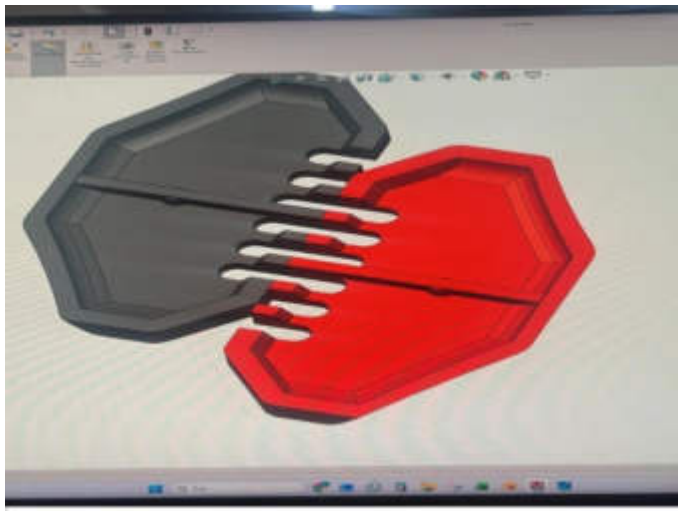


Figure 3. Specimens modeled in SolidWorks

Prior to testing, minor surface irregularities generated during the printing process were removed by light sanding in order to ensure uniform contact conditions during compression testing. The general mechanical and thermal properties of PLA used in this study are summarized in Table 1.

Table 1. The properties of PLA

Property	Typical Value	Unit
Density	1.24	g/cm³
Tensile Strength	50–70	MPa
Young's Modulus	3.0–4.0	GPa
Flexural Strength	80–110	MPa
Flexural Modulus	3.0–4.5	GPa
Compressive Strength	60–110	MPa
Impact Strength (Izod)	16–30	J/m
Elongation at Break	2–10	%

Compression tests were conducted using a ZwickRoell Zwick Z250 universal testing machine at room temperature (23°C). The crosshead speed was maintained at 1 mm/min throughout all experiments. Following the tests, the damaged specimens were visually examined to evaluate failure modes, layer separation and deformation behavior.

3. RESULTS AND DISCUSSION

The compression test results are summarized in Table 2. The findings clearly demonstrate that both support geometry and infill density substantially influence the compressive behavior of the FDM-manufactured specimens. In general, increasing the infill density from 15% to 50% improved the load-bearing capacity of the structures due to enhanced internal material continuity and reduced void content.

Among all tested configurations, the T support geometry produced with 50% infill density exhibited the highest compressive strength with a maximum load (Fmax) of 5702 N. In contrast, the lowest compressive performance was observed in the O geometry with 15% infill density, which reached only 997.6 N. The Triangle and 3-O geometries manufactured at 50% infill density achieved intermediate compressive strengths of 3727.1 N and 2823.3 N, respectively.

A notable observation was obtained from the T geometry produced at 15% infill density. Despite the relatively low infill ratio, this configuration reached a maximum load of 2484.5 N, outperforming all other 15% infill specimens and even exceeding the compressive strength of the O geometry manufactured at 50% infill density. This result indicates that structural geometry may have a greater influence on compressive performance than infill density alone.

Table 2. Results of the compression test

Support Geometry	Infill Ratio	Test Results, N (Fmax)	Infill Ratio	Test Results, N (Fmax)
T	%50	5702	%15	2484.5
O	%50	1759.7	%15	997.6
3-O	%50	2823.3	%15	1448.8
Triangle	%50	3727.1	%15	1489.9

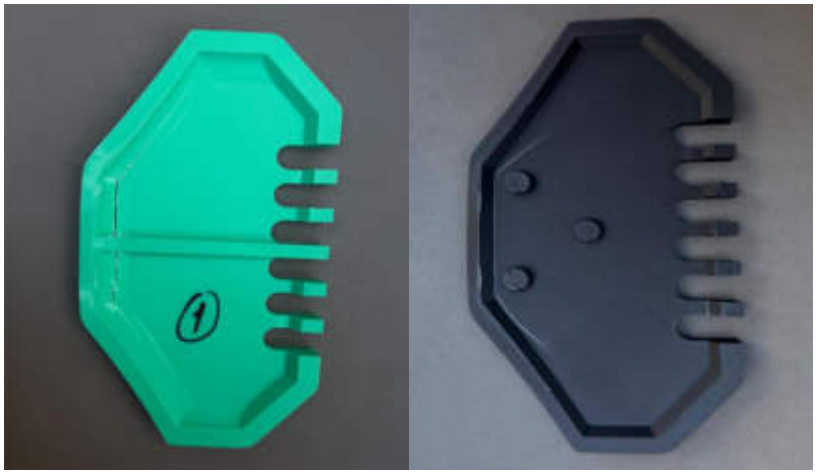
Representative failure modes after compression testing are presented in Figure 4. The failure behavior revealed that geometries with more continuous load-transfer paths exhibited improved structural integrity and delayed collapse under compressive loading. In particular, the T geometry demonstrated more stable deformation behavior, whereas the O geometry showed earlier localized collapse and reduced load resistance.



%15 triangle %50 triangle



%15 3-O %15 O



%50 T %50 3-O



%15 T %50 O

Figure 4. Specimens with 3-O, O, triangle and T support geometries after compression testing

Furthermore, the Triangle and 3-O geometries exhibited similar compressive strengths at 15% infill density; however, a more significant difference emerged at 50% infill density. This finding suggests that the effectiveness of increased infill density strongly depends on the selected support geometry. Overall, the results confirm that optimizing support geometry is essential for improving the mechanical performance of FDM-manufactured functional components.

4. CONCLUSION

In this study, the effects of support geometry and infill density on the compressive performance of FDM-manufactured snowboard attachments were experimentally investigated. Four different support geometries were produced with two different infill densities and comparatively evaluated through compression testing.

The experimental findings demonstrated that increasing infill density generally improved compressive strength. However, the results also revealed that support geometry can have a more dominant effect on mechanical performance than infill density alone. The T support geometry exhibited the highest compressive strength at both infill densities and achieved a maximum load of 5702 N at 50% infill density.

The O geometry exhibited the lowest compressive performance, indicating that geometrical design significantly affects load transfer capability and structural stability under compression. Additionally, the T geometry produced at 15% infill density outperformed the O geometry manufactured at 50% infill density, further emphasizing the critical role of support geometry.

Overall, the results indicate that optimized support geometries can significantly enhance the compressive performance of FDM-manufactured structures while potentially reducing material consumption and printing time. Future studies should investigate alternative filament materials, additional support geometries, and different printing parameters to further improve the mechanical efficiency of functional additively manufactured sports components.

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