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Investigation of the Effect of Deformation Rate on the Tensile Strength of PLA Parts Produced by 3D Printing with Different Contour Number and Infill Pattern

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3B Baskı ile Farklı Kontur Sayısı ve Dolgu Deseni ile Üretilen PLA Parçaların Çekme Dayanımına Deformasyon Hızının Etkisinin Araştırılması

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Abstract
In the contemporary era of additive manufacturing technologies, the production of components with intricate geometries from a diverse array of materials, including polymers, ceramics, metals and composites, has become a reality. In particular, polymer materials, which are easily and inexpensively available, as well as meeting the desired strength values by optimizing the production parameters, can often be produced by material extrusion based fused deposition modelling. Polylactic acid, a polymer of choice in numerous fields, including biomedical and automotive applications, is of particular interest in this study. The objective of this study is to investigate the effect of infill pattern and number of contours, which are production parameters, and deformation rate, which is a test parameter, on the tensile strength values of the related products in additive manufacturing products produced from the frequently used polylactic acid material. To this end, tensile test specimens were fabricated using three distinct infill patterns (zigzag, triangle and cubic) and three different contour numbers (2, 3 and 4). These specimens were then subjected to tensile testing at three different deformation rates (1, 5 and 25 mm/min). The resultant tensile strengths were obtained and the fracture surfaces were examined. The findings indicated that tensile strength values increased with an increase in the number of contours, that the effects of infill patterns varied depending on the deformation rate, and finally, that tensile strength values increased with increasing deformation rate.

***Keywords:** Fused deposition modelling; Polylactic acid; Tensile strength; Infill pattern; Number of contour; Deformation rate.*

Öz
Günümüz eklemeli imalat teknolojileriyle polimer, seramik, metal ve kompozit malzemelerden, mühendislik uygulamalarında talep edilen özellikleri karşılayacak karmaşık geometrili parçaların üretimi mümkün hale gelmiştir. Özellikle, kolay ve ucuz bir şekilde temin edilebilirliğinin yanı sıra, üretim parametrelerinin optimizasyonu ile arzu edilen dayanım değerlerini karşılayan polimer malzemeler sıklıkla malzeme ekstrüzyon esaslı eriyik yığma modelleme ile üretilebilmektedir. Endüstriyel uygulamalar olarak biyomedikalden, otomotiv sektörüne dek bir çok alanda tercih edilen polimerlerden biri de polilaktik asittir. Bu çalışmanın amacı ise, sıklıkla kullanılan polilaktik asit malzemeden üretilen eklemeli imalat ürünlerinde üretim parametrelerinden olan dolgu deseni ve kontur sayısı ile bir test parametresi olan deformasyon hızının ilgili ürünlerin çekme dayanım değerlerine olan etkisini incelemektir. Bu bağlamda, üç farklı dolgu deseni (zikzak, üçgen ve kübik) ve üç farklı kontur sayısı (2, 3 ve 4) ile üretilen çekme test numuneleri üç farklı deformasyon hızında (1, 5 ve 25 mm/dakika) çekme testine tabi tutularak çekme dayanımları elde edilmiş ve kırılma yüzeyleri incelenmiştir. Elde edilen bulgular neticesinde, kontur sayısının artmasıyla birlikte çekme dayanım değerlerinin arttığı, dolgu desenlerinin etkilerinin deformasyon hızına bağlı olarak değişim gösterdiği ve son olarak da artan deformasyon hızı ile birlikte çekme dayanım değerlerinin de arttığı tespit edilmiştir.

***Anahtar Kelimeler:** Eriyik yığma modelleme; Polilaktik asit; Çekme dayanımı; Dolgu deseni; Kontur sayısı; Deformasyon hızı.*

1. Introduction

Additive manufacturing (AM), commonly referred to as 3D printing, is a technique that has revolutionized the way products are designed, prototyped, and manufactured (Maraş and Bolat 2025). By enabling the creation of complex, customized products directly from digital models generated through computer-aided design (CAD), AM offers significant advantages over traditional manufacturing methods (Iftekar *et al*. 2023, Tan *et al*. 2020).

The most prominent superiorities include minimizing material waste, shortening production durations, and enabling the creation of custom, highly detailed parts that would be difficult or even impossible to fabricate using

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conventional methods (Ngo *et al*. 2018). These beneficial characteristics have generated considerable interest in its application across various areas, including aviation, automotive, healthcare, consumer goods, etc (Kanishka and Acherjee 2023). The widespread popularity of AM can also be attributed to its capability to work with a broad spectrum of materials. Research has shown that this technique is compatible with a variety of materials, including metals (Gupta *et al*. 2023), thermoplastic polymers (Kakanuru and Pochiraju 2020), ceramics (Nötzel *et al*. 2021), and composites (García *et al*. 2022), as well as innovative smart and biodegradable materials (Puppi and Chiellini 2020), enabling the production of end-use products across diverse industries.

The progress of modern society and the growing variety of needs have influenced the evolution of AM in several ways. In response to these needs, AM, which offers tailored solutions, has been classified into seven categories. Accordingly, AM is categorized as powder bed fusion, material extrusion (fused deposition modeling (FDM)), vat photopolymerization, material jetting, binder jetting, sheet lamination, and directed energy deposition (Valvez *et al*. 2022, Ergene and Yalçın 2023). Among the others, FDM is regarded as one of the most prominent techniques and widely used for the manufacturing of objects with complex geometries, primarily due to affordability and versatility (Wang *et al*. 2020). In FDM, a plastic filament is fed into a heated extrusion nozzle, where it is heated to a temperature above its melting point, turning it into a molten state. This material is then squeezed out through the nozzle, which moves according to a path defined by a code in CAD software. The molten filament is deposited onto a building platform, where it quickly cools and solidifies as it comes into contact with the surrounding environment. The object is progressively built up layer by layer, with each successive layer bonding to the one beneath it, following a carefully controlled deposition process that defines the 3D structure of the part (Zhou *et al*. 2020, Valino *et al*. 2019).

Thermoplastic polymers such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate glycol (PETG), polyamide (PA), and polyethylene (PE) are the preferred and fundamental materials in FDM-based AM technology primarily due to their availability, cost-effectiveness, favorable mechanical properties, and adaptability (Jandyal *et al*. 2022, Ma *et al*. 2024). PLA is a bio-based and compostable thermoplastic typically obtained from renewable resources such as starch, wheat, and sugarcane. Additionally, it contributes to the absorption of a significant amount of carbon dioxide during its production process (Baran and Erbil 2019). Due to its environmentally sustainable production process, PLA is regarded as a more favorable option compared to other petroleum-based polymers. As a bio-based thermoplastic, it has extensive usage, particularly, in FDM-based AM, thanks to its advantageous properties such as a relatively low glass transition temperature and melting point, excellent flowability, and good extrusion characteristics. Its lightweight nature, ease of processing, relatively lower energy demands during processing, good mechanical properties, recyclability, biodegradability, and versatility have all contributed to its widespread popularity and value in various applications (Tejedor *et al*. 2024). PLA is already used in disposable items and eco-friendly packaging applications and is of choice for manufacturing prototypes, toys, functional tools, small household electronics, and customized medical appliances (Lubombo and Huneault 2018). The mechanical properties of the printed parts are often a crucial consideration for their practical use. When reinforced with appropriate materials, PLA composites can serve as a building block of applications demanding superior mechanical performance (Zerankeshi *et al*. 2022). Due to better mechanical characteristics (yield strength, ultimate tensile strength (UTS), modulus of elasticity, etc.) compared to other thermoplastics such as ABS and PETG, PLA may become a material of choice for such implementations (Bolat *et al*. 2025). Its potential use in more durable applications is being explored.

The mechanical properties directly affect the performance and durability of printed parts. Hence, the mechanical characteristics of 3D-printed PLA are critical in determining its suitability for a wide range of applications, from biomedical implants to structural components and consumer products (Tümer and Erbil 2021). The ability of 3D-printed PLA to maintain its tensile strength, elongation at break, and modulus under varying conditions is paramount for ensuring the reliability and functionality of the final product. Therefore, understanding and optimizing the mechanical properties of PLA has become a focal point in the quest to enhance the performance of FDM-printed components (Rouf *et al*. 2022). This focus is further amplified as 3D printing technology is increasingly integrated into applications requiring precise mechanical behavior, such as load-bearing designs and dynamically loaded systems.

A thorough analysis of the current research on FDM and PLA highlights a predominant focus on the investigation and/or optimization of 3D printing process parameters on mechanical properties, particularly tensile strength and elasticity. Numerous studies have explored the effects of parameters such as printing temperature, printing angle, layer thickness, infill rate, printing or extrusion speed, raster orientation and nozzle diameter aiming to develop a comprehensive understanding of their influence on the mechanical behavior of printed parts. The tensile response, being one of the most critical properties for load-bearing applications, has been extensively examined through standardized mechanical testing, often revealing complex interdependencies between printing parameters and material performance. For instance, Tang *et al*. (2020) investigated the mechanical properties of 3D PLA parts, including tensile strength and elastic modulus, across a printing temperature range of 200 to 240 ℃. The mechanical characteristics were optimal at a printing temperature of 230 ℃, reaching 50.16 MPa and 4340.38 MPa, respectively. It was anticipated that lower temperatures resulted in incomplete material melting, while higher temperatures caused cooling issues and defects, both of which reduced performance. Yao *et al*. (2019) reported that the material's UTS was influenced by both printing angle and layer thickness. UTS increased significantly with the printing angle, rising from approximately 27 MPa at 0° to 57 MPa at 90° for a layer thickness of 0.1 mm. However, at the same angle, thicker layers slightly reduced UTS. Besides, fracture analyses showed that in-layer fractures were more common with smaller layer thicknesses (0.1 mm) due to material homogeneity, while interlayer fractures dominated with larger thicknesses (0.3 mm) due to increased stratification. Fracture behavior also shifted from in-layer to interlayer as the printing angle decreased from 90° to 0°. An experimental study was conducted by Wang *et al*. (2020) to investigate how the infill rate influences the dynamic mechanical properties of printed PLA parts. Higher infill rates reduced air gaps, leading to remarkable improvements in elastic modulus, tensile strength, and elongation at break. A key observation was that as the infill rate increased gradually from 20% to 80%, the tensile stress exhibited a moderate rise from 20 MPa to 28.5 MPa. Notably, when the infill rate was further increased from 80% to 100%, the tensile stress nearly doubled, reaching 54 MPa. Research conducted by Kechagias *et al*. (2023) at printing speeds of 30 – 70 mm/min revealed that printing speed was a critical factor influencing the mechanical response of 3D PLA, including toughness, tensile strength, and elastic modulus. As printing speed increased and the interlayer duration decreased, the mechanical response of the material deteriorated. The study of Khosravani *et al*. (2022) emphasized the influence of raster orientation and printing speed on the mechanical properties of 3D-printed parts. PLA specimens printed at 0° had the highest tensile strength and elastic modulus, while those at 90° exhibited a significant reduction in tensile strength, declining by 53.76%. As the raster orientation increased, both tensile strength and elastic modulus progressively decreased. Although printing speed were found had a lesser effect on strength compared to raster orientation, higher speeds reduced extrusion volume and stability, impacting print quality and efficiency. The findings highlighted the combined importance of optimizing raster orientation and printing speed for achieving desired mechanical performance and cost efficiency in 3D-printed components. In the study conducted by Kartal and Kaptan (2023-a), it was shown that nozzle diameter has a significant effect on the tensile strength of PLA material. In experiments with different nozzle diameters between 0.3 mm and 0.8 mm, it was observed that the tensile strength increased as the nozzle diameter decreased. This increase is explained by the thin layers obtained with smaller nozzle diameter, which improves interlayer adhesion. In addition to print parameters, post-processing techniques – particularly thermal treatment have also been shown to influence the mechanical performance of 3D samples (Kaptan and Kartal 2021). For instance, it was shown that the tensile strentgth of the 3D-printed PLA samples could improved almost 50% with an optimized annealing temperature and duration (Kartal and Kaptan 2023-b).

As mentioned earlier, the role of design parameters in determining the mechanical performance of 3D-printed PLA parts has been explored extensively. An analysis of the existing literature indicates that these investigations have predominantly been conducted at constant deformation rates (Rodríguez-Reyna *et al*. 2022, Fountas *et al*. 2023, Demir and Yüksel 2024). Although, influence of deformation rate have been examined in a few research (Vidakis *et al*. 2020, Balasubramanian *et al*. 2024, Altahir *et al*. 2024), there is still scarce attention on this phenomenon. Thus, a critical knowledge gap remains in understanding the synergistic interaction between deformation rate and design parameters in affecting tensile strength. This interaction is particularly important because real-world applications frequently subject parts to dynamic and variable loading conditions. This study seeks to address this gap by systematically investigating the combined effects of deformation rate, contour number, and infill pattern on the tensile strength of 3D PLA parts. By doing so, it aims to provide a deeper understanding of how these factors collectively impact material performance, ultimately contributing to the development of more reliable and application-specific designs. Such insights can drive the optimization of 3D printing processes and empower engineers or manufacturers to produce components with enhanced mechanical properties tailored to their functional demands.

To this end, 3D PLA specimens were fabricated using three distinct infill patterns: cubic, triangle, and zigzag. The outer wall of each specimen was configured with 2, 3, or 4 contour layers to examine the influence of wall thickness on mechanical performance. The tensile properties were evaluated with tests conducted at deformation rates of 1 mm/min, 5 mm/min, and 25 mm/min. Among the selected deformation rates, 5 mm/min corresponds to the standard testing speed commonly used in similar studies, while 1 mm/min and 25 mm/min were selected to capture the tensile behavior relatively at lower and higher deformation rates, respectively.

2. Materials and Methods

In this experimental effort, PLA+ (Beta brand) filament with diameter of 1.75 mm was preferred as the material and detailed material properties of the filament was shared in Table 1.

Table 1. Material properties of the used filament (PLA+) for 3D printing.

Property	Value
Density (g/cm^3)	1.23
Printing temperature range (°C)	210 – 230
Build plate temperature range (°C)	60 – 75
Young Modulus (MPa)	1500
Tensile Strength (MPa)	60
Elongation at break (%)	20
Izod Impact Strength (kJ/m^2)	6
Flexural Strength (MPa)	20

Tensile test samples were designed in Solidworks 2024 program according to ASTM D638 Type IV (Sola *et al.* 2023) and the technical drawing of the samples was presented in Figure 1a. After obtaining the CAD file, BambuLab Studio slicing software was utilized for slicing the part and then BambuLab P1S Combo 3D printer was used for 3D printing process as shown in Figure 1b and Figure 1c, respectively. Figure 1d exhibits the 3D-printed tensile test samples. The fixed and variable FDM parameters assigned to fabricate 3D PLA tensile test specimens were tabulated in Table 2. Since the effect of the number of contours and infill pattern on the tensile strength was investigated in this study, the other parameters were kept constant to give optimum values in the light of other studies in the literature. The details of the variable FDM parameters, namely infill pattern and the number of contours, are shown in Figure 2.

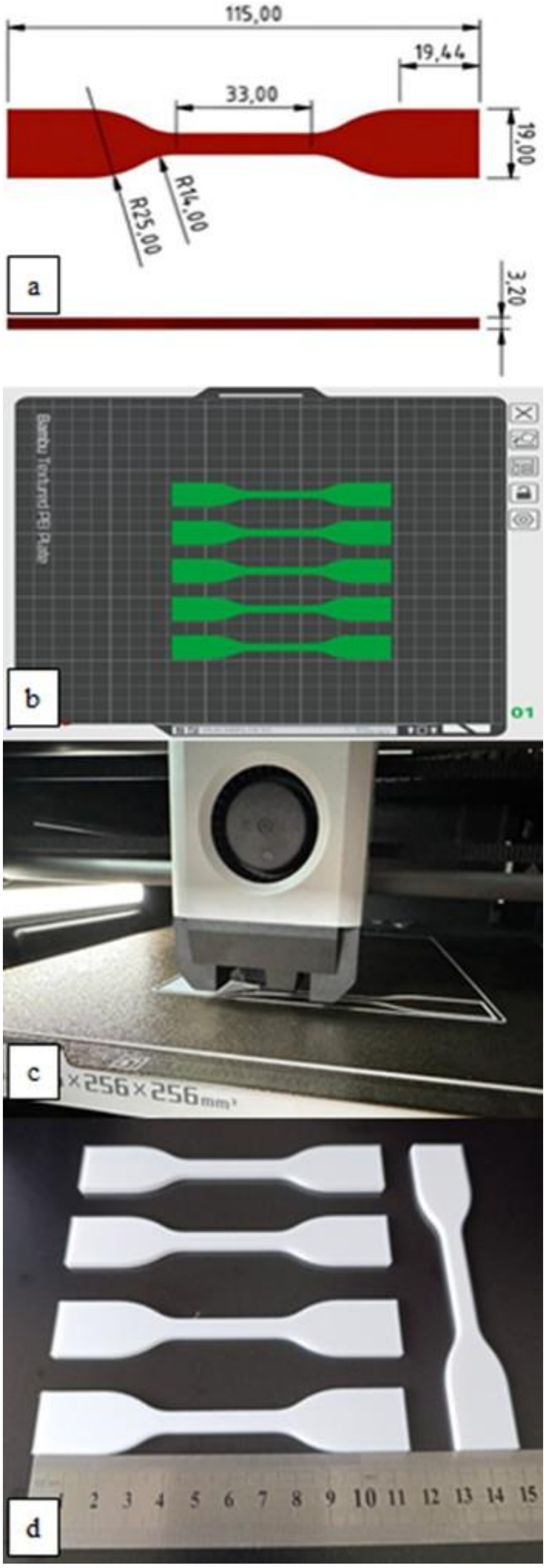

Figure 1. Additive manufacturing steps of the tensile test samples, a) technical drawing of the tensile test sample according to ASTM D638 Type IV, b) view of the samples in slicer software, c) 3D printing process, d) demonstration of the 3D-printed samples.

Following the additive manufacturing of the samples, tensile tests were performed with a Hardway Universal tensile/compression test machine that has a capability of 100kN. Tensile tests were carried out at deformation rates of 1 mm/min, 5 mm/min and 25 mm/min. Maxtext Software was utilized to record the force data during the tensile tests. The recorded force data were then divided by the minimum cross-sectional area of the samples to obtain tensile strength values.

Table 2. Assigned fixed and variable FDM parameters during 3D printing process.

Variable Parameters	
Infill Pattern	Cubic; Triangle; Zigzag
Number of Contour	2; 3; 4
Fixed Parameters	
Infill Rate (%)	50
Layer Height (mm)	0.2
Building Direction	Vertical
Raster Angle (°)	45/-45
Nozzle Temperature (°C)	210
Build Plate Temperature (°C)	60
Printing Speed (mm/sec)	50
Fan Speed (%)	100
Adhesion Type	Brim
Support Structure	None

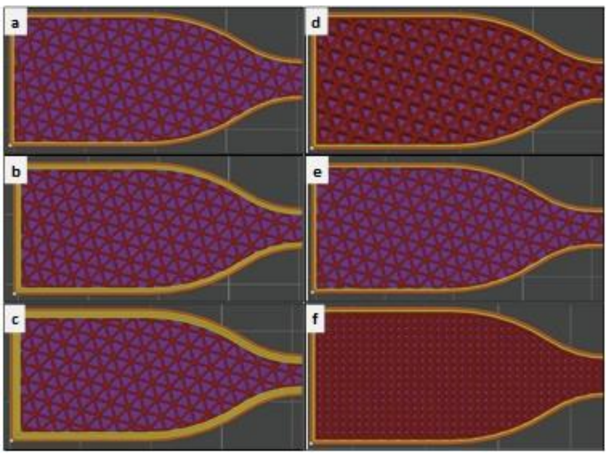

Figure 2. Detailed demonstration of number of contour and infill patterns, a) 2 contour, b) 3 contour, c) 4 contour, d) cubic pattern, e) triangle pattern, f) zigzag pattern.

3. Results and Discussions

As demonstrated in Figure 3, the tensile strength of 3D-printed PLA samples was found to be contingent upon both contour number and infill pattern, with the former being assessed at a test speed of 1 mm/min. The maximum average tensile strength was determined to be 46 MPa, with a standard deviation (SD) of 0.46 MPa, as observed in the 3D-printed sample characterized by a contour number of 4 and a triangle infill pattern. Conversely, the minimum average tensile strength of 35.6 MPa (SD: 0.58 MPa) was observed for the sample produced with a contour number of two and a zigzag pattern. This finding indicates that tensile strength values increase with increasing contour number, and the triangle infill pattern emerges as a preferred infill pattern at a test speed of 1 mm/min.

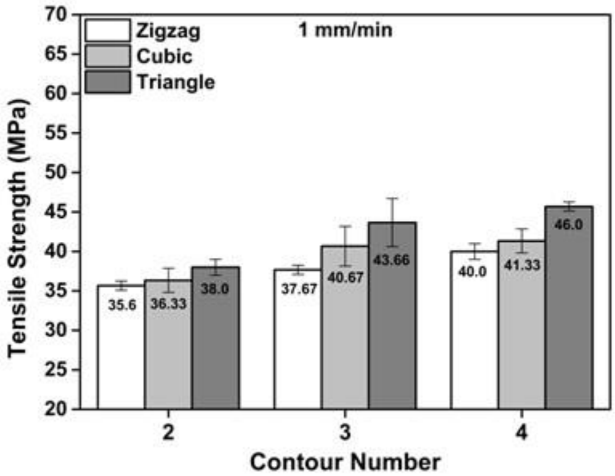

Figure 3. The effect of 1 mm/min deformation rate on the tensile strength of 3D-printed PLA parts with different infill patterns and contour numbers.

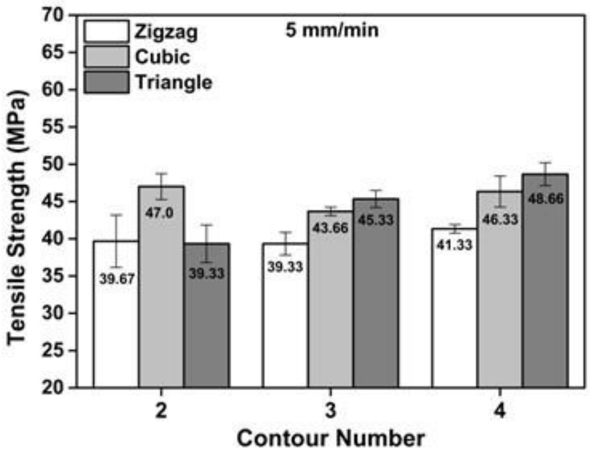

Figure 4. The effect of 5 mm/min deformation rate on the tensile strength of 3D-printed PLA parts with different infill patterns and contour numbers.

In Figure 4, change of tensile strength values of the PLA samples with the variation of contour number and infill pattern under 5 mm/min test speed can be seen. Among the samples with two contour numbers, the specimen with a cubic infill pattern exhibited the highest average tensile strength value of 47 MPa (SD: 1.73 MPa). The cubic specimen was followed by the zigzag and triangle specimens, which exhibited 39.67 MPa (SD: 3.51 MPa) and 39.33 MPa (SD: 2.52 MPa), respectively. In cases where the number of contours was 3 and 4, tensile strengths were determined from high to low in the triangle, zigzag and cubic infill pattern specimens, respectively. In addition, Hikmat *et al*. (2021) investigated the effects of manufacturing parameters on the tensile strength values of PLA samples by Taguchi analysis and reported that the values increased from approximately 47 MPa to 53 MPa with an increase in the number of contours from 2 to 3, while no significant change occurred in the tensile strength values with an increase in the number of contours from 3 to 4. In another study investigating the effect of infill pattern on tensile strength, it was concluded that zigzag infill pattern exhibited higher tensile strength than grid and concentric infill patterns in PLA products (Yeoh *et al*. 2020).

As shown in Figure 5, an increase in tensile strength values is observed with an increase in the number of contours. However, the specimen with a number of contours of 2 and a triangle infill pattern deviates from this general trend. At this test speed, cubic specimens exhibited the highest tensile strength values when the number of contours was 2 and 3, while specimens with a triangle infill pattern demonstrated the highest tensile strength values when the number of contours was 4.

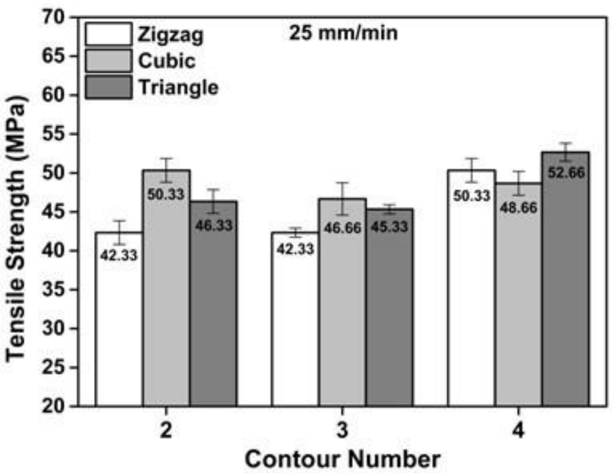

Figure 5. The effect of 25 mm/min deformation rate on the tensile strength of 3D-printed PLA parts with different infill patterns and contour numbers.

When the displacement rate vs. tensile strength graph given in Figure 6 is analysed, it is clearly seen that the tensile strength values increase with the increase in displacement rate from 1 to 25 mm/min. Although it was determined that the tensile strength values of the specimens with triangle infill pattern showed a near-linear increase with the increase in displacement rate, this near-linear increase trend did not occur in the specimens with cubic and zigzag infill patterns. The tensile strength value of 38 MPa (SD: 1 MPa) in the specimen with triangle infill pattern reached 39.33 MPa (SD: 2.52 MPa) at 5 mm/min and 46.33 MPa (SD: 1.53 MPa) at 25 mm/min displacement rate. In the cubic specimen, tensile strength values for 1, 5 and 25 mm/min displacement rates were calculated as 36.33 MPa (SD: 1.53 MPa), 47 MPa (SD: 1.73 MPa) and 50.33 MPa (SD: 1.53 MPa), respectively. The tensile strength values of the zigzag specimen were 35.6 MPa (SD: 0.58 MPa) at 1 mm/min, 39.67 MPa (SD: 3.51 MPa) at 5 mm/min and 42.33 MPa (SD: 1.53 MPa) at 25 mm/min.

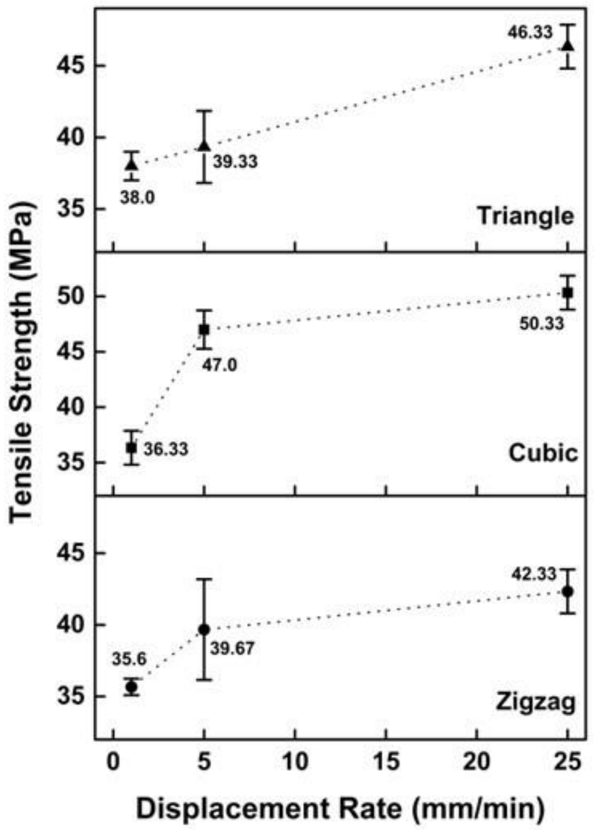

Figure 6. Comparison of the impact of varied deformation rates on the tensile strength of 3D-PLA parts prepared with different filling patterns (all specimens have a contour number of 2).

It was determined that the experimental results obtained from this study significantly overlap with the results of other studies in the literature. For example, the specimens produced from PLA material by FDM were subjected to tensile tests at five different test speeds of 2, 4, 6, 8 and 10 mm/min by Zhan *et al*. (2024). As a result, they suggested that tensile strength values of 39.02 MPa (SD: 2.2 MPa), 38.54 MPa (SD: 5.1 MPa), 42.33 MPa (SD: 4.5 MPa), 48.09 MPa (SD: 3.4 MPa) and 52.11 MPa (SD: 3.5 MPa) occurred at test speeds of 2, 4, 6, 8 and 10 mm/min, respectively. A consideration of the results of the present study and that of Zhan *et al*. (2024) reveals an increase in tensile strength with increasing displacement rate. This phenomenon can be attributed to the viscoelastic behaviour exhibited by polymers such as PLA, which is temperature-dependent and subject to variation in duration. It was established that specimens subjected to low displacement rates exhibited elevated temperatures, while those subjected to high displacement rates demonstrated reduced temperatures (Ilie 2023, Wang and Kari 2020). In addition, in a study conducted by Luo *et al.* (2022) which investigated the effect of deformation rate on the tensile properties of PLA parts fabricated using FDM, it was reported that the components produced via FDM inherently contain porosity and voids due to the layered nature of the 3D printing process. These inherent defects were found to contribute to a tendency toward brittle fracture, rather than ductile behavior, particularly under increasing deformation rates.

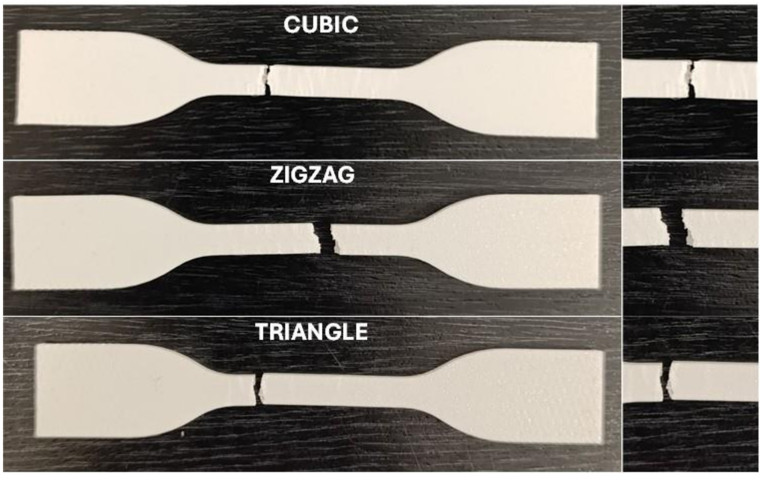

Figure 7. Macroscopic views of the 3D-PLA specimens produced with different infill patterns deformed with a test speed of 5 mm/min (all specimens have a contour number of 2).

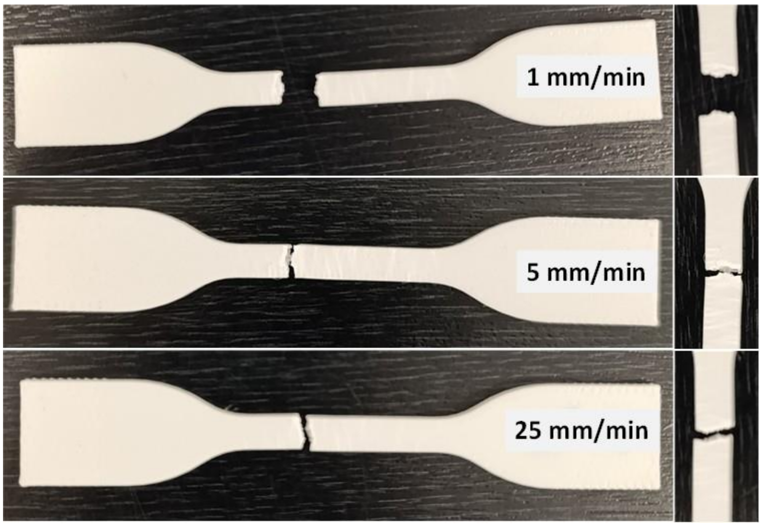

Figure 8. Macroscopic views of the 3D-PLA samples having cubic infill pattern deformed with different deformation rates (1 mm/min, 5 mm/min, 25 mm/min) (all specimens have a contour number of 2

The macroscopic images of specimens with cubic, zigzag and triangle infill patterns produced with two contour numbers tested at a displacement rate of 5 mm/min are presented in Figure 7. It can be stated that fractures occur in two cases: inter-layer and in-layer, especially in parts produced by additive manufacturing (Khosravani *et al*. 2022). In the inter-layer fracture type, a fracture occurs parallel to the layers forming the part, while in the in-layer fracture, a fracture occurs independently of the layers, except parallel to the layers. The specimens fabricated within the scope of this study were produced with a raster angle of 45° / -45°, and it can be concluded that zigzag specimens showed inter-layer fracture, while cubic and triangle specimens showed in-layer fracture. In addition, cubic and triangle specimens showed a relatively more ductile behaviour than zigzag specimens. As demonstrated in Figure 8, the fracture images of the specimens produced with two contours and a cubic infill pattern following tests at 1, 5 and 25 mm/min displacement rates reveal a transition in fracture behaviour from ductile to brittle as the displacement rate increases from 1 mm/min to 25 mm/min. This observation underscores the pivotal role of displacement rate in determining the mechanical properties of polymer components fabricated by FDM.

4. Conclusions

This study examined how infill pattern, contour number, and deformation rate affect the tensile strength of 3D-printed PLA parts. Zigzag, triangular, and cubic patterns were tested with 2, 3, and 4 contours at deformation rates of 1, 5, and 25 mm/min. The remarkable outcomes of this experimental study can be summarized as follows:

- ✓ The triangular infill gave the best strength, making it a good option for industrial use.
- ✓ More contours generally led to higher tensile strength.
- ✓ Increasing the deformation rate improved strength by 4% to 39%, depending on the pattern and contour combination.
- ✓ Zigzag patterns showed interlayer fractures, while cubic and triangular ones had in-layer fractures.
- ✓ All samples mostly failed in a brittle manner.

This research demonstrated that both deformation rate and print parameters significantly affect the mechanical behavior of the PLA parts. Building upon these findings, future research should explore a wider range of materials and process conditions, using structured experimental approaches such as the Taguchi method. Additionally, advanced modelling tools like Response Surface Methodology (RSM) and Artificial Neural Networks (ANN) could be employed to better understand complex parameter interactions and to optimize settings for improved mechanical performance.

Declaration of Ethical Standards
The authors declare that they comply with all ethical standards.

Credit Authorship Contribution Statement
Author 1: Investigation, Resources, Methodology, Writing – review
Author 2: Investigation, Resources, Methodology, Writing – review
Author 3: Conceptualization, Investigation, Data curation, Validation, Resources, Methodology, Writing – original draft and editing, Visualization, Supervision
Author 4: Conceptualization, Investigation, Data curation, Validation, Resources, Methodology, Writing – original draft and editing, Visualization, Supervision

Declaration of Competing Interest
The authors have no conflicts of interest to declare regarding the content of this article.

Data Availability Statement
All data generated or analyzed during this study are included in this published article.

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