PRODUCTION AND INVESTIGATION OF MECHANICAL PROPERTIES OF 1 WT% GLASS FIBER REINFORCED ABS MATERIAL VIA SLA 3D PRINTING

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ABSTRACT: *In this study, composite specimens were produced using the stereolithography (SLA)-based 3D printing method by reinforcing an acrylonitrile butadiene styrene (ABS)-based polymer matrix with 1 wt% of 3 mm long glass fibers. The aim of the study is to investigate the effect of low-ratio fiber reinforcement on the mechanical performance of parts produced via the 3D printing process.*
The glass fiber additive was homogeneously dispersed within the resin via mechanical mixing, followed by the fabrication of specimens using the SLA method. Tensile and flexural tests were conducted on the produced neat ABS and 1% glass fiber-reinforced composite specimens. The obtained results indicated that the low fiber content did not yield a significant increase in the tensile and flexural strength of the material. Weak fiber-matrix interfacial bonding and low fiber volume are considered the primary reasons for this outcome.
In conclusion, the mechanical improvement effect of low-ratio glass fiber reinforcement remained limited in ABS-based composites produced via the SLA method. For future studies, it is recommended to increase the fiber content, perform surface modifications, or optimize parameters controlling fiber orientation.

KEYWORDS: *ABS, Glass Fiber, Composite Material, 3D Printing, Stereolithography, Tensile Test, Flexural Test.*

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1. INTRODUCTION

Additive manufacturing (AM) technologies have revolutionized many sectors, such as aerospace, automotive, and biomedical, thanks to the design flexibility, material efficiency, and customization capabilities they provide in producing complex geometries(Fidan et al., 2023; Soori & Arezoo, 2025). Among these technologies, Stereolithography (SLA), which is based on the layer-by-layer curing of liquid photopolymer resins, stands out for offering high surface quality and dimensional precision(Susanto et al., 2025). However, the mechanical properties (tensile strength, hardness, etc.) of neat polymer parts produced by SLA are generally lower compared to parts produced by conventional manufacturing methods, and this limits the use of the technology in load-bearing structural applications(Sano et al., 2018; Susanto et al., 2025).

To enhance the mechanical performance of parts produced via SLA, the incorporation of reinforcement elements such as carbon fibers, glass beads, or glass fibers into the matrix material has become a common research topic(Hristophh, n.d.). In particular, glass fiber (GF) reinforcement is frequently preferred in polymer matrix composites due to its high strength-to-weight ratio and cost-effectiveness. Studies in the literature indicate that the effect of fiber reinforcement on mechanical properties depends on the fiber type (short or continuous), fiber volume fraction, and the interfacial interaction between the fiber and the matrix(Sahin et al., 2018; Sano et al., 2018). For instance, Susanto et al. (2025) reported that glass powder reinforcement increased the tensile strength and hardness of SLA resins but decreased the ductility of the material (Susanto et al., 2025). Similarly, Sano et al. (2018) reported that the use of continuous fibers in the SLA method significantly improved mechanical properties, but noted the difficulty in controlling the homogeneous dispersion and orientation of short fibers within the matrix(Sano et al., 2018).

One of the most significant challenges encountered in SLA-based composite production is the weak interfacial bonding between the fiber and the resin. Sahin et al. (2018) emphasized that surface modification of glass fibers (such as silanization) strengthens the chemical bonding with the matrix, which directly affects the ultimate strength of the composite(Sahin et al., 2018). Furthermore, in studies conducted by Moharana et al. (2024), it was stated that increasing the fiber volume fraction leads to viscosity issues, complicating the 3D printing process; however, reinforcements remaining below a certain ratio (such as 4%) may not provide the expected improvement in mechanical properties(Moharana et al., 2024). Hager (2023) stated that in short fiber-reinforced photopolymers, problems such as fibers protruding from the part surface and random orientation are factors limiting production quality and mechanical performance(Hristophh, n.d.).

Although the effects of high fiber ratios or complex surface treatments have generally been investigated in the existing literature, studies examining the "threshold" effect of very low-ratio and untreated fiber reinforcement are limited. In this study, composite specimens were produced via the SLA method by reinforcing an acrylonitrile butadiene styrene (ABS)-like photopolymer resin with 1 wt% short glass fiber (3 mm). The main aim of the study is to experimentally investigate the effects of low fiber ratio and fiber size on the tensile and flexural strength of parts produced by 3D printing and to evaluate the contribution of fiber-matrix interfacial interaction to mechanical performance.

2. MATERIAL AND METHOD

In this study, the production of fiber-reinforced polymer composites using the stereolithography (SLA) technique and the determination of their mechanical properties were aimed. The experimental process was carried out in four main stages: material procurement, preparation of the composite mixture, specimen printing, and mechanical testing.

2.1. Materials

A commercial photopolymer resin exhibiting Acrylonitrile Butadiene Styrene (ABS)-like properties, known for its high impact resistance and widespread use in industrial applications, was selected as the matrix material. Glass fibers (GF) with an average length of 3 mm were utilized as the reinforcement element. Within the scope of the study, the composite structure was formed by adding 1 wt% glass fibers into the matrix.

2.2. Preparation of the Composite Mixture

In the SLA method, the homogeneous dispersion of fillers within the resin is of critical importance in terms of print quality and mechanical performance. In this study, 3 mm glass fibers at a ratio of 1 wt% were added to the liquid ABS-based resin. In order to prevent agglomeration of the fibers within the resin and to achieve a homogeneous suspension, the mixture was mixed via mechanical stirring at a speed of 400 rpm for 5 minutes. Following the mixing process, the mixture was allowed to rest for a short period to remove air bubbles entrapped within the structure.

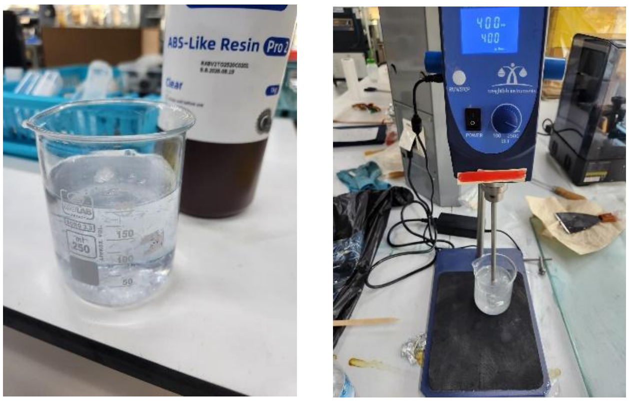

Figure 1. Mixing process of the fiber-reinforced ABS-like resin performed at 400 rpm for 5 minutes.

2.3. Specimen Production

The production of composite specimens was carried out using an Anycubic Mono 6Ks model Masked Stereolithography (MSLA) based 3D printer. During the printing process, parameters optimized in accordance with the curing characteristics of the fiber-reinforced resin were utilized.

The device parameters were set as follows:

- **Layer Thickness:** 0,040 mm (40 µm)
- **Exposure Time:** 2,500 seconds

Upon completion of the printing process, the specimens were carefully removed from the platform and washed in an isopropyl alcohol (IPA) bath for 30 minutes to remove uncured resin residues from the surface. Following the washing process, the specimens were subjected to post-curing for 180 minutes in a UV curing unit with a wavelength of 405 nm to ensure complete polymerization and achieve the final mechanical stability of the material.

Figure 2. Images of the specimens after 3D printing

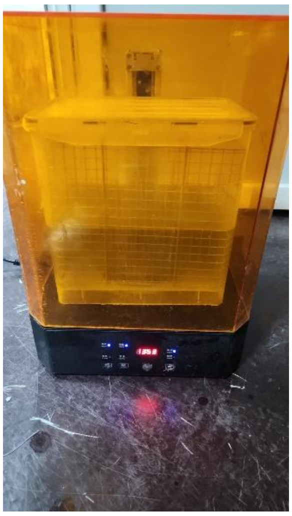

Figure 3. Washing of the 3D printed specimens in an isopropyl alcohol (IPA) bath for 30 minutes to remove uncured resin.

Figure 4. Curing process at 405 nm wavelength for 180 minutes.

3. MECHANICAL TESTS

In order to characterize the mechanical behaviors of the produced neat and composite specimens, tensile strength and modulus of elasticity were determined in accordance with the DIN EN ISO 527-1 standard. In this context, the tests were conducted at a tensile speed of 5 mm/min, while the modulus of elasticity calculations were based on a speed of 1 mm/min. Flexural strength and modulus were analyzed using the 3-point bending method at a test speed of 2 mm/min, with reference to the DIN EN ISO 178 standard. Five specimens were tested for each experimental group to calculate the means and standard deviations of the obtained data, thereby evaluating the changes in strength and stiffness of the materials.

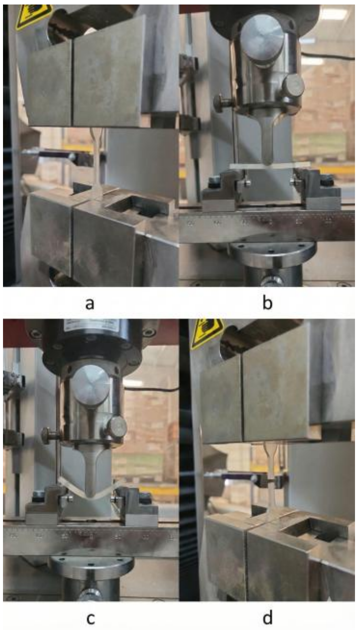

Figure 5. Illustration of tensile and flexural tests performed according to ISO 527-1 and ISO 178 standards.

4. RESULTS

In this study, the mechanical performance of neat ABS resin and 1 wt% short (3 mm) glass fiber (GF) reinforced composite specimens produced via the stereolithography (SLA) method was characterized through tensile and flexural tests. The obtained experimental data reveal the effect of low-ratio fiber reinforcement on the mechanical properties.

4.1. Tensile Test Results

A comparison of the tensile properties specifically Modulus of Elasticity, Tensile Strength, and Elongation at Break is presented in Table 1. This includes the graphs, means, and standard deviations derived from tests on neat ABS and 1% GF reinforced samples.

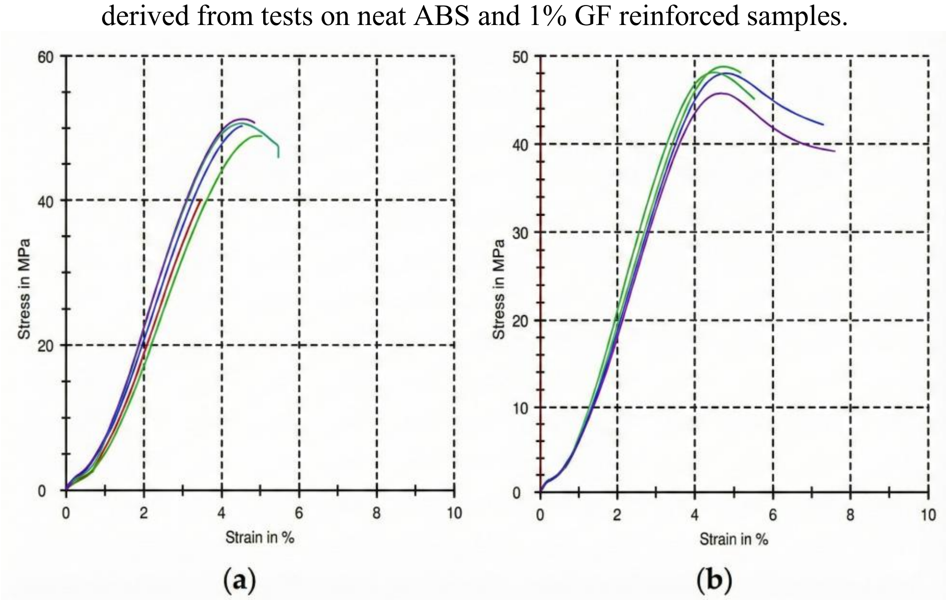

Figure 6. Tensile test graphs of (a) neat ABS resin and (b) fiber-reinforced ABS resin.

Table 1. Comparison of tensile test results of neat ABS resin and fiber-reinforced ABS resin.

Material Group	Tensile Modulus (MPa)	Std. Dev. (Modulus)	Tensile Strength (MPa)	Std. Dev. (Strength)	Elongation at Break (%)	Std. Dev. (Elongation)
Neat ABS	443.29	31.49	47.76	1.16	05.09	03.04
1% GF ABS	473.32	126.68	48.25	4.57	4.54	0.69
Variation (%)	+6.77%	-	+1.02%	-	-10.80%	-

As detailed in Table 1, the tensile test data reveals that incorporating 1 wt% glass fiber enhanced the material's stiffness. While the average modulus of elasticity of the neat ABS specimens was 443.29 MPa, this value increased by approximately 6.8% with fiber reinforcement, reaching 473.32 MPa. This increase is attributed to the fact that glass fibers possess a significantly higher modulus of elasticity compared to the polymer matrix and partially undertake the load transfer.

Another noteworthy point is the standard deviation values. While the standard deviation for the modulus was 31.49 MPa in neat ABS specimens, this value rose to 126.68 MPa in the fiber-reinforced specimens. This indicates that the mechanical mixing method used during the production process could not distribute the fibers with perfect homogeneity in every specimen and that fiber orientation varied from specimen to specimen.

No statistically significant increase was observed in the ultimate tensile strength (1.02% increase). Furthermore, the fact that fiber reinforcement rendered the material more brittle was confirmed by a 10.8% decrease in elongation at break, dropping from 5.09% to 4.54%.

4.2. Flexural Test Results

The flexural test outcomes for the specimens are tabulated in Table 2, which includes both the average values and the corresponding standard deviations.

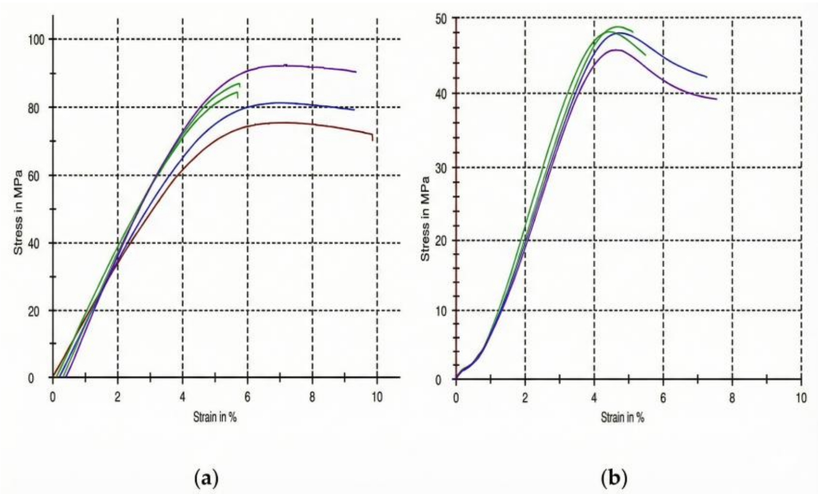

Figure 7. Flexural stress-strain curves of (a) neat ABS resin and (b) fiber-reinforced ABS resin.

Table 2. Comparison of flexural test results of neat ABS resin and fiber-reinforced ABS resin.

Material Group	Flexural Modulus (MPa)	Std. Dev. (Modulus)	Flexural Strength (MPa)	Std. Dev. (Strength)	Flexural Strain (%)	Std. Dev. (Strain)
Neat ABS	1986.67	111.77	82.79	1.91	6.27	0.06

1% GF ABS	1921.14	212.91	84.15	6.32	6.36	0.78
Variation (%)	-3.30%	-	+1.64%	-	+1.43%	-

The flexural test data (Table 2) revealed a different trend compared to the tensile tests. Contrary to expectations, the 1% glass fiber reinforcement caused a slight decrease of 3.3% in the flexural modulus. A negligible increase of 1.64% was observed in the flexural strength.

A closer look at the standard deviation data reveals that the variability in the flexural modulus of the fiber-reinforced samples is approximately twofold higher than that of the unreinforced ones. This high variation indicates that the fibers were randomly oriented between layers or relative to the printing plane during the SLA process, and that the reinforcing effect of the fibers was not fully realized in some specimens. As also stated in the literature, at low fiber ratios and in cases of weak interfacial bonding, fibers may act as defects within the matrix, hindering load transfer.

In summary, the addition of only 1% untreated glass fiber to the resin was insufficient to significantly strengthen the material. Although the material exhibited slightly increased stiffness [in tensile mode], the results varied significantly from specimen to specimen. This indicates that the fibers were not uniformly distributed throughout the resin. To achieve better results, it is necessary to either improve the mixing method or apply a surface treatment to the fibers.

5. DISCUSSION

The study reveals that adding 1 wt% short glass fiber to the ABS-like matrix offers constrained mechanical benefits. The primary factors limiting performance are identified as the weak fiber-matrix bonding and the low volume fraction of the reinforcement. While the high stiffness of the glass fibers led to a 6.77% increase in the tensile modulus of the composite, the ultimate tensile strength remained almost unchanged, and the flexural modulus exhibited a slight decrease of 3.3%, suggesting that the untreated fibers acted as structural defects rather than effective reinforcement elements under complex stress states. Furthermore, the significantly higher standard deviations observed in the composite specimens compared to the neat resin point to inhomogeneous fiber dispersion and random orientation caused by the mechanical mixing process, ultimately revealing that a 1 wt% loading ratio is below the critical threshold required for a significant mechanical enhancement without surface modification.

6. FINDINGS

The experimental analysis of the neat and composite specimens revealed distinct mechanical behaviors. The incorporation of 1 wt% glass fiber resulted in a 6.77% increase in the tensile modulus, indicating an improvement in stiffness. Despite the reinforcement, the ultimate tensile strength remained statistically unchanged (+1.02%). Conversely, a 10.8% drop in elongation at break was observed, indicating a loss in ductility. In contrast to the tensile properties, the flexural modulus exhibited a decrease of 3.3% with fiber reinforcement, and the flexural strength showed only a negligible increase of 1.64%. Additionally, the standard deviation values for the composite specimens were significantly higher than those of the neat resin for instance, the deviation in tensile modulus rose from 31.49 MPa to 126.68 MPa indicating a high variability in mechanical performance across different specimens.

7. CONCLUSION

Based on the findings of this study, It can be inferred that the addition of a low concentration (1 wt%) of untreated glass fiber is insufficient to provide a substantial improvement in the overall mechanical strength of SLA-printed parts. Although the reinforcement slightly enhanced stiffness, the decrease in flexural modulus and the lack of tensile strength improvement suggest that the fibers acted as structural defects or stress concentrators due to weak interfacial bonding and low volume fraction. Furthermore, the high variance observed in the test results demonstrates that the mechanical mixing method employed was not fully effective in ensuring a homogeneous dispersion and consistent orientation of the fibers during the 3D printing process. Therefore, to achieve significant mechanical enhancement in SLA-based composites, future research should focus on surface modification of fibers, such as silanization, and the investigation of higher fiber loading ratios.

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