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Effect of Support on Tensile Strength of Stereolithography Products

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Abstract. Stereolithography (SLA) is a 3D printing technology commonly used in many fields. This advanced printing technology makes it possible to produce a wide range of products with smooth surfaces with high precision. Nowadays, 3D printing technology is the Top most effective with almost absolute accuracy. Support is still needed to print corner protrusions. Still, a more significant concern is to minimize the cross-sectional area at each print layer to avoid bias when removing a print layer from the silicone. Support structures in small columns or frame structures to keep the model in the correct position during printing are often created in preparation for stereolithography 3D printing. These structures are printed with the model and removed after printing. The support structure has an essential influence on the quality and accuracy of the 3D-printed product. In this study, the survey model is fabricated based on SLA 3D printing technology with different support structures, and the mechanical properties of acrylonitrile butadiene styrene like resin (ABS like resin) are tested. Check the parameters on the compression testing machine, and the results show that the two-headed support structure is optimal for the surveyed plastic materials.

Keywords. SLA; Support; ABS like resin; Tensile strength; Microstructure.

1. Introduction

Stereolithography (SLA) is a three-dimensional (3D) printing technology commonly used in many fields. This advanced printing technology makes it possible to produce a wide range of products with smooth surfaces with high precision. SLA stands for Stereolithography, an additive manufacturing process in the photopolymerization family. SLA is selectively treated polymer resin layer by layer through ultraviolet (UV) beam irradiation, from which the object is made. The materials selected in SLA are all thermosensitive, liquid polymers.

In 3D printing technology, SLA is known as 3D printing technology, first invented in 1980 by Dr. Kodama[1]. Nowadays, 3D printing technology is the top most effective with almost absolute accuracy. SLA has much in common with direct light processing (DLP) or photopolymerization 3D printing technology, two similar technologies.

The SLA operation procedure is carried out as follows: In a photopolymer liquid tank, the print tray is submerged in a bath of liquid resin solution a fragile distance from

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the liquid surface (the tray is covered with a layer of liquid resin). The UV rays shine directly through the UV reflectors on the support tray, curing the liquid layer into a solid forming a precise cross-section of the part[2-9]. After each print layer is solidified, the print tray moves by one step, equal to the thickness of the print layer in the liquid, and the re-sweeping blade distributes the resin upwards in preparation for the formation of a new print layer. The part will be removed from the tank at the end of the printing process. If the printed parts need to be heat resistant and have mechanical properties required, they will be post-cured under UV light. Through this photopolymerization process, the liquid resin will solidify, and under UV light, they will activate the carbon monomer chains to harden the liquid plastic. From there, the detail is enhanced mechanically and, at the same time, forms an unbreakable bond.

With SLA technology, the print layer thickness can range from 25 to 100 µm[10]. The lower the print layer thickness, the more precise the fabrication of curved surfaces. However, with a thin printing layer, there will be a long manufacturing time, high cost, and a higher probability of printing failure. Typical applications typically have a print layer thickness of 100 µm. Top-down or bottom-up SLA 3D printers have different support systems. This series has the same support system as FDM. The support system is required when printing protrusions or hollows. The support angle is usually 30° with critical bows[11-15]. To reduce the number of printing layers, the printed product is traditionally printed flat horizontally during installation. SLA printer from the bottom up: The support system of this model is quite complicated. Support is still needed to print corner protrusions. However, a more significant concern is to minimize the cross-sectional area at each print layer to avoid bias when removing a print layer from the silicone. Therefore, when printing SLA from the bottom, the detail will often be placed on the side, and the need to strengthen the support parts is not too affected.

2. Materials and Methods

Acrylonitrile butadiene styrene like resin (ABS like resin) has similar properties to ABS plastic, such as high toughness, high precision, high detail and stability, better temperature resistance, and lower viscosity makes it achieve a higher print speed. The properties and parameters of the plastic are shown in table 1. Conduct experiments with specimens created according to ASTM 638 Type IV with a length of 115 mm, width of 19 mm, and thickness of 3.4 mm, as shown in figure 1. The angle of inclination is 15°, with three different types of support structures: Sample S1 is an anti-2-headed support structure; sample S2 evenly resists the whole bar structure; sample S3 evenly resists the entire bar, but the middle resists much, as shown in figure 2a, 2b, and 2c.

Table 1. ABS like resin and product parameters.

Product name: ABS like resin	Molding surface hardness: 80 - 85D
Absorption band: 405 nm	Viscosty: 100 - 350 MPa.s
Net weight: 500 g - 1.0 kg	Shrinkage: 3.62 - 4.24%
Printing speed: 2 - 18 s/layer	Applicable models: Most LCD/ DLP printers
Color: White, yellow. blue, black, gray, skin color, transparent light blue, transparent green	

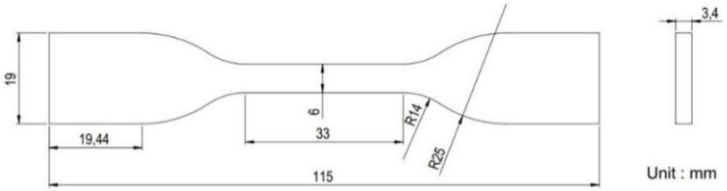
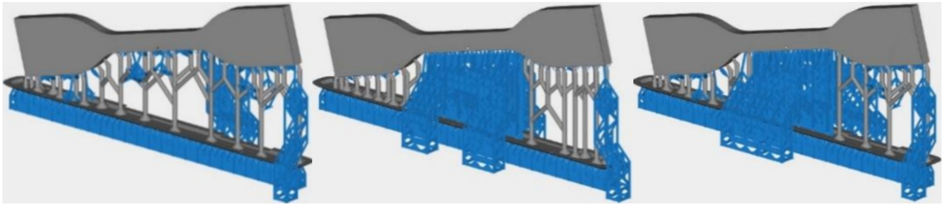


Figure 1. Specimen drawings are investigated according to ASTM 638 Type IV [16].



a) Sample S1 b) Sample S2 c) Sample S3

Figure 2. The support structure of samples.

Use the Zongheng3D Super Maker SLA-600 printer (table 2 and figure 3) to print samples with each supporting structure of five pieces. After printing, three groups of samples will conduct a tensile test of the specimen on the Testometric M350-10 Compression Tensile Test Machine (figure 4) with the parameters: Machine capacity 10 kN, speed range 0.001 to 1000 mm/min in steps of 0.001 mm/min, crosshead travel (excluding grips) 1100 mm, and throat 295 mm. From there, compare which group of samples with support structures has better mechanical properties.

Table 2. Specifications Zongheng3D Super Maker SLA-600 printer.

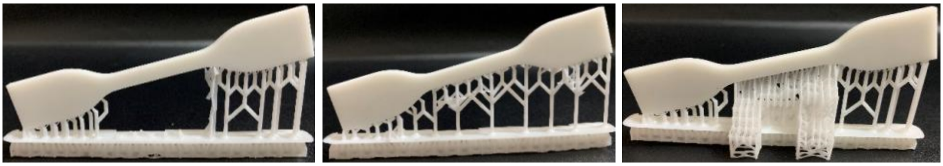
FEATURES	DESCRIPTION
Laser Type	Pulse, UV, all solid-state laser
Wavelength	355 nm
Laser Power	3 w
Coating Method	Automatic vacuum adsorption coating
Print Layer Thickness	0.05-0.2 mm
Material Volume	180 l about 225 kg
Spot Diameter	0.12-0.6 mm
Operating Software	ZH6.0
Equipment Weight	About 860 kg (Excluding materials)
Vertical Repeat Positioning Accuracy	± 0.002 mm
Horizontal Repeat Positioning Accuracy	± 0.001 mm
Maximum Manufactured Part Weight	70 kg
Reference Fabrication Weight	50-180 g/h
Power Supply Parameters	220 V/ 50 Hz
Recommended Print Layer Thickness	0.1 mm
Maximum Forming Volume	600 x 600 x 400 mm (customizable)
Recommended Part Scanning Speed	6000 mm/s
Recommended Jumping Speed of Parts	1200 mm/s
Working Ambient Temperature	20-28 °C

Figure 3. Zongheng3D Super Maker SLA600 printer.

Figure 4. Testometric Compression Tensile Tester M350-10.

3. Results and Discussion

After printing, the sample results of three groups of samples are obtained in the order as shown in figure 5.



a) Sample S1 b) Sample S2 c) Sample S3

Figure 5. Specimens obtained after printing.

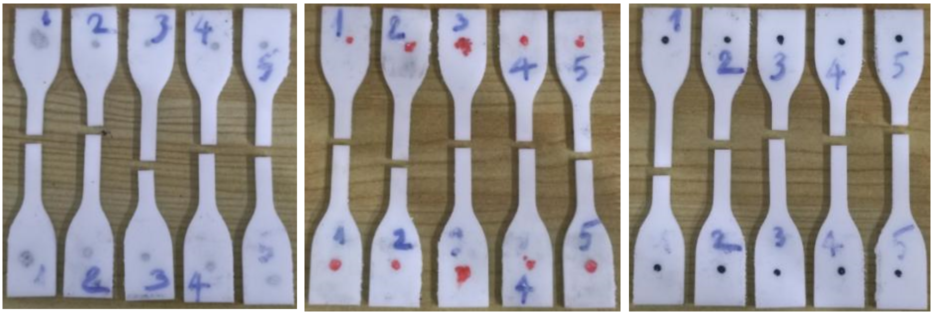
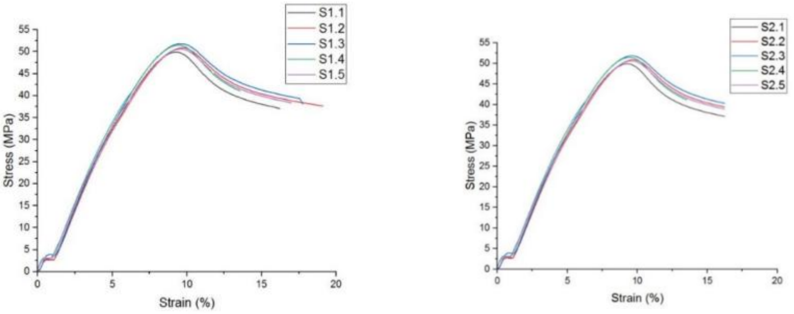


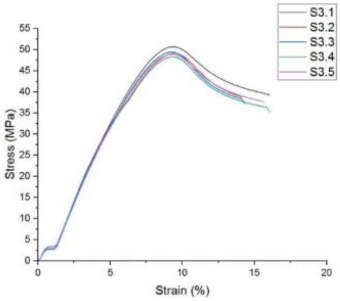
Figure 6. Tensile samples after testing.

After conducting tensile testing (figure 6), we obtained data and force and displacement of sample groups. Data processing is carried out to evaluate the optimum level of the experiment, and a graph showing the stress and deformation of the sample is obtained using Origin software, as shown in figure 7 and figure 8. The Stress-strain curves of samples indicate that the support structures surveyed have negligible effects on the tensile strength of ABS like resin plastic materials after SLA printing with support structures, as shown above.

Based on figure 7, the stress and strain of each group of samples are almost equal, and the elastic deformation is low, so ABS like resin material is suitable for household products and medical applications. The product does not bear large loads.



a) Sample S1 b) Sample S2



c) Sample S3

Figure 7. Stress-strain curves of samples.

Looking at figure 8, sample S1 has the highest ultimate strength with a value of 47.28 MPa, followed by sample S3 with a value of 46.2 MPa, and finally, sample S2 with a value of 44.06 MPa. The importance of the three samples does not have large deviations, so the support design has little effect on the tensile strength of this material. Namano S. et al. [5] showed that with the same printing angle, the number of support structures and their distribution have little effect on the printed part result. Reducing support has a relatively small impact on accuracy. Comparing studies related to the design of support for SLA printing [17-19] with materials other than those studied by this research, the studies concluded that support has little effect on tensile strength. However, there is a disadvantage: without support, materials will be saved, but accuracy will decrease compared to cases with support[20-22].

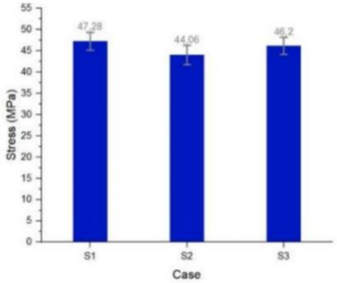


Figure 8. Diagram of average stress of three samples.

4. Conclusions

The stress and deformation charts results show that the tensile values of the above three samples are almost the same, without much difference—elastic deformation of printed samples with low ABS like resin materials. The support design does not affect the tensile strength of the product much. An anti-2-head support structure sample will be optimal for the surveyed plastic material since this structure has the least material, the simplest type, and good product surface quality. Thus, it can be concluded that by reducing the support structure of 3D printed products, it is possible to achieve optimal accuracy while saving resources and costs.

This study examined only different types of support structures in the same detail. In the future, the authors will investigate the experimental planning of many parameters simultaneously affecting the part's mechanical properties, such as support angle, part thickness, printing temperature, and print speed to find the most optimal parameters for the supported structured SLA 3D printing method.

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