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Original Article

Impact on Mechanical Properties of Thermoplastic Elastomers (TPE) Using Different Printing Directions in Additive Manufacturing

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Abstract *- One rapidly developing technology is 3D printing. These days, 3D printing is used all over the world. It is being utilized more and more in a variety of fields for the mass production and customization of all open-source designs. In recent years, there has been an increase in public awareness of and research into the potential of additive manufacturing as a replacement for traditional production methods. This study aims to propose the 3D-printed technique for different printing positions to evaluate the mechanical properties of Thermoplastic Elastomers, namely, Filaflex SEBS, and to prefer the same printing parameters for every direction. Then carried out the material testing on a Universal Testing Machine (UTM) for tensile strength, Young´s modulus, and elongation at break. The graphs are illustrated between them. In addition, discussed the load acting direction to the printing direction and layer interface.*

Keywords *- Thermoplastic Elastomers, 3D printing technology, additive manufacturing, Filaflex SEBS, Universal testing machine (UTM), layer interface.*

1. Introduction

One of the most popular rapid prototyping methods worldwide is Fused Deposition Modelling (FDM). The primary factors influencing its rising popularity and stability, safe and easy manufacturing process, low material cost, and accessibility of a range of building thermoplastics have all contributed to its widespread use[1]. The layer-by-layer deposition of extruded material through a nozzle utilizing feedstock filaments from a spool is how the FDM systems, invented by Stratasys Inc., now produce parts in elastomers, ABS, and investment casting wax[2].

In the FDM melt extrusion process, which uses CNC programming for component manufacturing, the material (polymer melt) that has been extruded through the nozzle head is directed onto the print bed and hardened right away. The movement works in 3 directions: X, Y, and Z axes; the nozzle head moves in the X and Y axes, and the print head moves in the Z axis. Processing the printing below the substrate's melting point is necessary to guarantee improved dimensional stability of the component created[3]. The type of initial component processing (grinding, extrusion, etc.) determines the mechanical sustainability of the fabricated part. Rotational speed, torque, barrel temperature, and other input variables during filament processing also have a significant impact on the mechanical sustainability of the FDM fabricated parts[4].

Usually, have many references on 3D printing regarding the influence of mechanical properties, printing parameters, and printing direction. The research on parameters and printing direction on ABS material can influence the tensile strength of the sample for an increase in infill rate, and laterally, the printed sample has a change[5]. The effect on mechanical properties is influenced by the change in infill rate, as well as specific changes in hardness to increase in infill[6].

This study looked at how the printing direction affected the Filaflex SEBS 3D printed sample, particularly horizontal, slant, and vertically printed on the mechanical properties.

2. Material and Method

2.1. Fused Deposition Modelling (FDM)

An FDM 3D-Printer from Creality company, which is an Ender 3 v2 model was used in this research work Figure 1, which has a High-quality extruder, High precision printing, and fast heating.

In this 3D printer, the extruder head moves in X-axis and Y-axis directions, and the build platform with dimensions 220 x 220 x 250 mm (L × B × H) moves in the Z-axis direction[7].

Fig. 1 Creality Ender 3 v2 printer[7]

2.2. Specimen

Due to the convenience of sample preparation and the specimen's suitability for FDM fabrication, a dog bone-like specimen was selected for the experiments. Since smaller radii reduce the dimensional precision of the FDM process, a cylindrical-type specimen was not employed. The design of the specimen is done in SolidWorks 2022, which is a student version. The specimen dimensions were based on test specimen 2/5A in the ISO 527 standard with a thickness of 4 mm because there aren't any material standards for parts made by additive manufacturing yet. The complete measurements are shown in Figure 10. Because the 2/5A specimen is smaller than the 1A specimen, less material and less production time are required to produce each specimen[8].

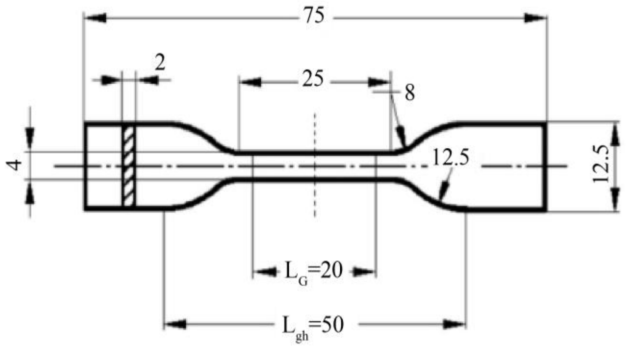


Fig. 2 ISO 527 2/5A Specimen

2.3. Filaflex SEBS

Filaflex SEBS (Styrene-ethylene-butylene-styrene) is a copolymer TPE that is strong and durable. TPE is primarily based on a 3-D filament, which is effortlessly deformed and bent into its unique shape. The filament now no longer best excels in flexibility and durability. The material is flexible in design, high performance, and easy to process, which has led designers to increasingly turn to it as their material of choice. It is a skin-friendly material and Biodegradable.

Filaflex SEBS is the ideal technical filament and a superb PVC substitute, especially in the industrial sector. The filament is appropriate for parts that must maintain their elasticity even at high temperatures and are used to dampen vibrations. The water-repellent filament can also be used to create components that are used in high-humidity environments and need to withstand a variety of weather conditions. This material is used in sectors like automotive, household appliances, and medical applications[9].

Filaflex SEBS by Recreus company. Table 1 shows the properties of the material from data form. It's a 3D printing fiber that has the waterproof ability and is resistant to chemicals and heat. In addition, the filament produces a spectacular very last end of the element and a wide variety of uses and programs inside the business field, along with the production of bendy seals, insulating elements, marine use, and demanding environments[10].

2.3.1. Applications

Filaflex SEBS can be used to create flexible prototypes for products such as gaskets, seals, covers, and other parts that need to bend or deform without breaking. The flexibility and softness of Filaflex SEBS make it suitable for creating wearable accessories like bracelets, wristbands, headbands, shoe insoles, and even custom-fit clothing components.

This material is often used to produce comfortable grips and handles for tools, sports equipment, and electronic devices, providing better ergonomics and shock absorption. Filaflex SEBS can be used to create realistic anatomical models for medical training, such as organ replicas, bones, and joints.

Its flexibility can simulate the feel of human tissue. Soft robotics often require flexible materials to create components like grippers, actuators, and sensors. Filaflex SEBS can be employed in these applications due to its elasticity[10].

Fig. 3 Filaflex SEBS material

Table 1. Material properties[11]

Material	Filaflex SEBS
Diameter	1.75 mm
Density	0.906 g/cm^3
Young's modulus	83 MPa
Tensile strength	32 MPa
Tear strength	73.5 N/mm
Shore hardness	90 A
Abrasion resistance	230 mm^3
Melting temperature	215^{0}c-250^{0}c

3. Experimentation Work

3.1. Slicer

Cura is a powerful 3D slicing software produced by Ultimaker, and it is an open tool. Ultimaker Cura offers over 400 settings for granular control. Ultimaker Cura 5.3.1 version is the latest and most used. Although the software will slice 3D files for any brand or model of 3D printer, the print profiles have been designed for Ultimaker 3D printers[12].

3.2. Samples Fabrication

Samples are printed in three different positions, I.E., horizontal, vertical, and slant. All are printed with the same printing parameters shown in Table 2, and 12 samples for each position.

For vertical, samples are attached, which makes a square shape structure for the support; for slant and vertical position, an additional brim is used, and general support is required for slant, which is shown in Figures 4,5,6.

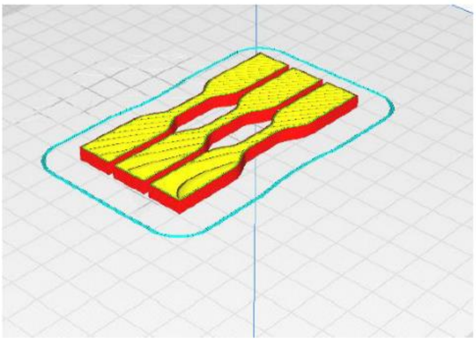


Fig. 4 Sliced in the horizontal position

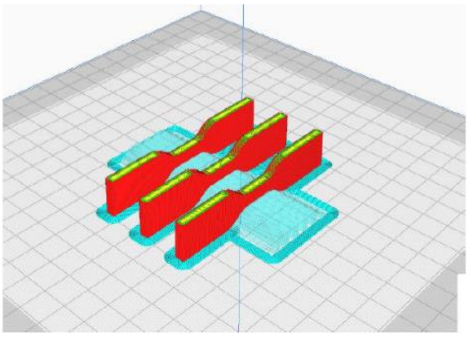


Fig. 5 Sliced in the slant position

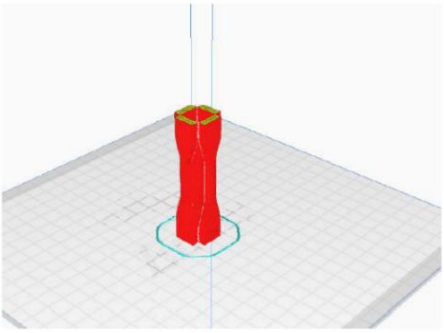


Fig. 6 Sliced in the vertical position

Table 2. Printing parameters

Printing parameters	Values
Nozzle diameter	0.4 mm
Bed temperature	55^0c
Nozzle temperature	240^0c
Printing pattern	Triangle
Top & bottom layer	Monotonic
Printing speed	70 mm/s
Infill Percentage	60%
Layer Thickness	0.3 mm
Extruder	Single

4. Results

Then conducted, the tensile test was conducted on 12 samples for each printing position of FDM-printed Filaflex SEBS. The tensile strength of 12 samples has been tested with the speed of 20mm/min and average values are being analyzed.

Graph 1 in this project represents the average values of tensile strength in the tensile testing machine. The x-axis holds the printing direction of samples in which samples were printed in Horizontal, slant, and vertical direction and the y-axis holds the tensile strength of the samples in megapascals (MPa). From the graph, the tensile strength of samples vertically printed is much lower compared to other samples. This effect might be due to the anisotropic properties of the samples. Theoretically, it is explained that during the layer-by-layer building process, interfaces between the layers occur. While performing the tensile test, the applied load acts perpendicular to the layer interface of vertically printed samples shown in Figure 6, and horizontally printed samples act parallel. So, to break a vertically printed sample, only one layer interface needs to be failed. However, for horizontally and slantly printed samples, several layers need to be failed, as shown in Figure 4. This difference in fracture behavior indicates anisotropic behavior. The results of horizontally printed samples prove this. Graph 1, when considering the results of slantly printed samples, shows a good result with an average tensile strength of 9.12Mpa. This is because slant-printed samples also have several layers, like horizontally printed samples. Also, slant-printed samples contain several layer interfaces when compared to horizontal-printed samples, as shown in Figure 5.

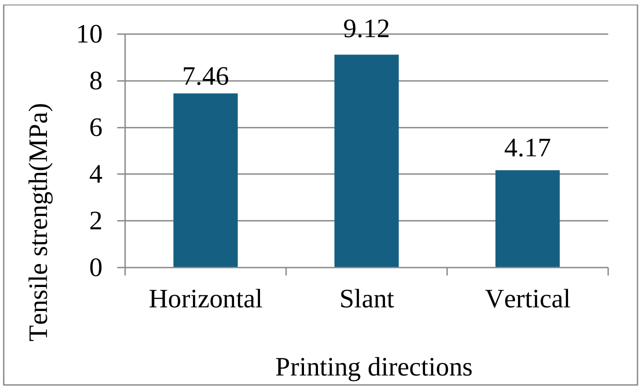


Fig. 7 Sliced in the slant position

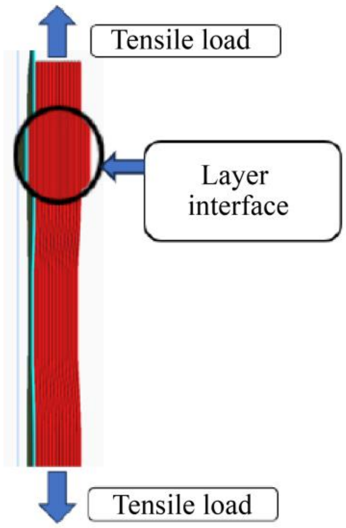


Fig. 8 Horizontally printed sample on tensile load

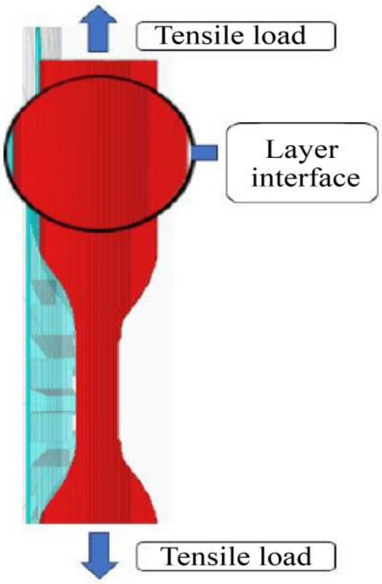


Fig. 9 Slantly printed sample on tensile load

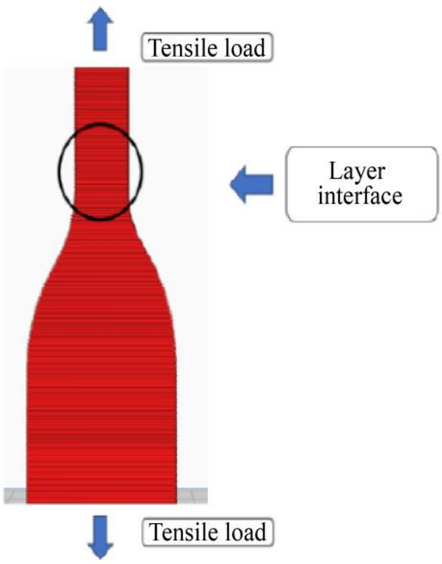
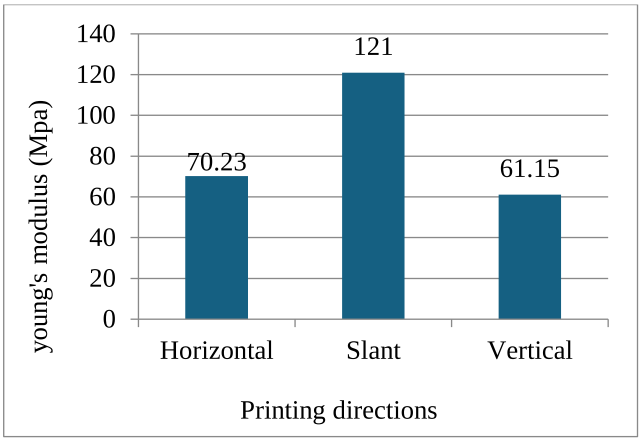
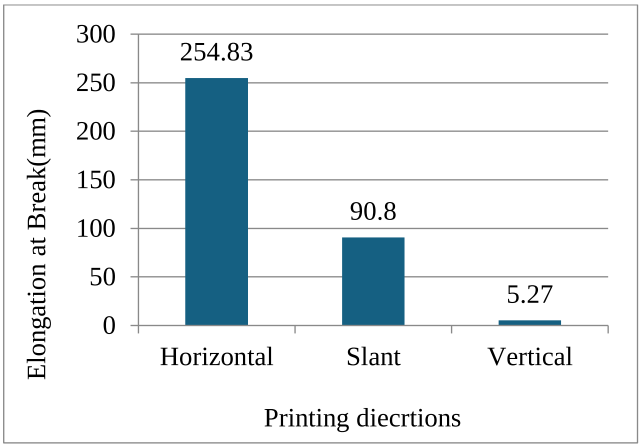


Fig. 10 Vertically printed sample on tensile load



Graph 1. printing directions versus Young's Modulus



Graph 2. printing directions versus Elongation at break.

Graph 2 in this project represents the average values of Young´s modulus in the tensile testing machine. The x-axis holds the printing direction of samples in which samples were printed in Horizontal, slant, and vertical direction and the y-axis holds the tensile strength of the samples in megapascals (MPa). From the graph, Young´s modulus of samples vertically printed is much less compared to other samples. Thus, slantly printed samples show a significant rise in Young´s modulus compared to vertically and horizontally printed samples. Both vertically and horizontally printed samples didn't have a great value in difference. In this case, the layer interface in Slantly printed is much stronger than the horizontal.

Graph 3 in this project represents the average values of elongation at break in the tensile testing machine. The x-axis holds the printing direction of samples in which samples were printed in Horizontal, slant, and vertical directions, and the y-axis holds the elongation at the break of the samples in millimetres (mm). This graph shows the elongation at break for vertically printed samples critically low compared to horizontally and slantly printed samples. This clearly illustrates that weak layer bonding between the layers for vertically printed samples. Uneven printing, degradation of material, and porosity also might affect the elongation of vertically printed samples. For horizontally printed samples, the elongation at break is an average of 254.83mm.

5. Conclusion

In conclusion, the strength of 3D-printed objects using the FDM technique varies depending on the printing conditions. At a speed of 70mm/sec with a layer height of 0.3mm and a 60% infill rate, the current work is completed with good results. The printing process must be handled carefully, and issues like adhesion can be solved using additional brim support. The printing parameters and printing environment both have a significant impact on the mechanical like Printing speed, Infill, Nozzle temperature, and Bed temperature. In addition, all of the specimens are printed using the same parameters and conditions to ensure consistency and to examine the mechanical properties under the same conditions. Printing directions of the samples have a significant effect on the strength of the material. Horizontally printed samples have higher elongation compared to Slantly and Vertically printed samples.

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