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Effect of Layer Thickness and Printing Orientation on Tensile Strength of Parts Printed by FDM

Kanwarjeet Singh[1], Gaurav Arora[2] and Pankaj[3]
[1,2]Assistant Professor, Delhi Skill and Entrepreneurship University, Wazirpur Campus, Delhi, INDIA
[3]M. Tech. Scholar, Delhi Skill and Entrepreneurship University, Wazirpur Campus, Delhi, INDIA

[2]Corresponding Author: aroragaurav82@yahoo.com

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ABSTRACT

Additive Manufacturing (AM) is and advanced production process that develops the product by depositing layer on layer from a CAD data. Out of all available techniques of Additive Manufacturing, Fused Deposition Modelling is one of the popular and widely used approach for fabricate thermoplastic parts. The present research work involves the development of Acrylonitrile Butadiene Styrene (ABS) parts utilizing FDM process by varying the thickness of depositing layer and build orientation. The tensile strength of the fabricated samples were evaluated. The results revealed that a maximum tensile strength is shown by the part having a layer thickness of 0.20 mm with horizontal build orientation.

Keywords- Additive Manufacturing, Fused Deposition Modelling (FDM), Build Orientation, Layer Thickness, Mechanical Properties.

I. INTRODUCTION

The growth and development of industries is largely driven by the advanced research and innovations in the field of product design, new materials and novel fabrication techniques. Basically, manufacturing processes are broadly classified as Formative, Subtractive, Additive and Joining. Out of this classification Additive manufacturing is one of the most popular technique amongst the researchers due to the elimination of costly tooling, customization of part design, low production and reduction of material wastage etc. Since the origination, various terms have emerged to describe the same technology including additive manufacturing, digital fabrication, rapid prototyping, 3D printing and layer-oriented manufacturing [1-2]. The advancements in this technique have been really shaped by novelty in software and materials, which have expanded the use of additive manufacturing into various engineering and other industries such as tooling, defence, automotive, fashion, aerospace, consumer goods, healthcare, and fashion etc. [3]. Additive manufacturing is a considered as a key element to combine conventional manufacturing systems with digital technologies. This integration helps in reducing the efforts and space requirement in establishing traditional manufacturing [4].

Additive manufacturing (AM) techniques are often categorized according to factors such as functionality of product, type of material used, shape and size of product, size of machine and type of energy used for layering etc. [5-6]. Selective Laser Sintering (SLS) is a widely used additive manufacturing (AM) process for fabricating of three-dimensional components from powdered materials. In this technique, a fine polymer powder is spread in thin layers and selectively fused to produce the required part. A variety of materials, including thermoplastics, ceramics, glass, and metals, can be used in SLS. Among these, polymer-based materials are the most commonly used, with Nylon 11 and Nylon 12 being widely preferred due to their favorable processing characteristics and mechanical performance [7-8].

Fused Deposition Modeling (FDM), is based on layer-by-layer additive manufacturing. In this process, a thermoplastic filament is supplied to a heated nozzle, where it is melted and extruded onto the build platform. The

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movement of the nozzle is controlled by a predefined tool path generated from the digital model for each individual layer, ensuring accurate material deposition. Repeating this process layer by layer results in the fabrication of the complete three-dimensional part [7-8]. Stereolithography (SLA) became the first commercially available additive manufacturing technology after being patented by 3D Systems in 1986. The process employs an ultraviolet (UV) laser to selectively solidify a liquid photosensitive resin, building the component one layer at a time. Continuous improvements in SLA technology have focused on increasing printing speed and enhancing resolution, allowing the fabrication of parts with intricate geometries, excellent dimensional accuracy, and smooth surface finishes [1].

Laminated Object Manufacturing (LOM) utilizes sheet-based materials such as metals, paper, and polymers as its raw materials. During the manufacturing process, these sheets are bonded together using methods appropriate to the material before being shaped into the final component. Metal sheets are typically joined through ultrasonic consolidation and subsequently machined to achieve the desired geometry. When paper is used, the sheets are laminated with an adhesive and precisely cut using sharp blades. In the case of polymer sheets, bonding is accomplished by applying heat and pressure, creating a strong laminated structure [9]. Selective Deposition Lamination (SDL) includes placing a sheet of paper on the build platform. Adhesive is then sprayed selectively onto the sheet, with a higher amount applied in the region forming the part and a lower amount in the support regions to allow easier removal later. In the next step, the paper feeding system places another sheet on top of the bonded layer. The build platform is then pressed against a heated surface to ensure proper bonding and uniform adhesion between layers. Once the required build height is reached, a cutting tool traces the geometry based on the design data, forming the outline of the product. This sequence is repeated layer by layer until the complete component is produced [10].

Out of all the available Additive manufacturing techniques, FDM has gained a significant attention amongst the researchers due to its simplicity, cost-effectiveness, and accessibility compared to other 3D printing methods. It supports a wide range of thermoplastic materials, allowing users to select materials based on required mechanical and thermal properties. Layer thickness represents the height of each deposited layer during fabrication and plays an important role in defining surface finish, dimensional accuracy, mechanical strength, and build time. Since FDM builds components layer by layer, the direction in which a part is oriented during printing directly affects how the layers are stacked and bonded. Therefore, the present study investigates the impact of thickness of layer and build orientation on the characteristics of the FDM specimens.

II. MATERIALS AND METHODS

The present research work involved the fabrication of Acrylonitrile Butadiene Styrene (ABS) specimens utilizing FDM technique. ABS is a widely used thermoplastic material in 3D printing, especially in Fused Deposition Modeling (FDM), due to its good mechanical strength, toughness, and impact resistance. ABS is commonly chosen for functional prototypes and engineering parts because it offers better durability and heat resistance compared to many other printing materials. It can also be easily post-processed through machining, sanding, or chemical smoothing, which improves its surface finish and appearance [11]. A bone shaped specimens as shown in Fig. 1 are fabricated by FDM process using ABS as raw material. Whereas, Table 1 represents the sample details as per the varying layer thickness and printing orientation.

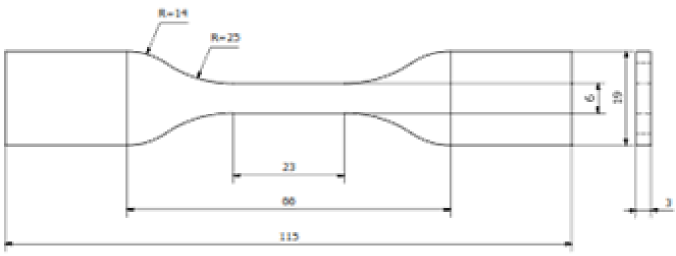

Fig. 1 ABS specimen developed by FDM

Table 1: Sample details with varying printing orientation and layer thickness

Process	Material	Printing Orientation	Layer Thickness
FDM		Horizontal	0.10 mm
		Vertical	
FDM		Horizontal	0.15 mm
	ABS	Vertical	
FDM		Horizontal	0.20 mm
		Vertical	
FDM		Horizontal	0.25 mm
		Vertical	

Initially CAD data was prepared of all the specimens as per the varying layer thickness as mentioned in Table 1 followed by the slicing of the component as presented in Fig. 2 (a) and (b). After that the developed data was converted in to STL format and fed in to the FDM machine for the development of required samples. Fig. 3 (a) and (b) presents the specimens fabricated in horizontal and vertical printing orientation and layer thickness varied from 0.10 mm to 0.25 mm by FDM process. Further, the mechanical properties of the developed samples were evaluated. Tensile testing were performed to evaluate the ultimate tensile strength of the developed samples. Fig. 4 presents the apparatus utilized for the tensile testing of the developed samples.

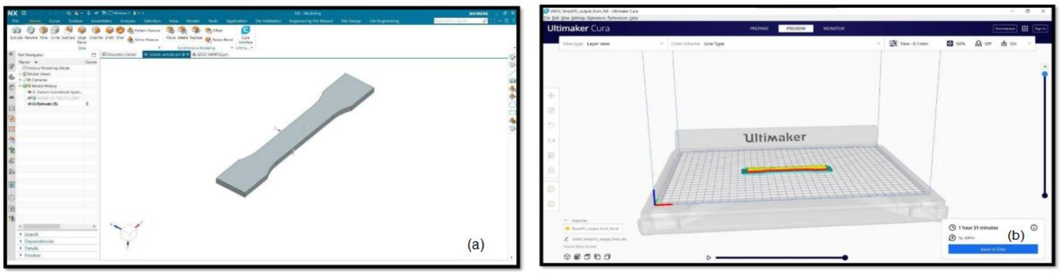

Fig. 2 (a) CAD modelling and (b) Slicing of the component

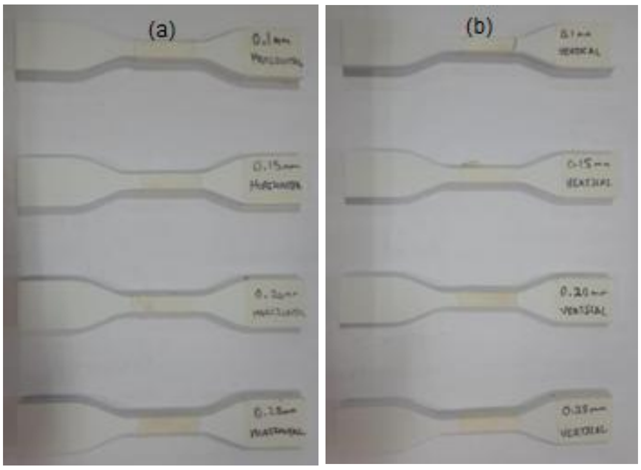

Fig. 3 FDM printed samples with varying layer thickness (a) Horizontal and (b) Vertical orientation

Fig. 4 Tensile testing apparatus

III. RESULTS AND DISCUSSION

The results of tensile testing of fabricated samples is represented in Fig. 5. The results revealed a superior tensile strength values for the horizontal printing orientation in comparison to the vertical orientation. The horizontal orientation has shown the superior tensile testing results as layers are parallel to the bed surface and less layer separation will be there. In contrast specimens built with vertical orientation are prone to delaminating.

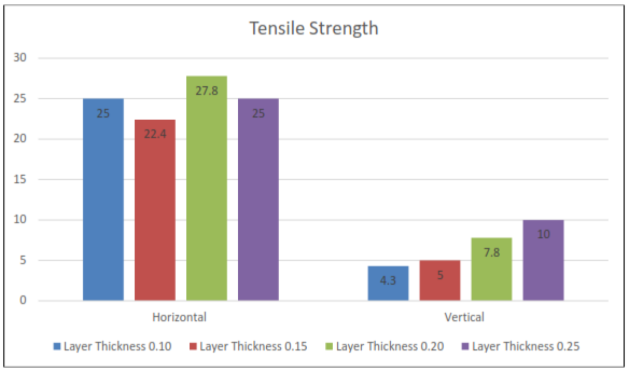

Fig. 5 Results of Tensile Testing of Samples

IV. CONCLUSIONS

The ABS specimens were successfully fabricated by FDM techniques with variation in layer thickness and printing orientation. Tensile strength were evaluated for the developed samples. The results revealed a higher tensile strength for the horizontal printing orientation as compared to vertical orientation. This was due to a less delamination of the layers as layers are parallel to the surface.

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