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Influence of 3D printing on Mechanical Qualities in Additive Manufacturing of ASA structure

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ABSTRACT

One kind of manufacturing method called additive manufacturing (AM) constructs complex three-dimensional components by adding individual layers together. Compared to injection-molded components, additive manufacturing components are still not extensively utilised as functional components. This is that additively manufactured component' marginal mechanical characteristics. In the present research, the Fused Deposition Modelling (FDM) technique is utilized to try to identify the specimen's mechanical properties when made of a polymer.The tensile and flexural capabilities of ASA components produced with similar injection-molded parts are analysed in the literature to evaluate the influence of infill % and build direction.For this endeavour, Styrene acrylate acrylonitrile (ASA) is the material of choice for conducting trials.Solidworks is used for design, and the component is then converted to STL file format.A STRATASYS F-170 FDM printer is used to print the specimen.It would be feasible to draw a conclusion that broadened tensile strength along the print direction was triggered by the ASA material's higher infill percentage.

Keywords: Acrylonitrile styrene acrylate, 3D printing, Injection mould, fused deposition modelling, and infill %.

INTRODUCTION

One kind of 3D printing technique is called polymer additive manufacturing. By building the entire portion one layer at a time, this approach creates a three-dimensional item. The first layer is extruded onto the second, which may or may not melt entirely.In the past, models were the primary goal of additive manufacturing, a sort of fast prototyping, in order to visualise the finished product as a prototype. These days, AM is widely used to produce final goods for the aviation, dentistry, and medical industries, as well as the automobile, food, and fashion sectors.By using computer-aided design (CAD) programmes, this approach creates the components file, which is then converted into files called STLs (standard tessellation files), which thinly slice the part.The nozzle path is guided by the information in this STL file, ensuring that The material layer covers the existing layer smoothly.This task's objective is to look at how the mechanical characteristics ofpolymer materials are affected by the print direction and percent of infill.

To improve aspects of manufacturing based on fused deposition modelling, the results can be compared with the injection-molded specimen's data.Because it is more environmentally stable and resistant to UV rays than conventional Acrylonitrile Butadiene Styrene (ABS), a polymer substance, ASA offers superior mechanical qualities.Due to the material's consistent roundness and diameter, this filament possesses special qualities.Once betterment is achieved, the ASA structure's property aids within replacement the ABS polymer.

Chhabra, Det al.[1]This article discusses the tensile strength of acrylonitrile butadiene styrene (ABS), polyethylene terephthalate glycol (PETG), and multi-material test pieces is examined as they pertain to the infill density, extrusion temperature, and material density. Using FDM 3D printing, 50% ABS and 50% PETG are combined layer by layer to create multi-material objects. The artificial neural network (ANN) and genetic algorithm-artificial neural network (GA-ANN), a hybrid tool in MATLAB-16.0, are used for training and optimisation. The tensile strength has been maximised to 4.54% using GA-ANN, according to experimental validation. **Radhwan, H.**et al. [2]Three crucial process factors are taken into account: infill, layer thickness, and orientation. It is investigated how they affect two reactions, namely the test specimen's tensile and flexural strengths. Variance analysis is used to assess the models' validity (ANOVA). It came to light that the best strength for fused deposition modeling (FDM) three-dimensional printing may be obtained by using layer 0 degree orientations, 100% infill, and 0.25 mm thicknesses. **Ramdani** et al. [3]Investigation Fused deposition material-based 3D printing technology has advanced quickly and with a range of features. The printed component quality that was obtained using the RSM's In comparison to the Taguchi [0.15 mm, 195^{o}C, 0^o] and default settings [0.1 mm, 200^o C, 0.0^o], the optimum parameter setting [0.05 mm, 199.8^o C, 45.1^o] was superior. settings. Furthermore, layer thickness had the greatest impact on the printed part's tensile strength, whereas raster angle was the primary cause of dimension inaccuracy. **Ramu Murugan** et al**. [4]** Examines how build factors including The mechanics of 3D printed structures are influenced by build orientation, layer height, fill density, extrusion temperature, and printing speed. A model constructed with a y-axis orientation of 45^0 produces higher mechanical qualities, according to preliminary research on the impact of build orientation. These tests were conducted by adjusting the specimen's y-axis orientation. Based on Taguchi's method, Poly Lactic Acid (PLA) material and a variety of process parameter combinations were used to produce the specimens. **Junhui Wu**et al.[5] Melt deposition type (FDM) forming printer will be used for the task. The PLA and cylinder model printing consumables were utilised as research items to examine how Slice height has an impact on dimensional accuracy, printing time, and consumables. Moreover, related parameters were optimised. The outcomes demonstrated that, under the assumption of maintaining printing quality, the lowest printing time could be achieved at a layer height of 0.14mm.**Mukosera**et al. [6]3D printing continues to demonstrate to be a really fascinating technology to watch out for, with its applications growing every day. In this research, we want to investigate the how 3D printing works as well as current and future possibilities.**Shahrubudin**et al.[7]Provides an overview of the many technologies used in 3D printing, analyses the manner in which they work, and then discusses the materials that are utilised in the manufacturing industry to enable 3D printing. **Jayant Giri** et al. [8] focuses on adjusting the layer thickness, print orientation, and cooling rate; to enhance the mechanical strength, surface quality, and build time, the tensile strength and build time are assessed for each value of the specified parameters.**Yash Magdum,** et al.[9]Solid three-dimensional items may be produced using additive manufacturing techniques like fused 3D printing. Less human labour is needed, and components may be manufactured faster. The 3D printed items' tensile strength, hardness, and surface roughness are influenced by several factors, covering fill density, layer thickness, and shell thickness. The main topic of the study is "Optimisation of Process Parameters for FDM 3D Printer 3D Printing Operation." The mechanical features and production time would be improved based on optimised parameters.**K Kalinowski** et al. [10]The study was conducted utilising a set of standard samples that were created using inexpensive standard materials (ABS) using a low-cost 3D printer. A number of characteristics were investigated to see how they affected certain mechanical properties of the samples, including the kind of infill pattern, infill density, shell thickness, printing temperature, and material type.**Jain** et al.[11]According to the study, since the direction of loading is parallel to the layers, a change in layer thickness has no appreciable impact on tensile strength for test specimens printed on the edge, that is, with length overall and thickness parallel to the build platform.**Godfrey C. Onwubolu** et al.[12]this study's group method for data modelling for prediction was used to establish a functional relationship between process parameters and tensile strength for the FDM process. An initial test was conducted to see if variations in angle of raster and orientation of portion had an impact on tensile strength. Tensile strength response was shown to be impacted by both process factors. The process factors taken into consideration for the more complex testing include layer thickness, orientation, raster width, raster angle, and air gap.**Ratiporn Munprom**et al. [13]Research, we methodically looked at the seven crucial process variables—flexural stress, hardness, and component dimension—that might have an impact on an object's quality. The importance of the parameters and the parameter optimisation may be ascertained by applying the Taguchi technique with the L8 (27) orthogonal array.**H. Ramezani Dana**et al. [14]Use the Arburg-Plastic-Free method of forming. To this end, four printing scenarios—each defined by the angle formed by the direction of tension and the printing direction in a layer—have been investigated: Every layer has either (i) 0° or (ii) 90°; (iii) layers that alternate between 0° and 90° from a layer to its higher one; (iv) layers that alternate between −45° and 45° for each layer from a layer to its upper one. Preparation, storage, and a comparison of the characteristics with injection-molded specimens of the same ABS comprise the experimental analysis technique that is given. The previously mentioned literature lists all of the research on polymer additive manufacturing as well as the factors that affect the goods produced via this technique. The use of ASA for FDM-based additive manufacturing has been documented in very few works. This research looks at how to assess the attributes of an FDM-manufactured ASA material specimen to obtain acceptable tensile and flexural strength.

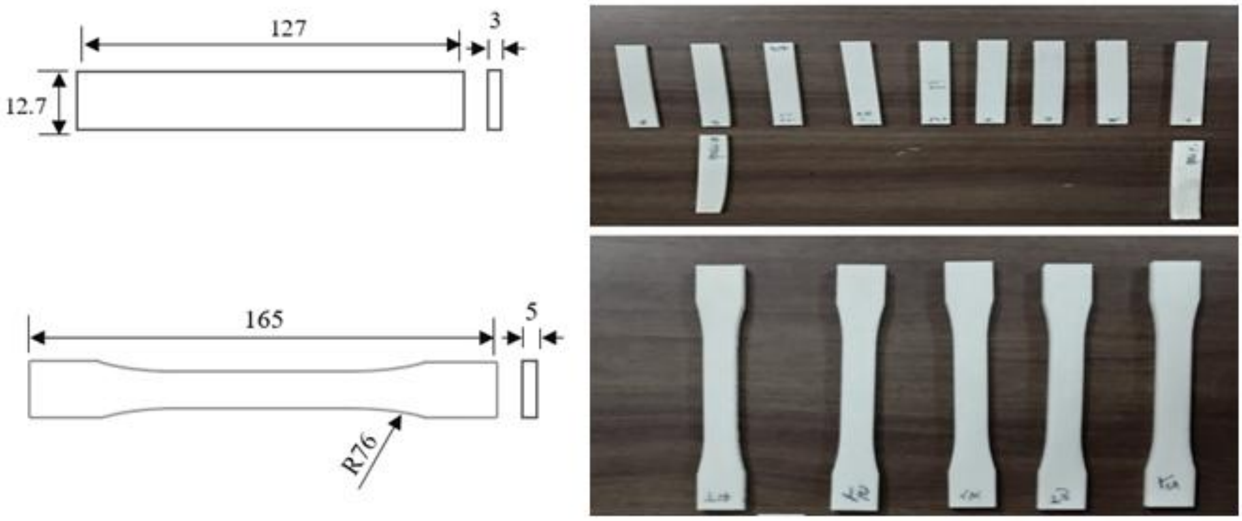
EXPERIMENTAL METHOD

Experimental Setup

A Stratasys F170 FDM printer was employed to fabricate the Acrylonitrile Styrene Acrylate specimens. The extruder's temperature was maintained at 220 ^{0}C.It was maintained between 60 and 90 ^{0}C on the construction platform. The printer's Cartesian coordinate is occupied by two nozzle extrusion systems.One nozzle is designed to extrude the framework material, while the other is meant to extrude the support material. The ASA wire filament with a diameter of 1.75 mm is wound onto the spool and fed through the nozzle. The construction platform is used to extrude the material.

The mechanical characteristics are modified by elements including infill %, print direction, and layer thickness.Maximum strength was achieved with a minimal layer thickness and a maximum percentage of infill. The printer's printing speed in this instance is 160 mm/s.For sample printing directions X-90^0, Y-90^0, and Z-90^0, the layer thickness is set at 0.178 mm.A total of three percentages of infill used: 25, 50, and 100. Per ASTM specifications, DS Solidworks 2020 is used to create the test specimens, and GRABCAD, a standard slicing tool for Stratasys printers, is utilised to slice samples.

Fig. 1 illustrates the specimens printed for tensile and flexural strength.The specimen dimensions for the tensile strength test are 165 mm in length, 19 mm in width, and 5 mm in thickness, in accordance with ASTM D 638 standards.The flexural strength test specimen parameters are Measurements: 127 mm in length, 12.70 mm in breadth, and 3 mm thick, in accordance with ASTM D 790 standards.A 10 KN universal testing equipment, utilised to test the specimens' tensile strength at PSG Tech's COE indutech in Coimbatore, India. With a single column eXpert 7600 machine equipped with a three-point bend fixture, the tests are conducted at the same centre to assess the specimens' flexural strength.



(a) **(b)**

Fig. 1: (a) ASTM D638 Type III in two dimensions & (b) Test specimens for flexural and tensile tests parts printed using FDM

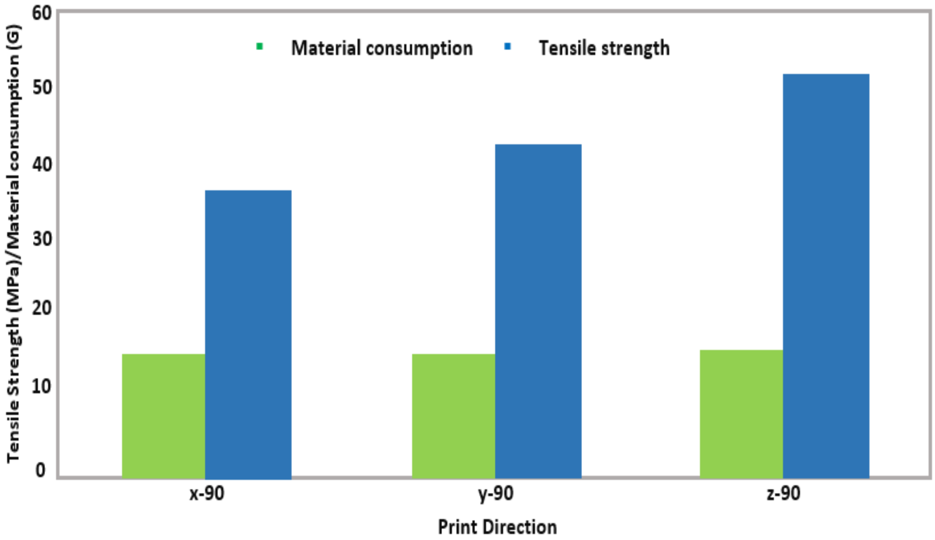
RESULTS AND DISCUSSIONS

The raster angle, raster width, raster to raster gap, and component arrangement orientation constitute a few of the influencing factors that affect an FDM generates specimen's strength. **Ramu Murugan** et al. [4] shows 0.2mm layer height and 80% infill density are compared, 27.1 MPa is found; it is optimal to use 100% infill percentage and 0.254mm layer height to obtain 53.4 MPa.The tensile and flexural strength of ASA specimens are evaluated in this work along with the impact of printing orientation and infill %. Table 1 calculates the test results.

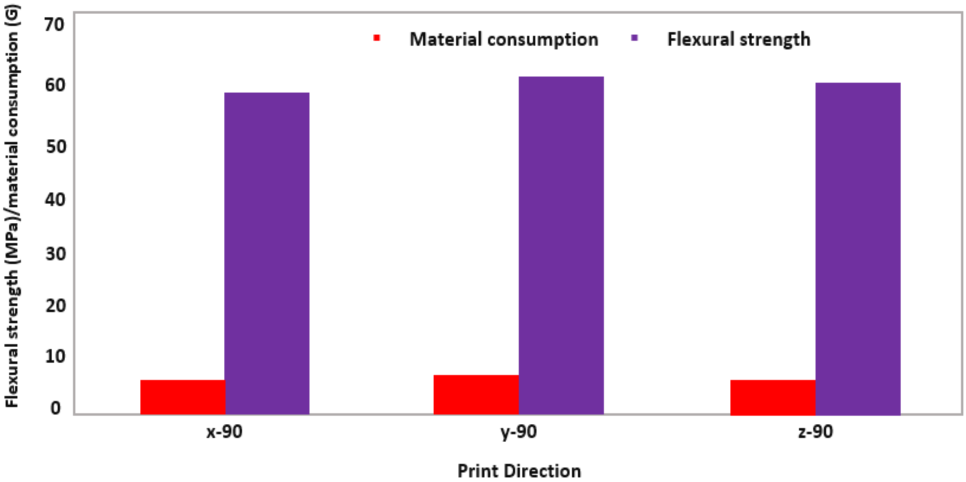
Table-1: A specimen printed with different parameters in terms of tensile and flexural strengths.

Run	Instructions for printing	proportion of infill	Height of Layer in Millimetres	MPa tensile strength	MPa flexural strength	Material Requirement for Flexural Grams	Tensile grams material consumption
1	X-90	50	0.127	29.8	58.3	7.99	23.151
2	X-90	100	0.178	34.1	54.4	5.122	17.706
3	X-90	25	0.254	37.4	58.1	5.991	13.606
4	Y-90	50	0.178	33.3	55.2	5.250	17.199
5	Y-90	100	0.254	53.4	59.5	6.111	16.055
6	Y-90	25	0.127	30.1	40.8	6.166	20.925
7	Z-90	50	0.254	41.2	59.9	6.849	16.002
8	Z-90	100	0.127	30.4	64.2	8.734	23.111
9	Z-90	25	0.178	32.7	66.7	6.556	11.801

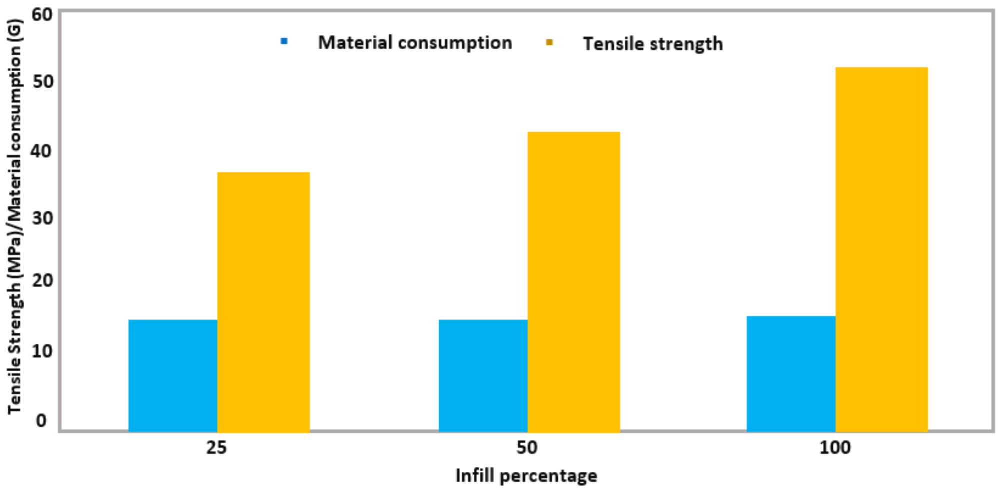
Figure 2a illustrates how the structure's direction affects variations in material usage and tensile strength.Z-90's strongest tensile strength is it is noticeable that the material usage is significantly lower.Tensile specimens are a caveat for the notion that material consumption isn't measured by printing specifications.As seen in Fig. 2b, the flexural strength of Z-90 is determined to be lower compared to that of Y-90.It is also discovered that all printing orientations have comparable material usage.The printing directions have no impact on the material usage, as shown in Figs. 2a and b. Therefore, in cases of challenging shape, any printing orientation may be used for least consumption of materials.


Material consumption
Tensile strength
Tensile Strength (MPa)/Material consumption (G)
60
50
40
30
20
10
0
x-90
y-90
z-90
Print Direction

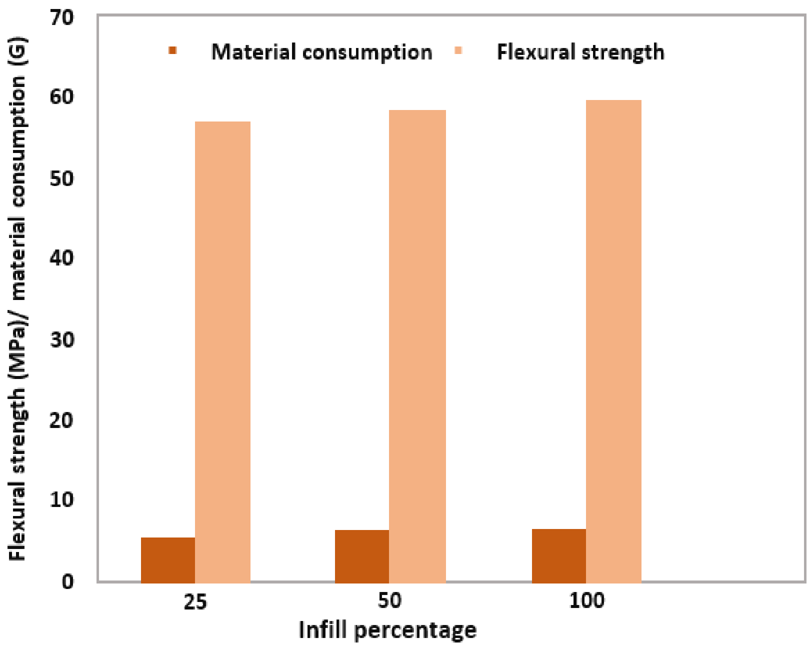
(a)


Material consumption
Flexural strength
Flexural strength (MPa)/material consumption (G)
70
60
50
40
30
20
10
0
x-90
y-90
z-90
Print Direction

(b)


Material consumption
Tensile strength
Tensile Strength (MPa)/Material consumption (G)
60
50
40
30
20
10
0
25
50
100
Infill percentage

(c)



(d)

Fig. 2: (a)Tensile strength in relation to material usage and print direction. (b)Flexural strength in connection to material consumption and print direction. (c)Tensile strength in relation to material consumption and the percentage of infill. (d)Relative to material usage, flexural strengthand infill %.

Fig. 2c illustrates how raising material consumption resulted in broadened overall strength when the infill percentage continues to remain at 100%.Because of the incredibly low strength to weight ratio, the tensile strength diminishes as the infill proportion lowers. as seen in Fig. 2c.In contrast, the strength rises as the infill percentage increases from 25% to 100% in both tensile and flexural instances.Precisely consequently, the infill influences both mechanical and material-related qualities.

As seen in Fig. 2d, the flexural strength rises somewhat as the infill increases.A 53.4 MPa tensile strength is achieved from an FDM printed specimen with a 100% infill percentage, in comparison to 27.1MPa **Ramu Murugan** et al. [4] for injection moulded parts.Nevertheless, the injection-molded part's flexural strength of 77.4 MPa **Hameed, A. Z**et al. [15]is a little bit higher than the specimen created with FDM, with an approximate 25% infill percentage of 66.7 MPa. Due to the influence of the infill percentage, compared to the injection moulded material, the ASA printed material has a lower flexural strength.

CONCLUSION

The most recent study examines the effects of printing orientations and Tensile and flexural strength infill percentage for a typical ASA material.Printed and tested specimens agree to ASTM specifications.The ideal tensile strength of 53.4 MPa is observed in the ASA specimen while printing in 100% infill and Z-90 orientation.The results demonstrate higher tensile strength in compared to injection moulded examples from the literature.With 25% infill and the Y-90 printing direction, the flexural strength is just 66.7 MPa.

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