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The Influence of Operational Settings on the Tensile Strength of an FDM-Printed Abs Component

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Abstract: This paper's purpose is to investigate tensile strength of FDM-print ABS components. FDM has evolved beyond rapid prototyping to rapid manufacturing in recent years, allowing items manufactured using the FDM process to be used immediately. Poor and anisotropic mechanical qualities, on the other hand, had a substantial influence on the use of fused model manufactured components. By carefully selecting framework, the automated qualities often FDM components can be improved. There will be three parameters on which the research is going through, angle of raster, height of layer, and breadth of raster, were chosen in this work to investigate their impact in the tensile samples. The components are manufactured to the ASTM D638 Type 4 standard.
The inflated tensile strength was found with a angle of raster of 0 degrees. Because of the larger bonding surface between the layers, a lower layer height is associated with better tensile strength. The strength of a tensile component improves up to a point when the raster width is increased, after which the existence of void diminishes and tells how strong a material is when it is stretched.
Keywords: 3d printing, fused deposition modelling (FDM), acrylo nitrile buta diene styrene (ABS), Infill Percentage, Additive Manufacturing (AM), raster angle, raster breadth.

I. INTRODUCTION

Traditionally AM has been utilized for rapid prototyping (RP) objects, primarily for the creation of visual models for design verification and the fabrication of functional testing goods throughout product development. Without the use of any special tools or fixtures, parts can be immediately manufactured from a computer-aided design model. It aids in the reduction of product development cycle time.

FDM is a commonly used AM technique for constructing three-dimensional components by depositing material layer by layer through a liquefier nozzle while moving in the X-Y plane. The molten material is extruded through a heated liquefier, which heats the material filament to a semi-solid condition and uses a solid section of the filament as a piston to push the melted part through the nozzle. Following the deposit of one layer, the build table is shifted downward in the z direction and another layer is placed. Any complex geometry can thus be constructed layer by layer.

Many industries, including as automotive, aerospace, pharmaceuticals, electrical appliances, and retail product industries, use FDM-fabricated components. However, the weak and anisotropic mechanical characteristics of the FDM-fabricated part limit its further applicability. The mechanical qualities of the FDM part are crucial indicators of its quality. Some research has been done on the consequence of procedure parameters on the machine-like qualities of fused filament fabrication (FFF) component in terms of mechanical properties.

It used finite element analysis to examine the tensile strength of FDM tensile specimens and discovered that a 0° raster angle had higher tensile strength than a 90° angle of raster[9]. The effect of layer height, raster angle, and number of shell perimeter on the tensile strength of an open source 3D printer manufactured ABS part was researched. They observed that tensile strength decreases with increment in raster angle towards 90°, while higher tensile strength at lower value of layer height has been obtained It developed an analytical model for elastics stress, strain and moduli for FDM-printed part using plane stress approach. They found that tensile stress gradually decreases with increasing raster angle, minimum elastic modulus attained at 50° to 60° angle of raster.

3d printing is the new requirement innovation used by the industries only practical and aesthetically pleasing prototypes were selected for this procedure , and a most suitable or correct word which can be acceptable phrase or you can say appropriate will be rapid or fast prototyping .The main significant advantage of using a 3d printer is that capability to assemble extremely complicated design and structures or formal designs which was almost unfeasible to establish by human palm[2] .In the 2020's fused deposition modelling (FDM) will be the most used 3d-printing technique because it make use of a uninterrupted material which made specimen layer by layer according to the X,Y,Z axis and also manufacture void -components or components with inside strut structure to make the specimen lighter.

The term additive manufacturing also used in metal working and end-use parts production contexts than among polymer, stereo-lithography, inkjet was the minimal familiar technology regardless it was invented in 1950 and can't understood because of the complex nature. Other expression used as synonyms have included desktop manufacturing and demand manufacturing. Machining term was not replaced by the term subtractive instead of complementing it when the term that cover removal method is needed.

The term additive manufacturing (AM) technology , process that print sheet by sheet object with the help of 3d modelling software. When we compare with conventional manufacturing the advantages of this method are its ease of use, it takes low cost to manufacture a product which can be any kind of complex objects and it don't waste material. This type of technology is applied in various fields such fields like automotive engineering, biomedical engineering, aeronautic engineering and food industry also. Although additive manufacturing is broadly used in the industry and is linked with applications such as the manufacture of functioning prototypes, it also incorporates end to end used application such as the bulk productions of constituents . The word direct-fabrication which was coined by additive manufacturing process with the help of this tool the specimens were made immediately through STL file. Automated control- tool (CNC) transfigurize numerous machine tools that manufacture process through digitization.

In the back 1980s additive manufacturing and material synthesis is used. In the 1984 a process known as stereolithography which use ultra violet lasers to cure photo polymers which was developed by Chuck Hull. Chuck developed a format which we say STL file format by this broadly received by the three-dimensional- program and also by the computerized slicer software & other Infill conditions which uses today. The plastic extrusion company in the early 1980s introduced the new technology "3D printing" which was licensed by Stratasys company under the FDM layer to layer process.

The majority of research effort has been engrossed functioning that what will be the effect off the angle of rasters on the ductile characteristics of the ABS components, according too our findings. The impact of height of the layer and width of the raster their tensile strength has received little attention. Further, there has been very little work done using ABS as a printed medium. As a result, while using ABS as a printing material, it's important to look-over the consequence of the length of layers, breadth of raster, & the angle of rasters. The major objective off this study is to determine how angle of raster, height of layers, and breadth of raster effect the ABS component's tensile properties. This specimen is made here with the ASTM D638 type4 standard and with different raster angle the specimen is made to check the strength of the material so we can get the best outcome from the mechanical test for future use.

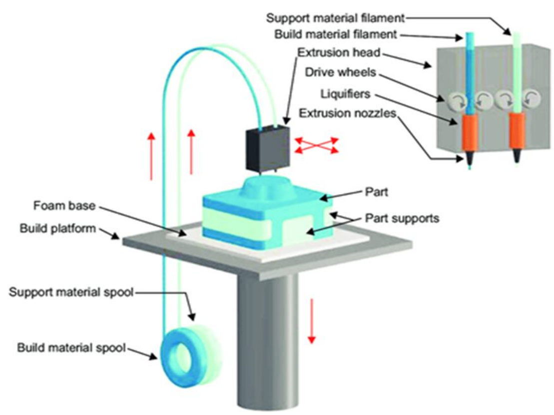


Fig-1 : Fused Deposition Modelling Printer

II. SPECIFICS OF THE EXPERIMENT

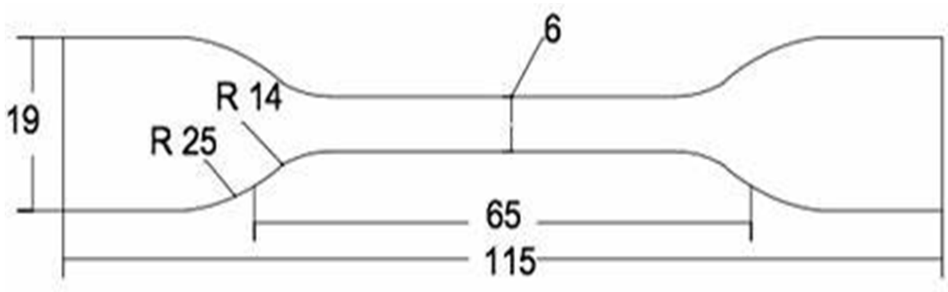
Fabrication of specimens under test conditions the primary goal of this study too explore the tensile characteristics of an FDM printing component. The test component was outlined and fabricated in accordance with ASTM- D638 Type 4, which specifies the structure and dimensions (every measurement was in millimetre) a dog-bone-shape sample.

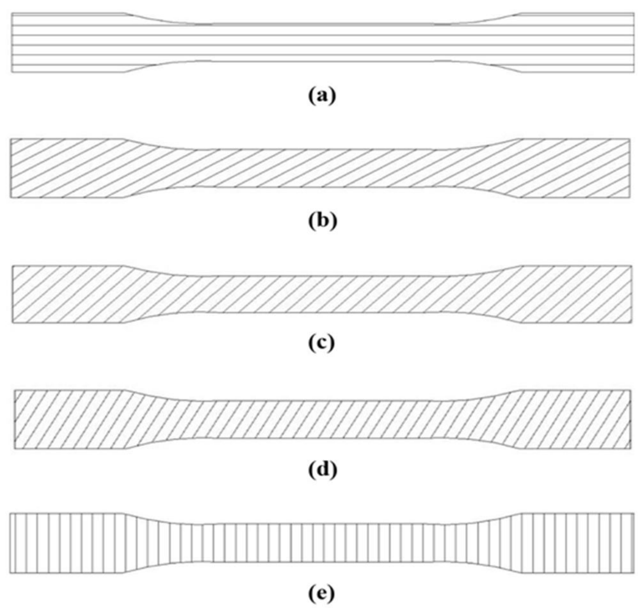
The effect of three process parameters, namely raster angle, layer height, and raster width, on tensile characteristics is investigated in the current work. The raster's gradient relative to machine's X axis is denoted as raster angle. Figure 2 shows the specimen model from the top, with specimens arranged at various raster angles on the machine's XY plane. The layer thickness collected at the tip of the nozzle is known as layer height. Layer heights of 100, 150, 200, 250, and 300 mm are all examined. The globule of material's beads in the course of raster collecting can be characterized as raster width. The raster width is modified between 400, 500, 600, and 700 mm in four distinct settings. The open-source printer's potential range is utilized to determine the height of the layers including width of the raster's, which is shown graphically in Figure 3.

III. FABRICATION OF SAMPLES

The angle of the raster with height of the layer were altered by 5 levels in this study, while the raster width was modified at four levels. After considering every conceivable amalgamation of the processes of parameters, a sum of ten demonstrations were run, with the complete set of experiments being run twice. All of the specimens were printed using ABS filament on a Omega double extruder 3d printer, which is an FDM printer that is open source with excellent-precision. A constructed chamber is included in the apparatus with a measurements of 600 -600- 600 mm, a posture precision about 710 mm, with the diameter of the nozzle which is about 0.3mm, according to the manufacturer's specifications.

Figure 4 The schematic diagram for the testing components was developed in computer aided software & given input as an STL. file. That file were then loaded within fused deposition 3d printer (flash forge)software for designing the instrument route along with modify each one of the procedure constraints. As indicated in table 2, each one of the sample were made using identical procedure parameters. The specimens were ASTM D638 tensile specimens (Figure 2).





Notes: (a) 0°; (b) 30°; (c) 45°; (d) 60°; (e) 90°

Parameter	Unit	Level
Raster angles	°	0, 30.0,45.0
Length of layers	mm	120, 170, 220
Breadth of the rasters	mm	350, 450, 550

Fig-3 Table 1 Different raster angles

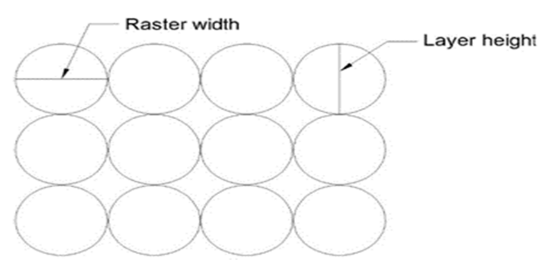


Fig-4 Layer height and layer width are shown graphically

IV. WORK METHODOLOGY

This research initially set about with wide literature about FDM and AM and it's importance in this generation. Additionally the work has been proceeds towards the standard of the specimen that will be ASTM D638 TYPE-4 which is a method to check the mechanical properties of plastics with some standard. In this research we check mechanical properties of the ABS material which have been discussed earlier. The fabrication of the specimen is done by the Omega double extruder 3D printer by which the dumbbell shape specimen is made. FDM Method is used to print the specimen and this fabricated specimen undergone some mechanical test. The mechanical test which has been performed were tensile with different angles of the specimen is made with infill percentage.

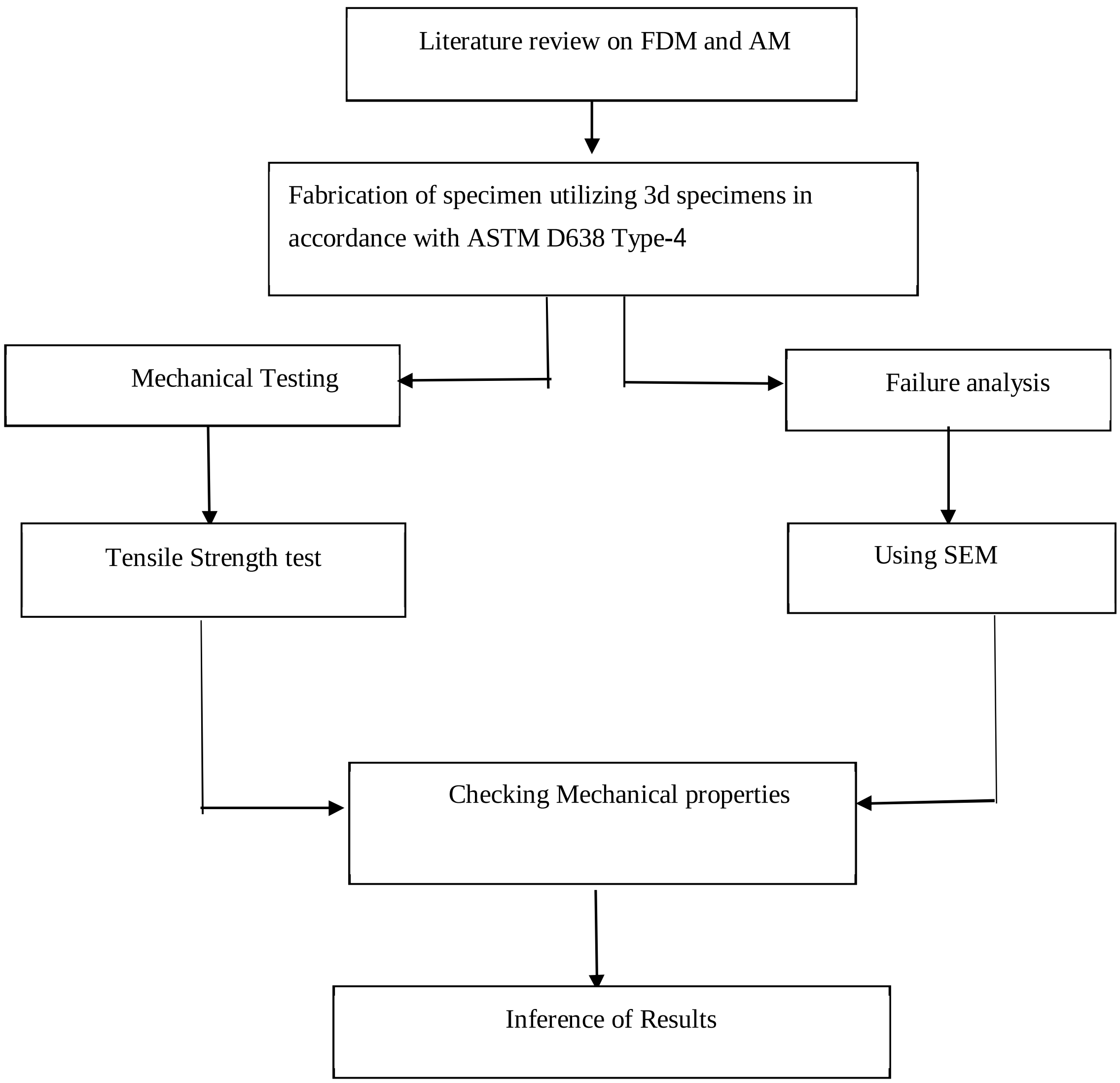


Fig-2 Methodology

V. MATERIALS

1) *ABS Material:* It's a terpolymer assemble alongside crosslinking acrylonitrile & styrene with poly-butadiene. The acrylonitrile adds chemical resistance, hardness, fatigue resistance and rigidity and it also increase the heat deflection temperature. Styrene adds rigidity, improving ease and gives the shinning to the plastic. The polybutadiene gives ductility and toughness at lower temperature and it is also a rubbery substance. We need fewer force when we use ABS component but while using, PLA it re-quires more force to extrude. It also help to extrude small parts more accurately than PLA, the object will be more sharp and accurate. ABS requires more temperature glass transition temperature about 205-250 degree Celsius and some bad fumes during printing can be dangerous for health. ABS is also cheaper.

2) *Polylactic Acid (PLA) Material:* It is produced from renewable resources that's why it became most popular material and it is used most widely in 3d printing. In spite of the name polylactic acid it is potentially ambiguous, because PLA is not a polyelectrolyte, but a polyester. PLA glass transition temperature is mid of 60-65 degree Celsius, It has biocompatibility with the human body. It requires less temperature than ABS. No unwanted harmful fumes are produced. PLA is used in food packaging, compost bags, loose- fill packaging. It has applications in engineering plastics, where the stereo complex is amalgamate with a rubber-like polymer such as ABS. ABS and PLA are two types of plastic. Both materials are thermoplastic, which means that when heated, they become flexible and moldable, and when cooled to room temperature, they revert to their solid condition..
3) *HIPS Material:* High-impact polystyrene (HIPS) is a kind of polystyrene that can withstand a lot of impact. High-impact polystyrene is a robust, long-lasting, non-toxic, and recyclable synthetic copolymer. HIPS is also soluble in Limonene, a common solvent obtained from lemon peel.HIPS is a graft copolymer made up of pure polystyrene and polybutadiene rubber in terms of chemistry. It blends polystyrene's hardness with rubber's flexibility to create a high-impact thermoplastic that is durable and strong without being fragile.It also known by the trade name Bextrene, is commonly utilized in the production of toys and appliances. It's also utilized in packing and cases for products.

VI. EXPERIMENTAL WORK

A. Three-Dimensional Component Fabrication

The technology 3d printing that creates solidified things at the side of piling them one on top of the other is a great technology for manufacturing products. A single axis (the x- axis) is used to start this layer and works its way to the next (y- axis). Subsequent to finishing the pair axis, that advances to the z- axis, to-some-extent thickens that item and gives it a solid 3d form. The 3d printer gets the design from the computer as input through a software interface.

The ASTM D638 standards are used to create the specimens for tension testing. The dimensions and geometry chosen here are similar to the Type 4 dog bone model, which measures 115 milli meter long, 19 milli meter broad, and 4 milli meter deep, as well as 6 milli meter broad, 33 milli meter extended, with a gauge length pertaining to 25 milli meter.

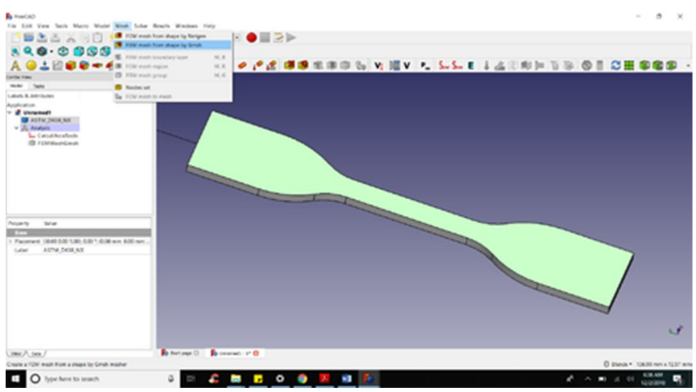


Fig:3 CAD model

Table 2

Filament Parameters	Value
Liquefier temperature	230-250 °C
Bed temperature	95-100 °C
Fan speed	0 %
Average time for printing	45 min/sec
% Infill	100 %
Filament used	ABS

B. Tensile Test

UTM, which shows the testing configuration utilized for each specimen, is used to establish the specimen's Ultimate Tensile Strength. At a steady chamber temperature, the INSTRON 5569 which is a universal testing equipment which was utilized to assess sample's tensile properties. Each model type is represented by five specimens. During tensile testing, the sample steadiness is critical, hence that sample is under inquiry which is meticulous place in the middle of the pair of the load cells..

For each attempt at uniform results, At a pace of 3 mm/min the INSTRON wedge was set to free. The continuous data transfer occurs in the middle of the monitor system and the gathering of the data with the apparatus as late as the specimen hold out for concluding tensile strength and which can be break-down.

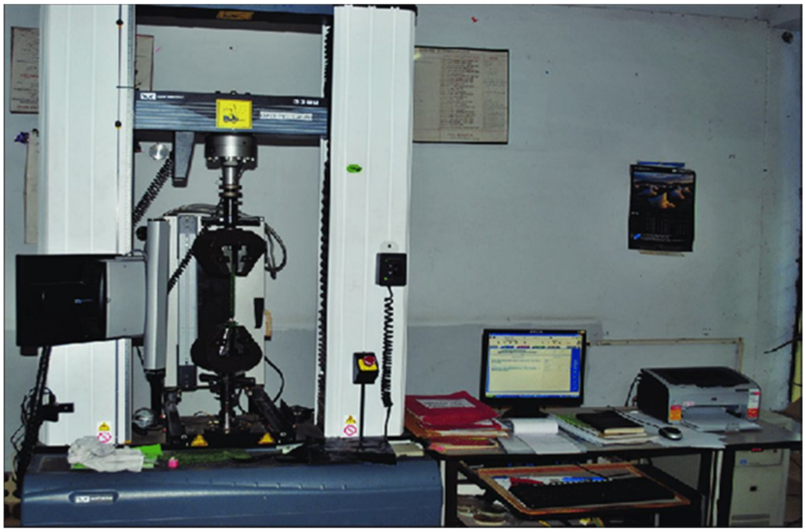


Fig-4 Instron tensile testing machine

C. Experimentation Design

Structure of examination (DoE) is a useful strategy for trial planning that combines Taguchi's symmetrical exhibit with the fewest possible redundancies to obtain measurably significant data. The L9 array was chosen, as well as the parameter degrees. The minimal number of experiments to be run, based on the total number of stages of freedom, must be determined before setting on the orthogonal array. The number of experiments required to learn about the factors must be more than the total number of degrees of freedom available. When calculating the total degree of freedom, add one degree of freedom to the normal mean of the response under investigation. Every number below learns about one fewer level of freedom than the number of levels available for that factor. As a result, all of the degrees of freedom, excluding the impact of interactions, are 1+. The total ranges of freedom are 3 in the case of 3 independent variables, each with 3 levels.

This condition is met by an L9 orthogonal. Following the determination of the minimal range of demonstrations. The number of unbiased variables and the diversity of component ranges for each variable with no dependency determine the orthogonal array. The height of layer, the width of raster and the angle of raster are all the factors.

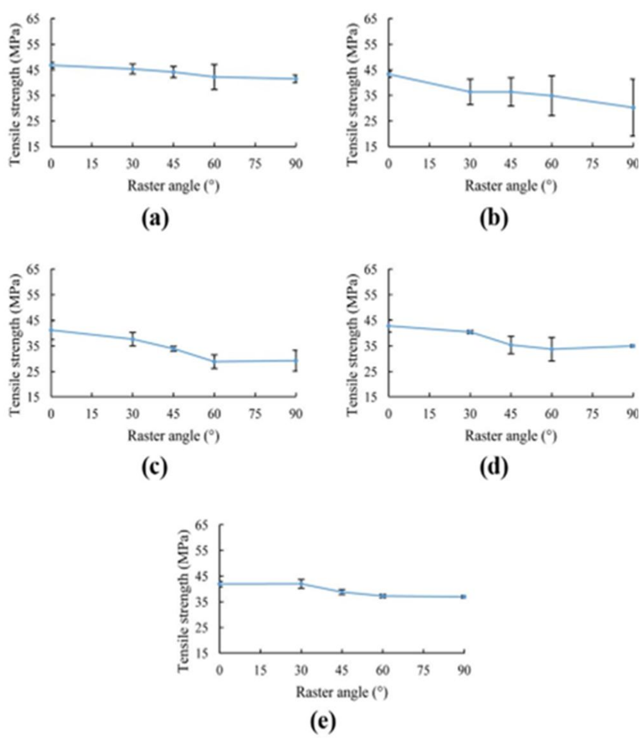
Fig-5 After tensile test specimen

VII. RESULTS

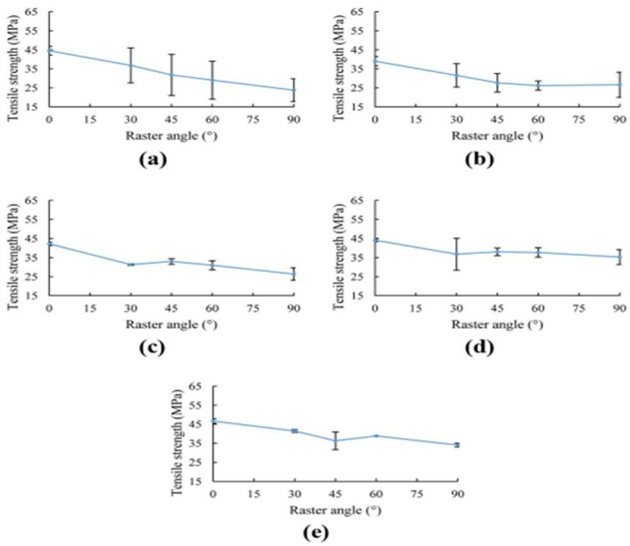
To investigate how the angle of raster, length of the layer, & width of the rasters is influenced tensile characteristics of - FDM component, a bulk number of specimens were printed with FDM.. All rasters are aligned with the loading direction with a zero degree angle of raster during a tensile demonstration. All rasters are positioned at thirty degree, forty five degree, and sixty degree to the loading direction during tensile testing. The tensile examination is performed, rasters are deposited at a ninety degree angle of raster perpendicular to the machine's x-axis or loading direction.

Figure 5 (A)-(E) depicts influence angle of rasters on tensile strength at various layer heights until maintaining the breadth of rasters at 399.5 mm. Tensile strength appears to diminish when the angle of raster is inclined. In comparison, the strength of 150 mm layer height has been shown to be more variable [figure 5 (b)]. The combination of a 0° raster angle and a 100 mm layer height resulted in a greater tensile strength (46MPa) for 400 mm raster width. While the combination of a 60° raster angle and a 200 mm layer height resulted in a lowering strength (47.56 MPa)

S.no	Sample	Tensile Stress (MPa)	Young's Modulus (MPa)
1.	1	46.54	3246.21
2.	2	51.32	2843.20
3.	3	47.56	3362.45
4.	4	48.04	2785.36
5.	5	48.43	3246.10
6.	6	50.26	2985.22
7.	7	47.95	3133.94
8.	8	46.59	3504.23
9.	9	49.30	2844.23

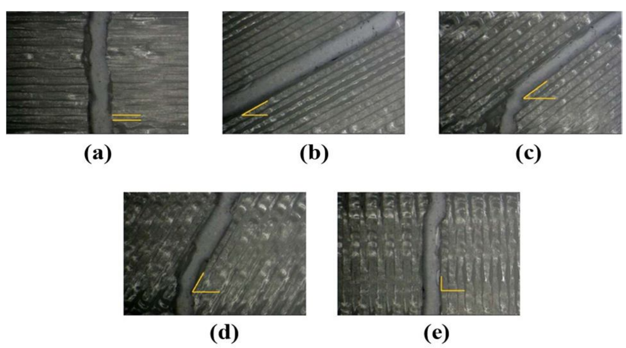


The influence of angle of rasters on the ultimate tensile characteristics of different sheet heights at 550 mm raster width is shown in Figure 7(a)-(e). The tensile strength variability was found to be greater at 100 mm layer height. The graphical depiction shows that tensile strength diminishes as the raster angle increases for all layer heights. At zero degree angle of raster and 320 mm length of layer for 550 mm breadth of raster, higher tensile strength (51.32 MPa) was attained.



VIII. FAILURE ANALYSIS

Fig-8 At various raster angles, failure tensile specimens



Note- (a) at 0º (b),(c) at 30.0º and (d),(c) at 45º

Response Table for Signal to Noise Ratios

Level	Raster Angle	Length of layer	Raster Width
1	33.76	33.66	33.53
2	33.67	33.64	33.89
3	33.61	33.75	33.62
Delta	0.15	0.12	0.37
Rank	2	3	1

Response Table for Means

Level	Raster Angle	Length of layer	Raster Width
1	48.78	48.17	47.47
2	48.24	48.08	49.52
3	47.95	48.71	47.98
Delta	0.83	0.62	2.05
Rank	2	3	1

Larger is better

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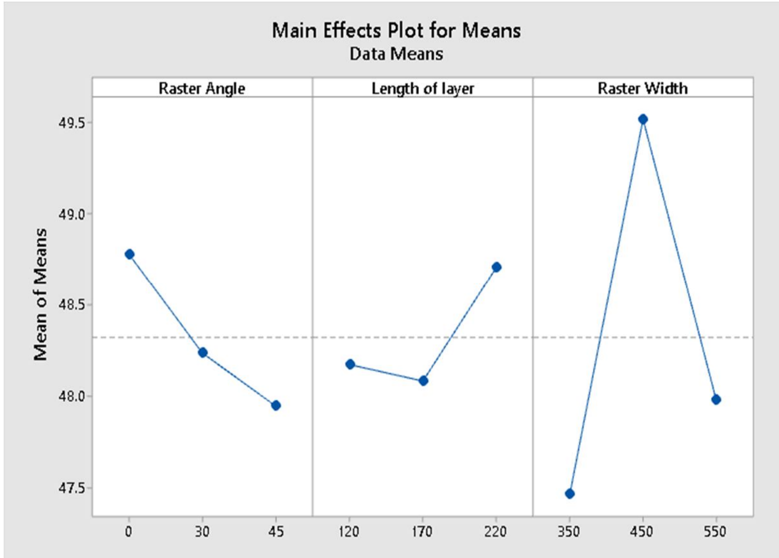

Regression Equation

Tensile	=	46.72 - 0.0185 Raster Angle + 0.0053 Length of layer
Test		+ 0.00257 Raster Width

IX. CONCLUSION

This study looked at the effects of angle of rasters ,thickness of layers, and breadth of raster on the tensile properties of FDM manufactured ABS components. The specimen's tensile strength is most affected by the raster angle because the bonding area between layer surfaces is larger at lower layer heights, tensile strength is higher at the 0° angle of raster, whereas the 90° angle of raster provided lower will be the tensile strength. Higher tensile strength may be obtained up to a point due to the increased thermal mass of the raster; after that, voids form between rasters, which are a major source of fracture initiation and propagation, weakening the components and resulting in decreased tensile performance .Furthermore, the impact of factors on intermediate levels is uncertain, which might be due to the large number of parameters that conflict or interact.As a result, a thorough examination of process variables is required to fully comprehend the tensile deportment of ABS specimens.

AM parts are always weaker than injection molding specimens or original material ones. An injection molding item may achieve eighty percent of its strength by positioning the lines in load direction.

X. ACKNOWLEDGEMENT

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XI. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

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