THE INFLUENCE OF OPERATIONAL SETTINGS ON THE TENSILE STRENGTH OF THE FDM-PRINTED ABS COMPONENT

A Dissertation Submitted

In partial fulfillment of the requirement for the Degree

MASTER OF TECHNOLOGY

In

MECHANICAL ENGINEERING

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in
“PRODUCTION AND INDUSTRIAL ENGINEERING”
By

ARPIT SINGH

(Enrollment No. 2000100471)

Under the Supervision of

Dr. MOHD ANAS

Associate Professor

DEPARTMENT OF MECHANICAL ENGINEERING INTEGRAL UNIVERSITY, LUCKNOW

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CERTIFICATE

This is to certify that **Mr. Arpit Singh** (Enrollment No. 2000100471) ha**s** carried out theresearch work presented in the thesis titled **"THE INFLUENCE OF OPERATIONAL SETTINGS ON THE TENSILE STRENGTH OF THE FDM-PRINTED ABS COMPONENT"** submitted for partial fulfillment for the award of the **Degree of Master of Technology in Mechanical Engineering** from **Integral University, Lucknow** under my supervision. The thesis embodies result of original work, and studies are carried out by the student himself.

Therefore, I deem this work fit and recommend for submission for the award of the aforesaid degree.

Dr. Mohd Anas

Associate Professor

Department of Mechanical Engineering

Integral University, Lucknow

Date:

DECLARATION

I hereby declare that the thesis titled "**The Influence of Operational Settings on the Tensile Strength of the FDM-Printed ABS Component"** is an authentic record of the research work carried out by me under the supervision of **Dr. Mohd Anas**, Associate Professor Department of Mechanical Engineering, for the period from 2020 to 2022 at Integral University, Lucknow. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certify that I have not willfully taken other's work, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertation, thesis, etc., or availability at web-sites without their permission, and have not included those in this MTech thesis citing as my own work.

Date:

Signature:

Name: Arpit Singh

Enrollment No: 2000100471

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At this moment of accomplishment, I wish to pay my heartfelt gratitude and sincerest thanks homage to my guide, Professor **Dr. Mohd Anas**, department of mechanical engineering, Integral University Lucknow. This work would not have possible without their able guidance, support and encouragement. Under their guidance I have successfully overcome many difficulties and learned a lot. They used to review my thesis progress, give their valuable suggestions and made correction. Their unflinching courage and conviction will always inspire me, and I hope to continue to work on their noble thought.

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Arpit Singh

(Enrollment No: 2000100471)

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ABBREVIATION

3D	Three Dimensional
AM	Additive Manufacturing
DOE	Design of Experiment
FDM	Fused Deposition Modelling
ANOVA	Analysis of Variance
SLA	Stereolithography
SLS	Selective Laser Sintering
MJF	Multi Jet Fusion
DLP	Digital Light Process
DMLS	Direct Metal Laser Sintering
PJ	Poly Jet
EBM	Electron Beam Melting
PLA	Polylactic Acid
ABS	Acrylonitrile Butadiene Styrene
HIPS	High Impact Polystyrene
CNC	Computer Numerical Control
FEA	Finite Element Analysis
CAD	Computer Aided Design
ASTM	American Society Of Testing Material

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.

CHAPTER- 1

INTRODUCTION

1.1 INTRODUCTION TO ADDITIVE MANUFACTURING

3D Printing

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, stereolithography, 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.

3D printing is becoming increasingly popular in a variety of applications, and the modern industrial industry is eager to use it to replace traditional methods whenever possible. This is mostly owing to the several advantages that 3D printing can provide over traditional energy-intensive procedures, including the capacity to build complicated geometries as a single unit/part with no joints, cheaper material and labor costs, and an excellent surface polish. Compared to traditional technologies, reduced energy consumption, single-step processing temperature, less process complexity (CAD model-Print-Install), nearest form completion, rapid production time, short lead time, and cheaper overall cost are all advantages. Additive manufacturing (AM) and fast prototyping are other terms for 3D printing (RP).

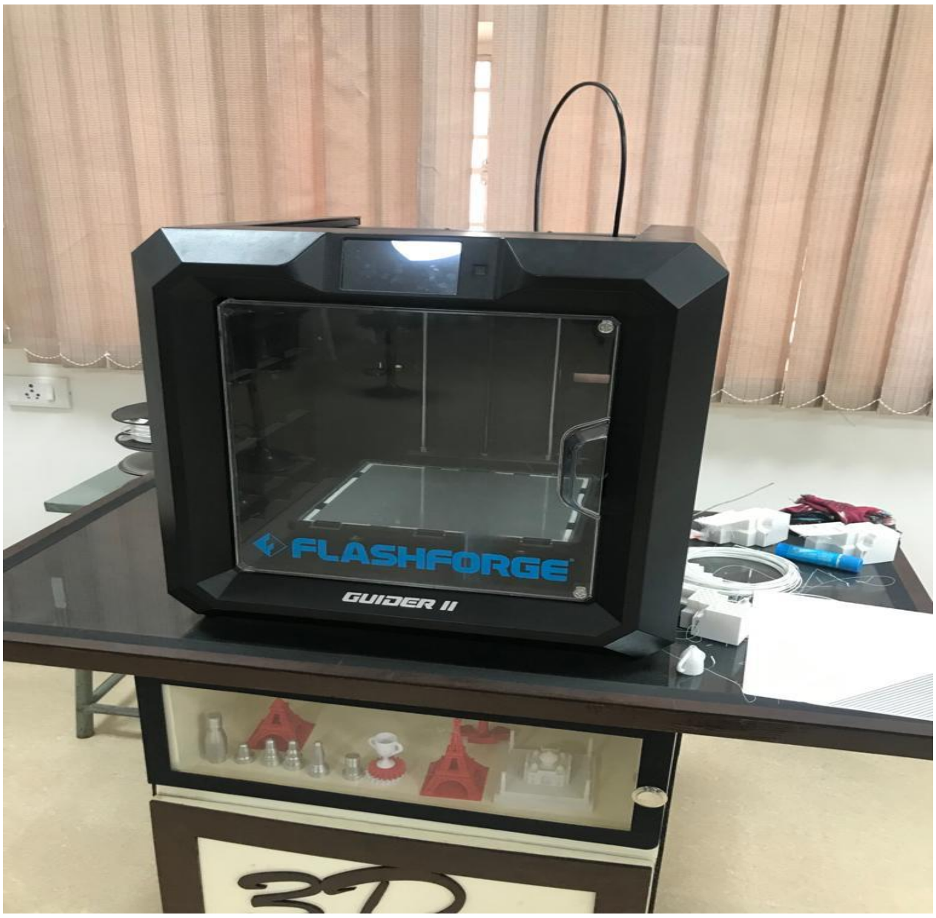


Fig-1.1 Flash forge 3d printer

3D printing is a common method for producing three-dimensional solid items from a digital design. The proper selection of printing settings is essential for producing high-quality 3D printed objects. The goal of this study is to look at the qualities of 3D printed specimens.

1.2 ADDITIVE MANUFACTURING

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) trans-figurize numerous machine tools that manufacture process through digitization. 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.

In the last several decades, additive manufacturing (AM) technologies have advanced dramatically; new materials and procedures with higher performance, including multi-material production capabilities, have been offered. As a result, some sectors have switched from traditional product development procedures to new approaches such as additive manufacturing. The fact that AM technologies minimize the cost and time of product creation has accelerated this progress. Despite this progress, the primary use of additive manufacturing is the manufacture of prototypes and conceptual items. One of the main reasons for this limited application is that the mechanical performance of AM parts is still unknown, as the AM process and parameters influence the mechanical properties that result, which can vary greatly. One of the primary reasons for this restricted applicability is that the mechanical performance of AM components is yet unknown, as the AM process and settings influence the final mechanical characteristics, which may differ significantly from the raw material.

AM is currently at an all-time high that appears to be unstoppable. PolyJet technology has improved year after year since Stratasys combined with Objet. A carriage is used in the PolyJet process to jet photopolymers onto the build plate. The substance is then cured with UV light. This enables the production of both stiff and flexible materials in a single construct. The printer develops a gel-like fluid to function as support material for any complicated shapes, which is simply removed at the end of the construction. This technique enables the production of high-resolution components with intricate characteristics that closely resemble the final resolution aesthetics needed for marketing and prototype purposes.

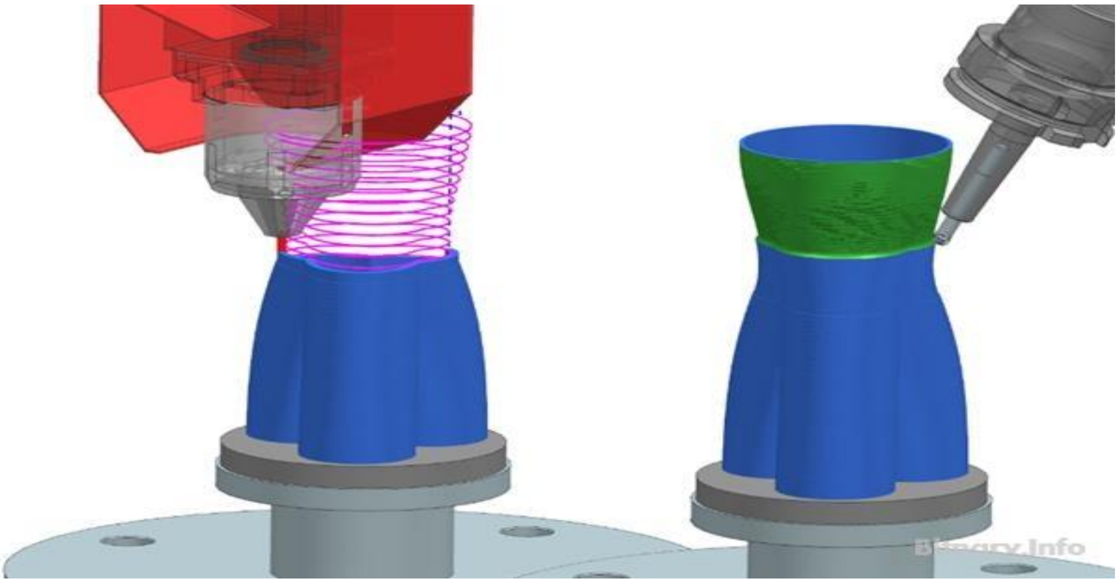


Fig-1.2 Additive Manufacturing

1.3 **Different types of 3d printing**

The phrase "3D printing" refers to a group of manufacturing techniques that work in layers to create items. Each has its own method for forming plastic and metal components, as well as material selection, surface polish, durability, production speed, and cost.

3D printing comes in a variety of forms, including:-

- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Fused Deposition Modelling (FDM)
- Digital Light Process (DLP)
- Multi Jet Fusion (MJF)
- Poly Jet
- Direct Metal Laser Sintering (DMLS)
- Electron Beam Melting (EBM)

Let's take a look at some of the most common plastic 3D printing procedures and see when they're most useful to product developers, engineers, and designers.

1.3.1 Stereolithography

The first industrial 3D printing technology is stereolithography (SLA). SLA printers are particularly good at manufacturing items with a lot of detail, flawless surface finishes, and tight tolerances. Surface finishes on SLA components are not just attractive, but they may also help with the part's function—for example, checking the fit of an assembly. It's frequently employed in the medical field, with anatomical modeling and microfluidics among the most prevalent uses. SLA components are printed using 3D Systems' Vipers, Pro Jets, and I Pros 3D printers.

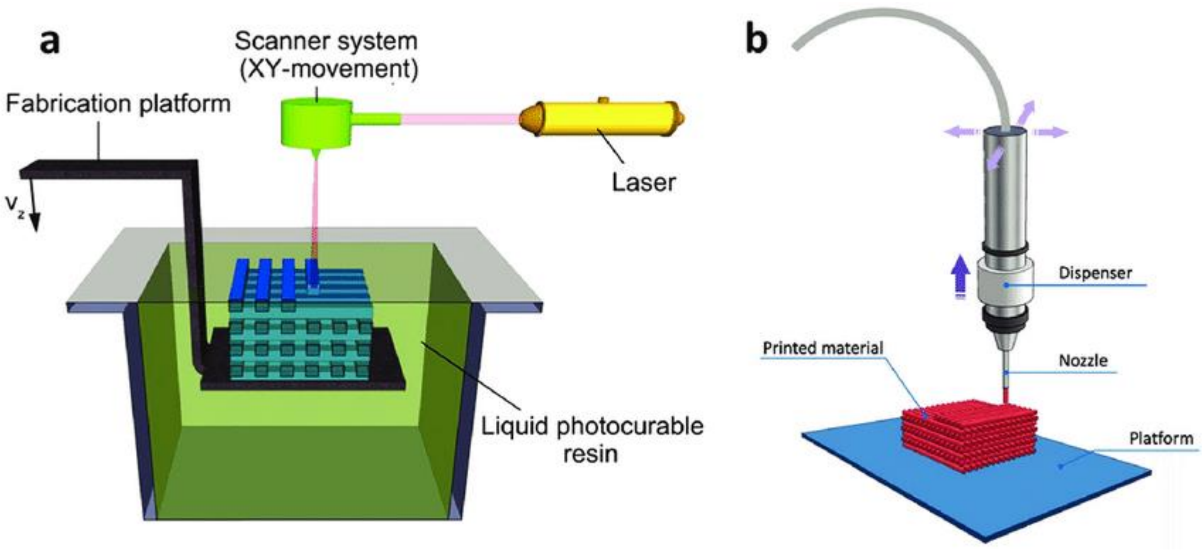


Fig-1.3 Stereolithography process

1.3.2 Selective Laser Sintering (SLS)

Nylon-based particles are melted together into solid plastic using selective laser sintering (SLS). SLS components are robust, ideal for functional testing, and can support live hinges and snap-fits since they are constructed of actual thermoplastic material. Parts are stronger than SL, but the surface finishes are rougher. Because SLS doesn't require support structures, the whole build platform may be used to stack many parts into a single build, allowing it to handle bigger part volumes than other 3D printing techniques. Many SLS components are used to develop designs that will be injection-molded in the future. We utilize sPro140 equipment from 3D Systems for our SLS printers. SLS is an additive manufacturing (AM) process that employs a laser as the power source to sinter powdered material (usually nylon or polyamide), autonomously targeting the laser at places in space described by a 3D model, and binding the material together to build a solid structure. It works in the same way as selective laser melting does.

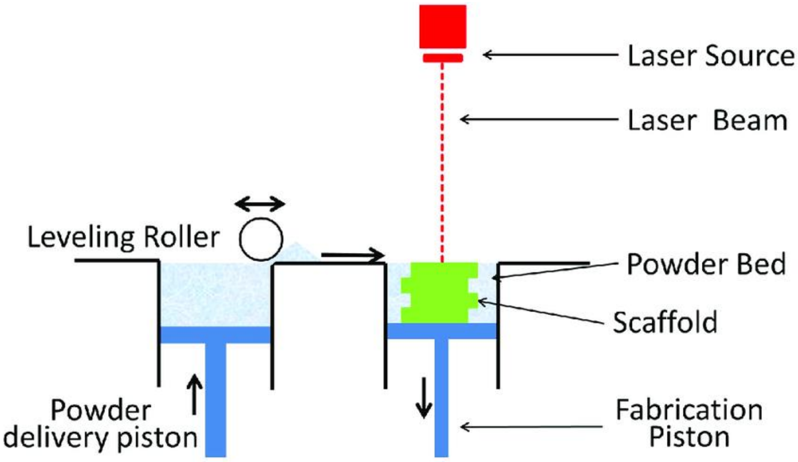


Fig-1.4 selective laser sintering (SLS)

1.3.3 Poly Jet

Poly Jet is a plastic 3D printing technology with a difference. It may create pieces with a variety of characteristics, such as colors and materials. Designers can use the technique to make elastomeric or overmolded prototypes. If your design is a single, hard piece of plastic, we recommend using SL or SLS since it is more cost-effective. PolyJet, on the other hand, can save you money on tooling if you're developing an overmolding or silicone rubber design early in the development cycle. This can save you time and money by allowing you to iterate and evaluate your design more quickly.

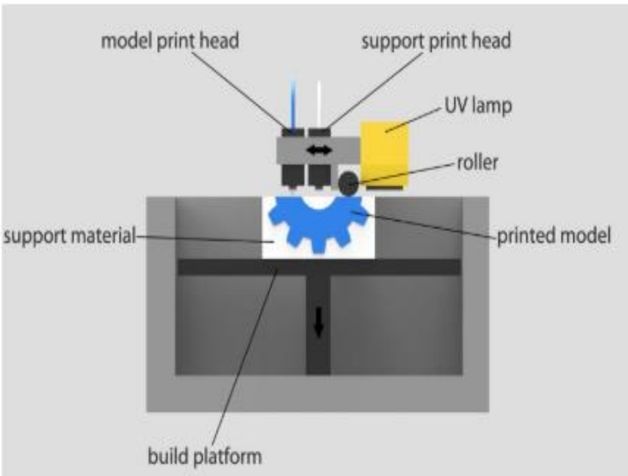


Fig-1.5 Poly Jet printing

1.3.4 Fused Deposition Modelling

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.

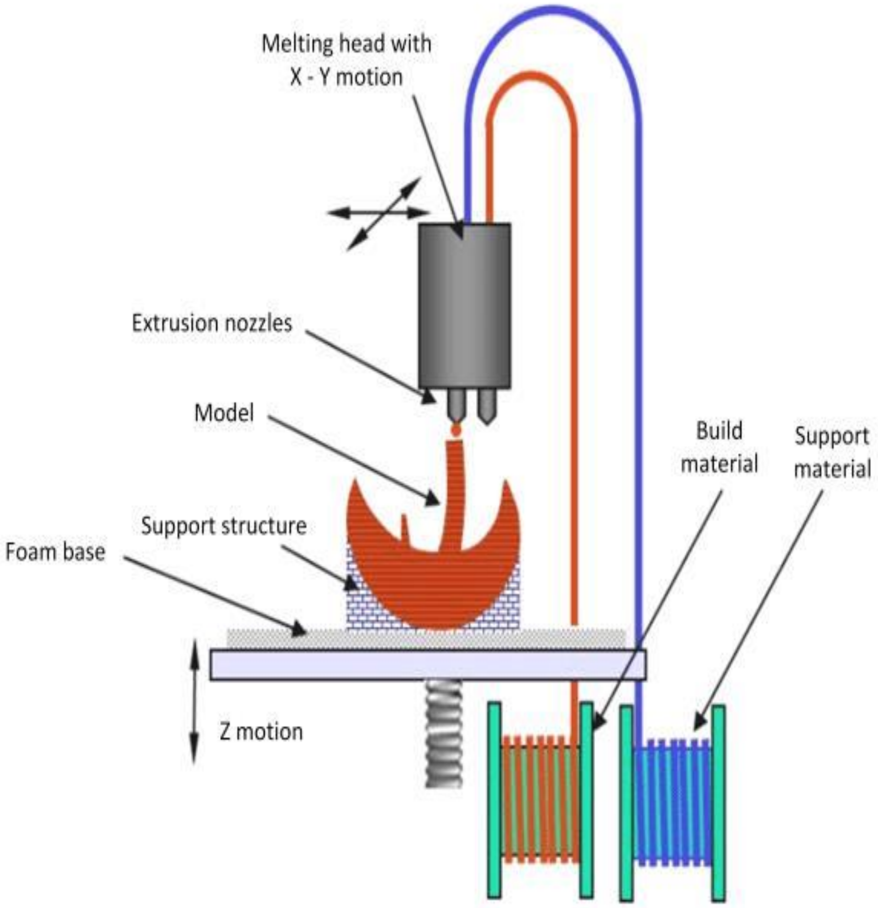


Fig-1.6 Fused Deposition Modelling (FDM)

1.3.4 Digital Light Processing (DLP)

In the same way as SLA cures liquid resin with light, so does digital light processing. The main distinction between the two technologies is that DLP use a digital light projector screen, whereas SLA employs a UV laser. DLP 3D printers can now image a whole layer of a build at once, resulting in speedier build times. While DLP printing is most commonly utilized for quick prototyping, its increased throughput makes it ideal for low-volume plastic component manufacturing runs.

One of the most intriguing 3D printing technologies currently available is Digital Light Processing. It's also the only one that's seen widespread adoption in other sectors, with most digital cinema projectors including the technology.

Using a projector, the procedure is carried out. This projector cures a photopolymer resin one layer at a time, curing just the regions that need to be solidified according to the 3D printer model and leaving the rest uncured. After one layer is finished, the component is moved up by one layer height (e.g. 50 microns) and the procedure is repeated.

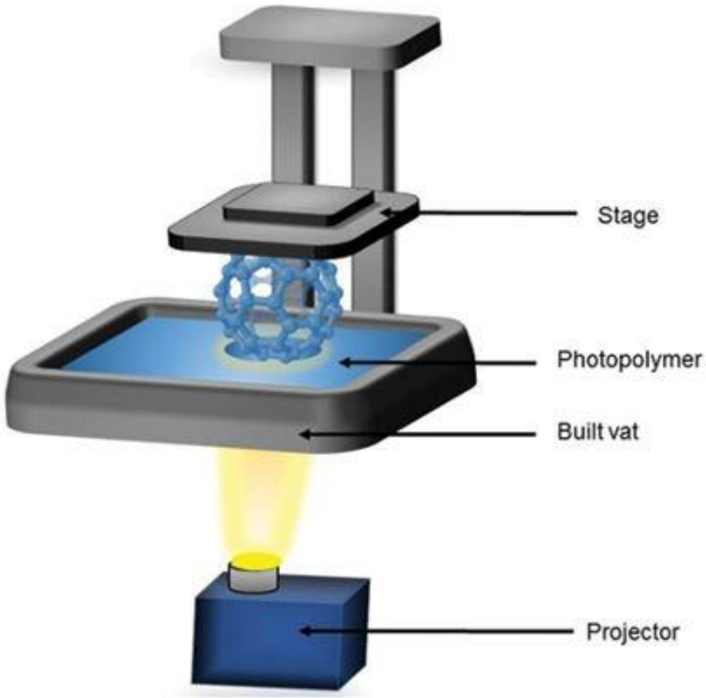


Fig-1.7 Digital Light Processing

1.3.5 Multi Jet Fusion (MJF)

Multi Jet Fusion, like SLS, uses nylon powder to construct functioning pieces. MJF employs an inkjet array to deliver fusing chemicals to the bed of nylon powder, rather than a laser, to sinter the powder. Then, to fuse each layer, a hot element passes over it. In comparison to SLS, this leads to more uniform mechanical qualities and a better surface polish. The MJF technique also has the advantage of having a faster construction time, which results in cheaper manufacturing costs.

Fig-1.8 Multi Jet Fusion (MJF)

1.3.6 Direct Metal Laser Sintering (DMLS)

Metal 3D printing expands the scope of metal part design. Direct metal laser sintering is the method we utilize to 3D print metal objects at Proto labs (DMLS). It's frequently used to turn multi-part metal assemblies into a single component, as well as lightweight pieces with interior channels or hollowed-out features. Parts made using DMLS are as dense as those made with traditional metal manufacturing processes like machining or casting, making it suitable for both prototype and production. Metal components with complicated geometries are also ideal for medical applications where a part design must resemble an organic structure.

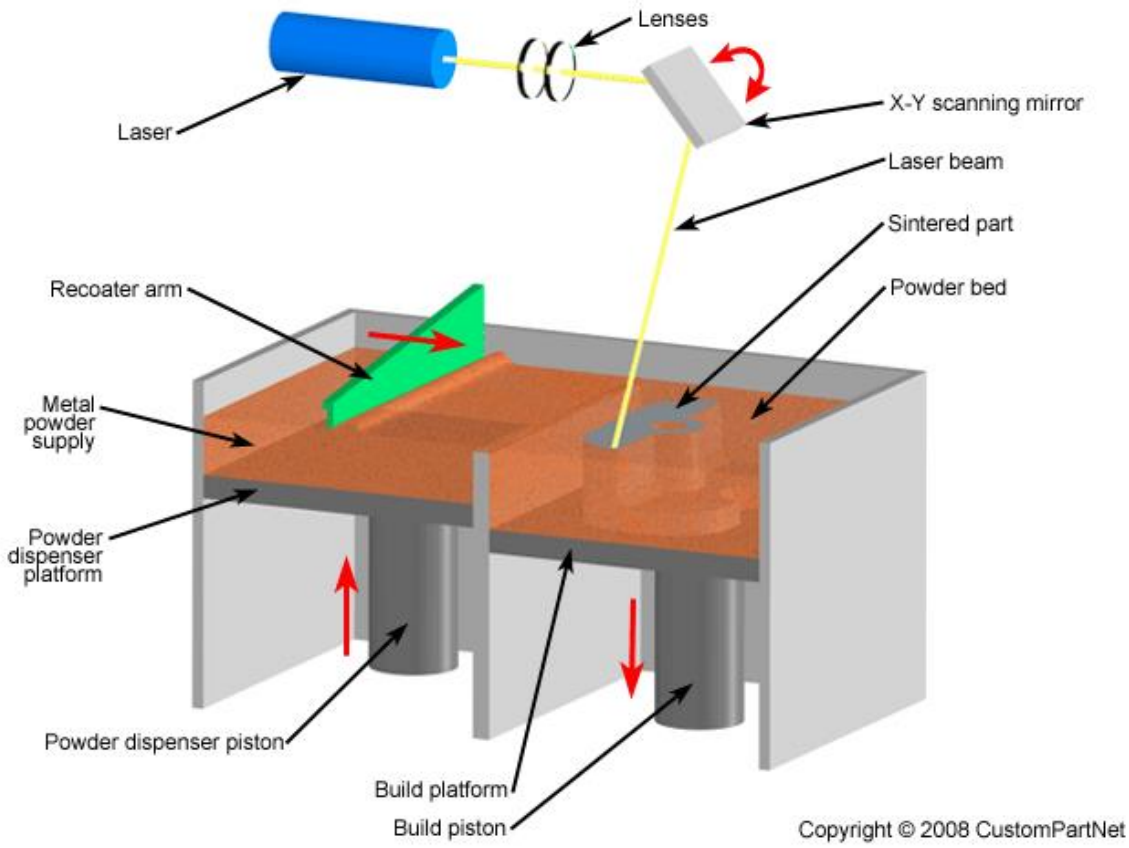


Fig-1.9 Direct Metal Laser Sintering (DMLS)

1.3.7 Electron Beam Melting (EBM)

Another metal 3D printing technique is electron beam melting, which involves melting metal powder with an electron beam controlled by electromagnetic coils. During the construction process, the printing bed is heated and vacuumed. The substance in use determines the temperature to which it is heated.

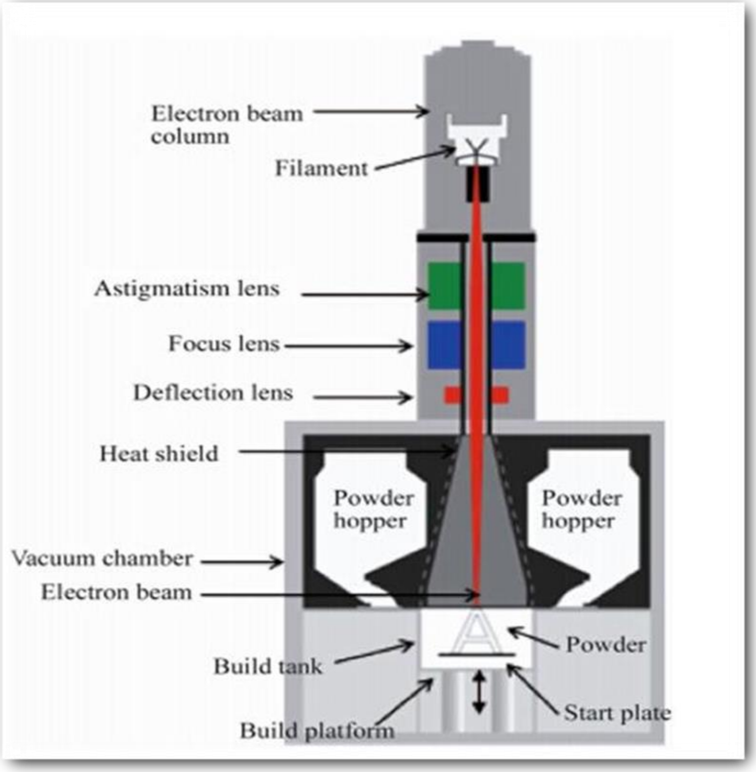


Fig-1.10 Electron Beam Melting

1.4 DIFFERENT FILLAMENTS USED IN 3D PRINTING

1.4.1 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.

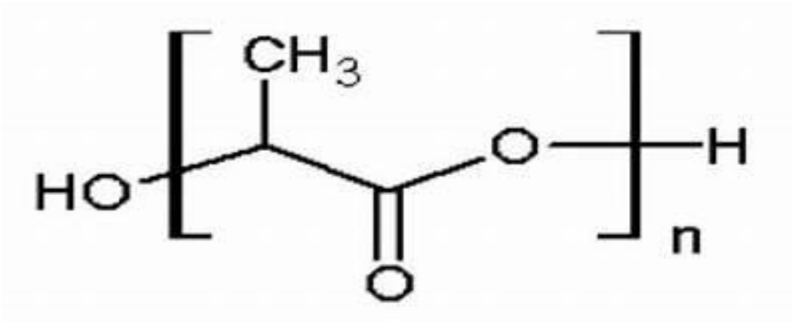


Fig-1.11 PLA Chemical Formula

1.4.2 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 requires 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.

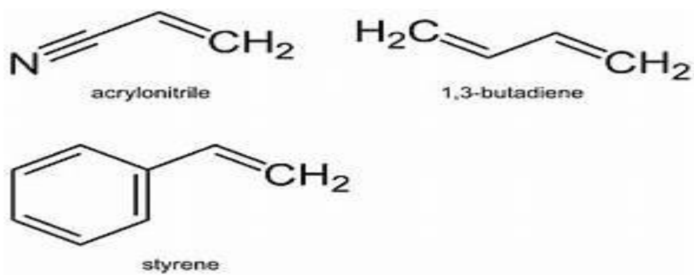


Fig-1.12 ABS Chemical formula

1.4.3 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.

Fig-1.13 HIPS filament

1.5 WHAT IS CAD SOFTWARE?

CAD, also known as computer-aided design and drafting (CADD), is a technique for design and technical documentation that substitutes an automated process for human drawing. You've undoubtedly used 2D or 3D CAD software like AutoCAD or AutoCAD LT if you're a designer, drafter, architect, or engineer. These often used software tools may assist you in creating construction documentation, exploring design concepts, visualizing ideas through photorealistic renderings, and simulating the performance of a design in the real world.

Using computers (or workstations) to help with the development, revision, analysis, or optimization of a design is known as computer-aided design (CAD). With the use of this software, designers may work more productively, produce better designs, enhance communications through documentation, and build databases for production. When incorporated into patent applications, CAD designs are beneficial in securing goods and inventions. Electronic files for printing, machining, or other industrial processes are frequently the CAD output. Additionally, the words computer-aided design and drafting (CADD) and computer-aided drafting (CAD) are employed.

Electronic design automation refers to its application in the design of electronic systems (EDA). The process of producing a technical drawing using computer software is referred to as mechanical design automation (MDA) in mechanical design.

CAD software for mechanical design either creates raster images to illustrate the overall look of created things or vector-based graphics to represent the objects of conventional drawing. But it involves more than simply geometrical forms. The output of CAD must transmit information, such as materials, procedures, measurements, and tolerances, in accordance with the conventions particular to the application, much like when technical and engineering drawings are manually drafted.

Since CAD is a component of the entire digital product development (DPD) activity inside the PLM processes, it is used in conjunction with additional tools that are either integrated modules or stand-alone solutions, such as:

- Finite element analysis (FEA) and computer-aided engineering (CAE) (FEA, FEM)
- Computer numerical control (CNC) machine instructions are part of computer-aided manufacturing (CAM).

- Motion simulation and rendering that is photorealistic.
- Utilizing product data management for document management and revision control (PDM)

CAD is also used to accurately create the photo simulations that are frequently needed in the creation of environmental impact reports, in which images of existing environments are superimposed with computer-aided designs of proposed buildings to show what the area will look like if the facilities are allowed to be there.

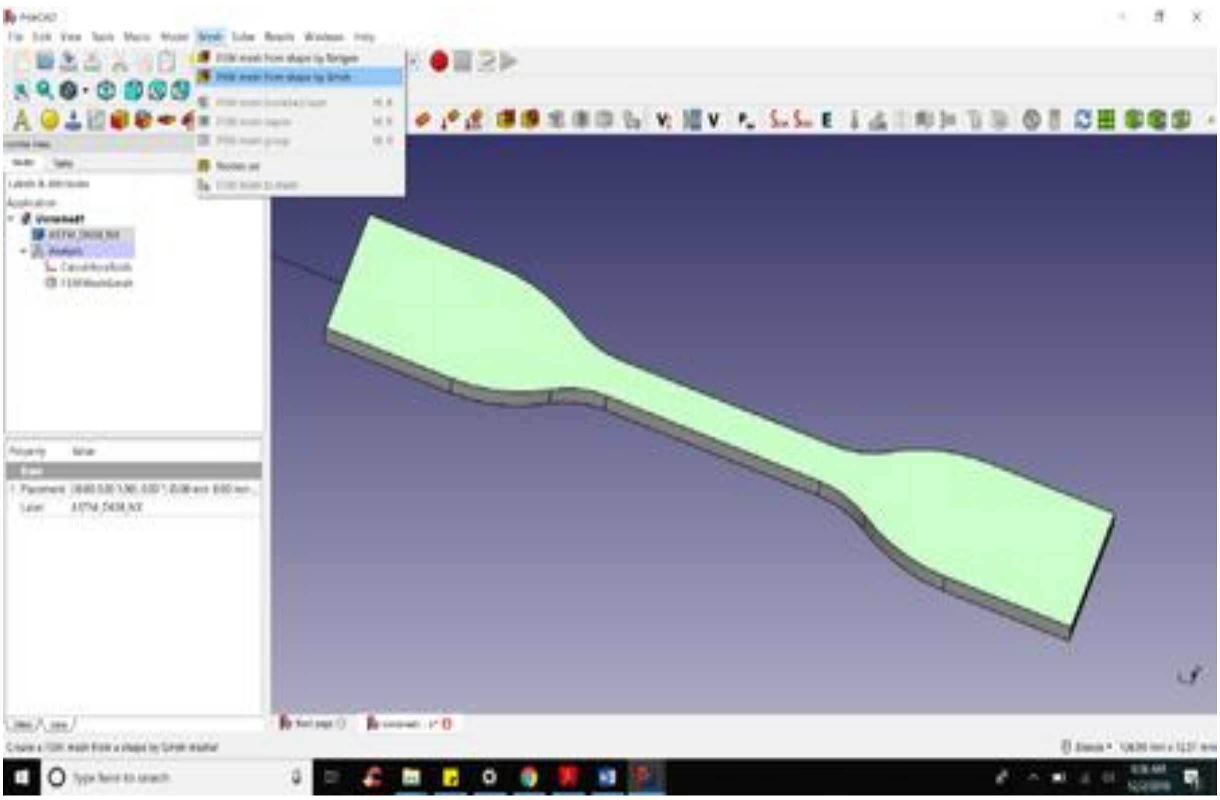


Figure-1.14 CAD sample design

Engineers have also found CAD to be helpful. Utilizing history, features, parameterization, and high-level restrictions as four characteristics. The model's individual characteristics may be examined in the building history so that a specific section, rather than the entire model, can be worked on. The size, form, and other characteristics of the various modeling elements may be determined by parameters and restrictions. The CAD system's characteristics may be used to a wide range of measuring equipment, including those for tensile strength, yield strength, electrical, and electromagnetic properties. Additionally, consider the stress, strain, timing, or how a given temperature affects an element.

1.6 SOME MAJOR TERMS-:

1.6.1 Infill patterns-:

You might be unsure about the purpose of infill if you're new to the 3D printing industry. As the printer constructs each layer, infill gives the 3D print internal support. Without infill, it would be incredibly challenging to print the upper layers because the plastic would droop over the print's empty spaces.

Infill will have an impact on the finished product's strength or feel in addition to the printing process itself. You should have a broad notion of the pattern and proportion you want to employ once you know what your print will be used for.

Different infill patterns will be present depending on whatever slicer you choose. While certain patterns are shared by all slicers, some have some really distinct patterns.

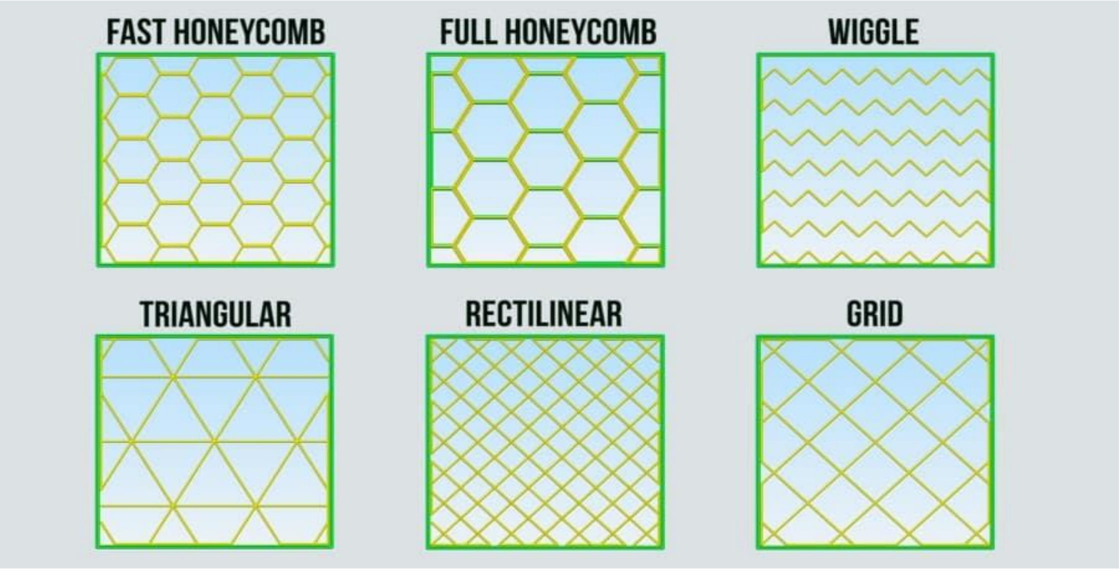


Fig 1.15 different infill patterns

1.6.2 Raster Angle-;

Raster angle refers to the raster tool path's angle with regard to the build table's x-axis. Typically, only 0-90° or 0° to 90° in 15° increments are permitted for raster angles. For instance, a selection of 45° will produce a raster tool path inclined at 45° to the x-axis in the bottom layer, and the tool path direction will then alternate in the subsequent layers above. An illustration of several FDM process parameters in a layer of deposited round section

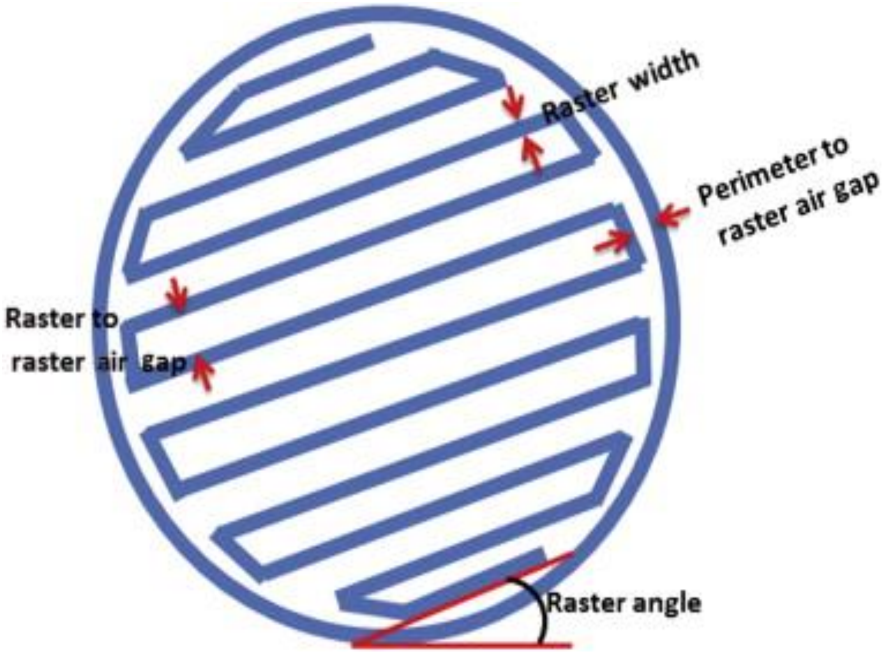


Fig 1.16 raster angle

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

Thomas. S. Lumpe et al. [2018] studied that recent advances in additive manufacturing technology enable the fabrication of monolithic, multi material parts and structures. The findings in this work present an important step towards the understanding of the micro structural mechanics and properties of such 3D printed parts, focusing on the inter facial behaviour . Applying systematic specimen manufacturing and testing methods, the tensile strength of these interfaces for selected material combinations at different strain rates is investigated.

Megan Waytashek et al. [2019] he studied that for tensile testing, it was determined that the tensile testing of the 3d-printed specimens showed that the 45° raster orientation angle made the strongest specimen at an ultimate tensile strength of 64 MPa. The 0° and 90° raster orientation were not much less at 58 MPa and 54 MPa. A 3-point bending fixture was used to conduct flexural testing on printed specimen.

J. Justo , L. Tavara et al. [2016] The mechanical characterization of long fibre reinforced plastics manufatured with an ALM machine has been carried out. Microscopic inspection of the materials was also done. The results showed that, at the present stage of the technology, the product obtained by ALM can not compete, in terms of mechanical properties, with the autoclave manufacturing of common pre-preg materials.

S .Aravind Raj et al.[2017] This study was conducted to know the mechanical properties of 3D printed PLA by various mechanical and degradation test. 3D printed specimen was fabricated as per ASTM standards and tested using standard equipment. Results were positive and good, PLA can be competitive material to ABS as well as the fabrication process was totally ecofriendly due less emissions and wastages caused by conventional manufacturing process.

Francois Decuir et.al [2016] Fused deposition modeling (FDM) printers are becoming more frequent in everyday use. These types of 3D printers are extremely useful for rapid prototyping. Fused deposition modeling printing melts the printing material and extrudes it through a nozzle. The material is laid out in a layer by layer fashion until the object is completed printing.

Angel R Torrado et. al [2015] One of the most common materials utilized by material extrusion 3D printing is acrylonitrile butadiene styrene (ABS). The work presented in this research explored the effect of the addition of reinforcing materials on the mechanical properties of ABS in an effort to create materials with enhanced physical properties.

Joshua M Pearce et .al [2015] he studied that as the number of prosumer printers has expanded rapidly, they now make up the majority of the 3-D printer market and of these printers those in the open-source lineage of the RepRap also have expanded to dominate. Although still primarily used for prototyping or hobbyist production of low-value products, the RepRap has the capacity to be used for high-value distributed manufacturing.

Shilpesh R. Rajpurohit and Harshit K. Dave et .al [2018] – The purpose of this paper to study the tensile strength of the fused deposition modelling (FDM) printed PLA part. In recent times. In the present investigation, effect of raster angle, layer thickness and raster width has been investigated on the tensile properties of the FDM printed PLA part.

CHAPTER-3

METHODOLOGY

3.1 WORK ANALYSIS

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 flash forge 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 and angle of raster.

3.2 Need of present work:

The fused deposition modelling is a latest 3D printing technique, by using this technique we can produce many complex mechanical parts at very low cost and directly from computer models of that part. Now days these parts are widely used in packing, D.I.Y. projects, producing broken parts (Ex. Xerox machine gears), even some biomechanical parts. The designer using rapid prototyping techniques to print mechanical parts requires raw data like wear rate, surface hardness, compressive strength / tensile strength, etc. To predict part's life cycle and performance in real situations. This arises an immediate need for mechanical test data especially compressive strength and strength to weight ratio. As strength to weight ratio comes into play the widely used solution for obtaining high ratios in FDM printed parts in infill percentage , infill pattern and different angle of raster, but as the literature review suggested there is no experimental data is available for FDM printed ABS part plastic. This research work is done in order to provide that particular test results to facilitate designers to predict tensile behaviour of FDM printed ABS parts.

3.3 Problem formulation:

In order to solve the current problem an experimental study has been designed. In this study several specimens with different infill patterns, and infill percentages with different raster angles will be printed using the 3D printer and ABS as test material. Then these specimens will be tested under controlled conditions on UTM for collecting raw data on their compressive behaviour. These data will then be processed by using some specific software to generate relation graphs etc.

3.4 Purpose of present work:

The Purpose of this research is to analyse the 3D printed ABS parts and check the tensile strength of the samples with different parameters.

With the help of different parameter's we may get to know the mechanical property of the material such as:

1. Infill percentage
2. Raster angle
3. Layer height

The majority of research effort has been focused on the effect of the raster angle on the tensile characteristics of ABS components.

3.5 Selection of Tensile standard:

Since the main objective of the study was to observe tensile characteristics of the specimen, therefore specimen was made according to ASTM D638 standards.

Specimen was tensile on a UTM and the failure load was recorded. Since the specimen will not fail like brittle materials, therefore the point at which permanent deformation of specimen took place was considered as point of failure. In order to analyse the effect of infill percentage and infill pattern on the print time and mass of material used Flash Print software is used to calculate print time and mass of material used.

Table 3.1 Major Properties of sample

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
Bulk Density	1.0-1.05 g/cm^3
Printer	Flash Forge Guider 2
Colour	Yellow
Printing firm	Integral University, CADD Center Hazratganj
Infill Pattern	Hexagonal
Printing Method	FDM
Shell Thickness	0.45-0.140
Layer Thickness	0.2-0.4

Figure-3.1& 3.2 Flash Forge Guider-2 & Specifications of Printer

Table 3.2 3D Printer Specifications:

Name	Guider-2
Number of Extruder	1
Print Technology	Fused Filament Fabrication
Screen size	5.0” colour IPS Touch Screen
Build Volume	280*250*300mm
Layer Resolution	0.05-0.4
Build Accuracy	±0.2mm
Positioning Accuracy	Z axis 0.0025mm; XY axis 0.011mm
Filament Diameter	1.75mm
Nozzle Diameter	0.4mm
Print Speed	10-200 mm/s
Software	Flash Print
Support Formats	Input:3MF/ STL/ OBJ/FPP/BMP/PNG/JPG/JPEG Output: GX/G
OS	Win XP/Vista/7/8/10, Mac OS, Linux
Device Size	490*550*560 mm
Net Weight	30 Kg
AC Input	Input: 100V-240V AC,47-63Hz Power:500W
Connectivity	USB cable, USB stick, WiFi, Ethernet

3.6 Instron Tensile Testing Machine

Manufacturer of universal testing machines and other test equipment used to assess the mechanical qualities of materials and components is Instron (an ITW subsidiary).

Harold Hindman and George Burr, who collaborated at MIT, joined together to research the characteristics of novel materials that would be used to parachutes in 1946. Together, they created a device for evaluating materials that uses strain gauge load cells and servo-control mechanisms. As a result, Instron Engineering Corporation was established.

Dr. Mario Grosso established CEAST in 1953 with the intended goal of renovating instruments that had been sent from the United States under the Marshall Plan. CEAST is now a part of Instron. Later, the business developed polymer testing equipment using its knowledge. The business is now situated in Pianezza, Turin, and focuses in testing thermoplastic polymers for impact, rheology, and HDT/Vicat. Although Instron purchased CEAST in 2008, it still functions in a somewhat autonomous manner.

3.7 Areas of application

- Testing for tensile strength
- Testing for compressive strength
- Tests for fatigue
- Testing for flexural strength
- Impact testing (drop-weight and pendulum)
- Testing for Heat Deflection Temperature
- Testing the Vicat softening point
- Testing the melt flow index
- Testing for rheology

The tensile strength and compressive strength of materials are tested using a universal testing machine (UTM), sometimes referred to as a universal tester, materials testing machine, or materials test frame. A tensometer is a former term for a tensile testing device. The name's "universal" element refers to the fact that it can test a variety of materials, components, and structures for tensile and compression in accordance with industry standards (in other words, that it is versatile).

Fig-3.3 Instron universal testing machine

CHAPTER-4

FABRICATION OF SAMPLES

4.1 PROCESS OF MAKING SAMPLES

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.

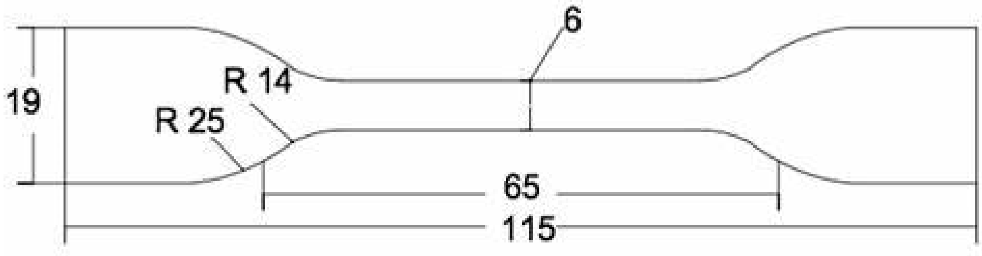


Fig-4.1 Sample dimensions

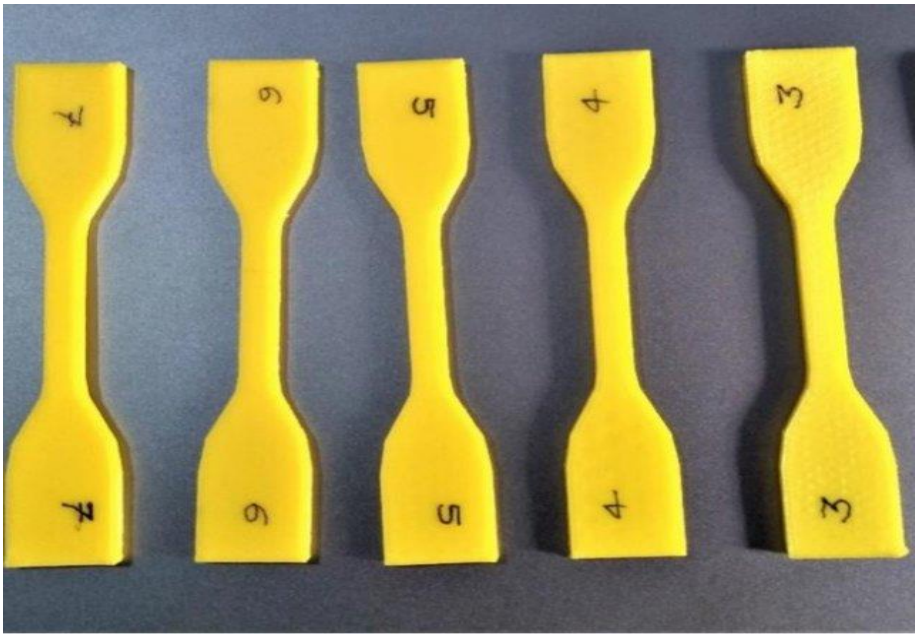


Fig-4.2 Specimen

4.2 Specification of sample

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.

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

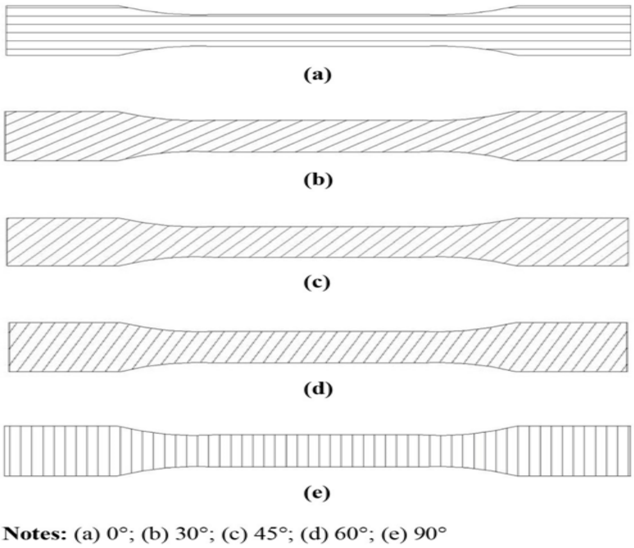


Fig-4.3 Different Raster Angle

Table 4.1 Different Parameters

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

CHAPTER-5

EXPERIMENT

5.1 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.

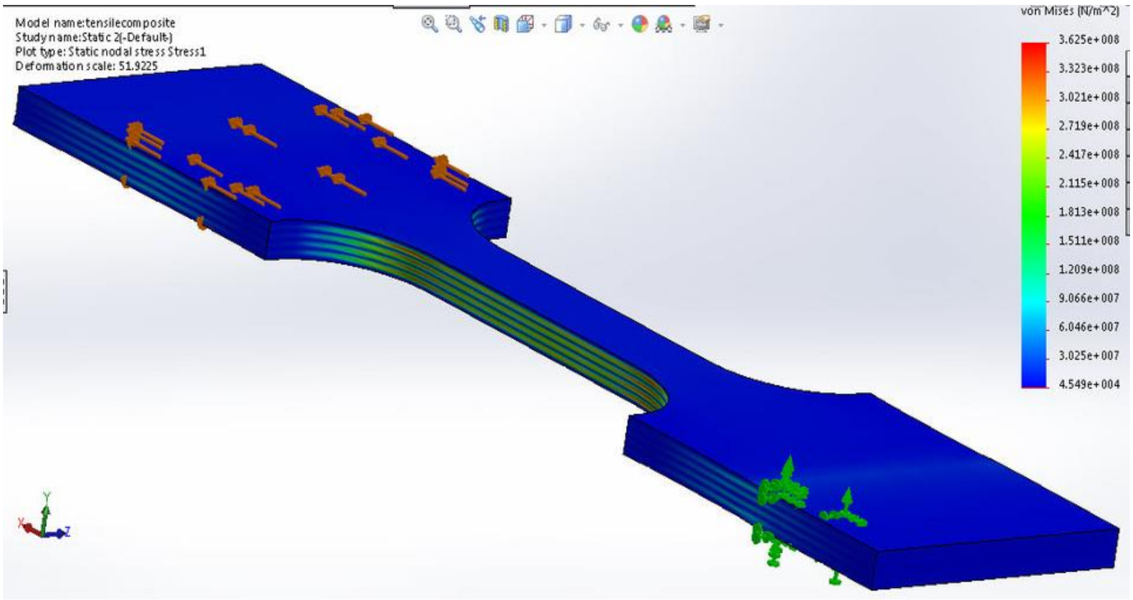


Fig-5.1 Specimen CAD model

5.2 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.

Tensile testing, commonly referred to as tension testing, is a crucial engineering and materials science test in which a sample is put under controlled tension until it fails. Ultimate tensile strength, breaking strength, maximum elongation, and decrease in area are characteristics that may be directly determined by a tensile test. Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics may all be calculated from these observations.

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.

5.3 DESIGN OF EXPERIMENT

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-5.2 After tensile test specimen

CHAPTER-6

RESULTS

6.1 ANALYSIS OF EXPERIMENT

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. Depicts influence angle of rasters on tensile strength at various layer heights until maintaining the breadth of raster 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 . The combination of a 0° raster angle and a 100 mm layer height resulted in a greater tensile strength (51.32MPa) 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).

6.1 TABLE TENSILE READING

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

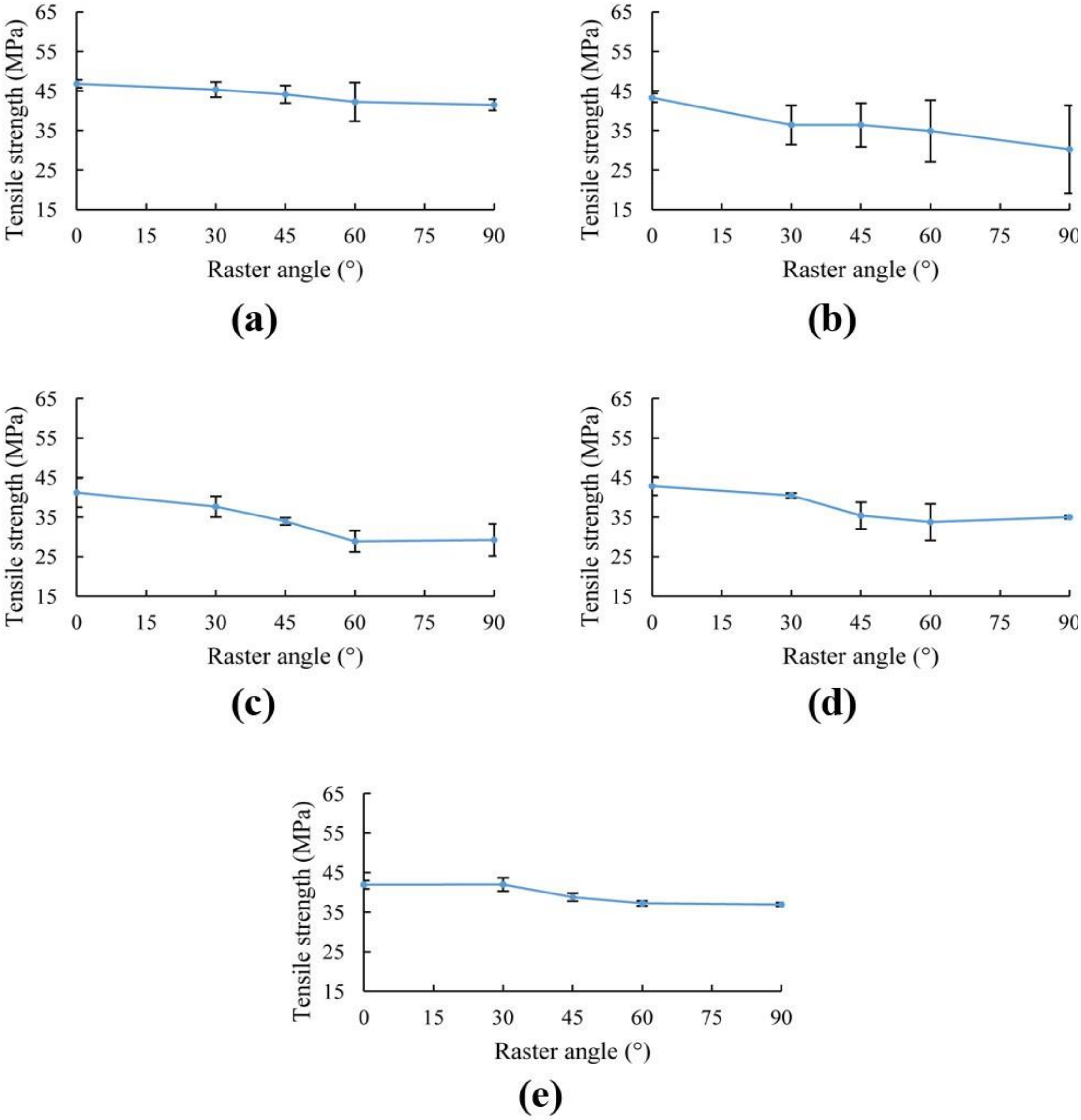
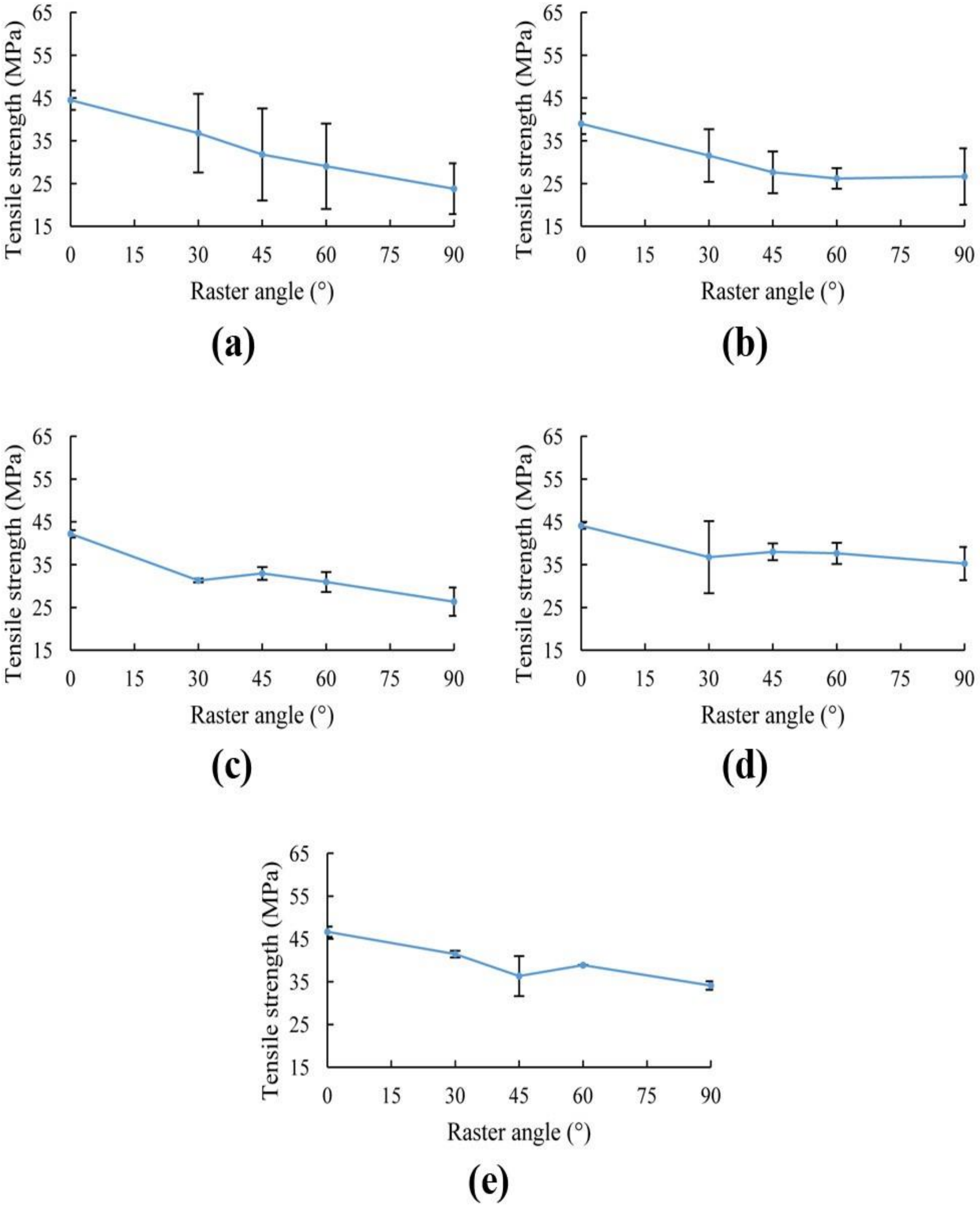


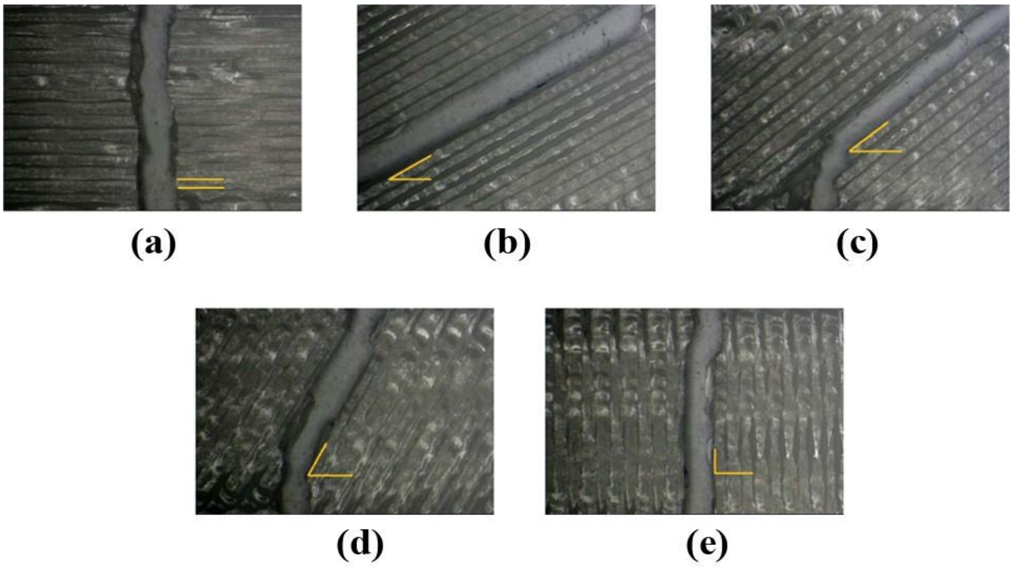
Fig-6.1 Different raster angle

The influence of angle of rasters on the ultimate tensile characteristics of different sheet heights at 550 mm raster width is shown in Figure (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**.**



6.2 Failure analysis

In this analysis we can see damage images of tensile specimen that is in images from (a) to (e) these images we get from SEM (Simple electron microscope) with the help of this device we can see the fracture images of tensile specimen and study their properties.



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

Fig-6.2 At various raster angles, failure tensile specimens

CHAPTER-7

CONCLUSION

This study looked at the effects of angle of raster, 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.

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LIST OF PUBLICATIONS

1. "**THE INFLUENCE OF OPERATIONAL SETTINGS ON THE TENSILE STRENGTH OF AN FDM-PRINTED ABS COMPONENT**" Arpit Singh, Mohd. Anas. "International Journal for Research in Applied Science and Engineering Technology **(IJRASET)**" Vol - 10, Issue - vi, June 2022 ISSN: 2321-9653

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APPENDIX-1

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

Arpit Singh[1], Mohd Anas[2]
[1]Department of Mechanical Engineering, Integral University, Lucknow.
[2]Associate Professor, Department of Mechanical Engineering, Integral University, Lucknow

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.

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