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The significance of 3D printing parameters on mechanical performance of 3D printed specimen using FDM technique

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ABSTRACT
Fused deposition modelling (FDM) is one of the processes used in additive manufacturing (AM). This creates objects by heating, extruding and deposits the material layer by layer in a predetermined path. The mechanical characteristics of produced parts seem to rely on the processing (parameters) settings. It is necessary to investigate the competing benefits of these processing factors.
This work focuses on investing the significance of 3D printing parameters on tensile and flexural properties of produced parts. The investigation carried out on a Polylactic acid (PLA) material . Total 7 categories were made with different combination 3 parameters for both tensile and flexural test. The chosen parameters are: Layer height, print speed and number of contours. Modelling of the specimens was done using solidworks. All the specimens were printed on Hydra 16A 3D printing machine at AMS – India Pvt Ltd Bangalore. Tensile test and flexural tests were carried out. Additionally, utilising Ansys workbench, further validation is done by simulating both tensile and flexural tests.A comparative analysis was done on experimental results vs simulations results. From the investigation it was observed that as we increase the print speed the quality of the material decreases and Number of contours has a effective influence on both tensile and flexural properties of the specimen. Among all the categories the category which has combination of Layer height = 0.20 (mm), print speed (mm/sec) = 2 and number of contours = 6 has highest tensile stress of 47.59 (N/mm^2) and flexural stress of 77.32 (Mpa).

I. CHAPTER 1. INTRODUCTION

1.1 Problem Definition

To study the significance of 3D printing parameters on mechanical performance of 3D printed specimen using FDM technique.

1.2 Introduction to3D printing.

Using a computer-generated design, 3D printing, sometimes referred to as additive manufacturing, is a technique for building three-dimensional objects layer by layer.

A 3D item is produced by the additive method of 3D printing, which involves building up layers of material. A final design is cut from a larger block of material in subtractive manufacturing techniques, which is the opposite of this. The result is minimal material waste due to 3D printing.

The formal name for what was formerly known as rapid prototyping and popularly known as 3D printing is additive manufacturing. Before a system or component is released or commercialised, a procedure for quickly generating a model of it is known as rapid prototyping, or RP. In other words, it's important to produce something rapidly so that it can serve as a prototype or basis model for further models and, ultimately, the finished product. Rapid prototyping is a term used by both management consultants and software engineers to describe a method of piecemeal creation of business and software solutions that enables clients and other stakeholders to test ideas and offer feedback throughout the development process. Rapid prototyping was a term frequently used in the context of product development to describe methods that produced physical prototypes straight from digital model data. This article discusses these latter technologies, which were first created for prototyping but are now utilised for a variety of other things.

Users of RP technology have realised that this phrase is insufficient and, in particular, does not accurately characterise more recent implementations of the technology. There is frequently a much tighter link to the finished product because to improvements in the output quality of these devices. We are unable to categorise them as "prototypes" because many parts are being directly fabricated in these machines. Rapid prototyping also ignores the fundamental idea behind these technologies, which is that they all use additive manufacturing to create things. New nomenclature should be used, according to an ASTM International Technical Committee that was recently established. While this is still up for controversy, the phrase "additive manufacturing" is currently used in recently established ASTM consensus standards.

The fundamental idea behind additive manufacturing, or AM, is that a model that was previously created using a three-dimensional computer-aided design (3D CAD) system may be immediately manufactured without the need for process planning. The process of creating complicated 3D objects directly from CAD data is substantially simplified by AM technology, even if it is not as straightforward as it may seem. The geometry of the part must be carefully and thoroughly analysed for other manufacturing processes in order to determine things like the order in which various features can be fabricated, the tools and processes that must be used, and any additional fixtures that might be needed to finish the part. In contrast, AM just requires a few fundamental dimensional information and a little comprehension of how the AM machine functions and the materials that are utilised to construct the part.

The fundamental to how additive manufacturing (AM) functions is that parts are created by layering on material, with each layer being a thin cross-section of the part created from the original CAD data. Each layer must, of course, have a finite thickness in the physical world, so the part that results will be close to the original data. The finished piece will be more similar to the original the thinner each layer is. The materials that can be used, the manner the layers are made, and the way the layers are connected to one another are the main areas where marketed AM machines to date differ from one another. These variations will dictate things like the finished part's precision as well as its mechanical and material qualities.

1.2 Applications

1.2.1 Aerospace.

The capacity to produce lightweight yet geometrically complicated items, like blocks, makes 3D printing popular throughout the aircraft sector. Due to the ability to construct an object as one complete component via 3D printing, lead times and material waste are reduced when compared to traditional manufacturing methods.

1.2.2 Automotive.

Due to the inherent weight and cost savings, the automotive sector has embraced 3D printing. Additionally, it enables the quick creation of novel or customised components for testing or small-scale production. As a result, if a specific part is no longer available, it can be made as part of a small, custom run that also includes the production of spare parts. Alternately, components or setups can be printed overnight and are prepared for testing before a larger manufacturing run.

1.2.3 Medical.

Making custom implants and gadgets using 3D printing has applications in the medical field. For instance, a digital file that is matched to a scan of the patient's body can be used to quickly produce hearing aids. Costs and production times can both be significantly decreased using 3D printing.

1.2.4 Robotics.

The robotics business is an excellent fit for 3D printing because of its quick manufacturing, flexibility in design, and simplicity of design customization. This involves efforts to develop customised exoskeletons and quick, effective robotics.

II. CHAPTER 2 LITERATURE SURVEY

2.1 History.

- Stereolithography Apparatus, the first 3D printing method ever, was invented by Charles Hull in 1984. (SLA).
- Built in 1987, the first Stereolithography Apparatus (SLA) 3D printer was available for purchase. The final result was created using this machine's usage of laser beams to harden photopolymer resins.
- Binder Jetting, formerly known as Zprinting, was created by ZCorp in 1993.
- 1999: Scientists are all the rage with 3D printed organs. Scientists are investigating how this technology might be used in medicine.
- A completely functional, 3D-printed tiny kidney that can filter blood was developed in 2002.
- 2005 saw the start of Dr. Adrian Bowyer's RepRap Project, an open-source project to create a 3D printer that could print a variety of simple items.
- The first SLS printer that could be produced on a large scale and meet industry demand was created in 2006.

- Darwin, a self-replicating printer that was made in 2008, is a relaunch of an updated model first in 2005.
- 2008: Shape ways was a marketplace where designers could show off their work and get comments. It was a collaborative atmosphere where architects, artists, animators, and other professionals participated.
- 2008: A fully working 3D-printed prosthetic limb including a socket, foot, knee, etc. is introduced for the first time.
- 2008 saw the debut of Cupcake CNC, the first DIY open-source 3D printer kit from MakerBot.
- 2011 saw the creation of the first 3D-printed aircraft. This unmanned aircraft passed satisfactory flying tests.
- I. Create the first-ever materialized 3D prints of gold and silver in 2011.
- 2012: A prosthetic lower jaw is 3D printed and implanted in an 83-year-old woman.
- 2013: The online platform for 3D printing services, 3D Hubs, is established.
- 2014: The world's largest online retailer, Amazon, opens a store for 3D printing
- 2015 saw the founding of Desktop Metal and the introduction of a metal 3D printer suitable for offices.
- 2016 saw the release of Local Motors' self-driving 3D printed minibus, OLLIE. IBM Watson, which converses with the customer, drives the minibus.
- 2017 saw the Dutch opening of the first 3D printed bridge in history, built by BAM Infra.
- 2018: Researchers at the University of Minnesota 3D print a prototype of a bionic eye, and the world's first human cornea is printed in 3D.
- 2019 will see the release of the first 3D-printed human heart.
- 2020: Using 3D printing to create face shields, face masks, nose swabs, ventilator splitters, and other items to aid in the fight against the Covid-19 epidemic.
- 2021: Indian Army Engineers built Concrete 3D Printed Houses for Jawans.
- 2022: Military Engineering Services 3D Printed a Runway Controller Hut at Pune Airbase.
- 2023:Stanford scientists develop new composite 3D printing material for stronger nanostructures.

2.2 The generic Advanced manufacturing process.

From the virtual CAD description to the physical resulting part, AM requires a number of processes. Different goods will incorporate AM in varying amounts and ways. While larger, more sophisticated products with more engineering content may utilise AM during several phases and iterations throughout the development process, small, relatively basic goods might solely use AM for visualisation models. Additionally, due to the speed at which they may be produced, AM is used when early stages of the product development process only call for rough pieces. Parts may need meticulous cleaning and post-processing (such as sanding, surface preparation, and painting) at later stages of the process before they can be used. AM is helpful in this situation due to the intricacy of form that can be made without having to take tools into consideration. The numerous stages of the AM process will be thoroughly examined later on, but to put it briefly, most AM processes at least partially involve the next eight steps.

Step 1: CAD

All additive manufacturing parts must begin with a software model that accurately depicts the external geometry. Almost any professional CAD solid modelling software can be used for this, but the final product must be a 3D solid or surface representation. This representation can also be made using reverse engineering tools (such laser and optical scanning).

Step 2: Conversion to STL

Nowadays, almost all CAD systems can produce a file format like this, and almost all AM machines accept the STL file format, which has become a de facto industry standard. This file provides descriptions of the original CAD model's exterior closed surfaces, which are used to calculate the slices.

Step 3: Transfer to AM Machine and STL File Manipulation

The AM machine must receive the STL file detailing the component. Here, the file may undergo some general processing to make it the ideal size, location, and orientation for construction.

Step 4: Machine Setup

Before starting the build process, the AM machine has to be correctly configured. The construction parameters, such as material restrictions, energy supply, layer thickness, timings, etc., would be related to such settings.

Step 5: Build

The process of making the part is largely automated, and the machine may operate mostly unattended. To verify that no mistakes have occurred, such as running out of material, electricity, or software, etc., only cursory monitoring of the machine is required at this stage.

Step 6: Removal

The components need to be removed when the AM machine has finished building them. In order to accomplish this, you might need to communicate with the machine, which might include safety interlocks to make sure, for instance, that the operating temperatures are low enough or that there are no actively moving parts.

Step 7: Post-processing

Parts may need some further cleaning after being taken out of the machine before being put to use. At this point, parts might be fragile or contain extraneous components that need to be removed. As a result, doing so frequently calls for patience and precise, skilled physical manipulation.

Step 8: Application

Possibly now is the time to use the parts. Before they are suitable for usage, they can also need extra treatment. For instance, they can need painting and priming to get a surface quality and texture that is suitable. If the finishing criteria are exceedingly strict, treatments could be time-consuming and difficult. In order to create a finished model or product, they might also need to be combined with other mechanical or electrical parts.

2.3 Advantages & Disadvantages of 3D printing.

Advantages	**Disadvantages**
can be applied to many different produced goods.	Jobs in manufacturing will go down.
Simple to create a prototype from any product design.	Sections that are too thin risk collapsing.
monetary efficient.	Manufacturing thick pieces takes longer time.
conserves labour hours	It is only suitable for usage with tiny things.
prevents the waste of raw materials.	It is not environment friendly.
fastest production and prototyping method.	It might be challenging to keep a product's copyright.
Printing on many materials is feasible.	To solidify photoreactive resins, certain materials require post processing such as washing, sanding, or UV ovens.
A full assembly or family of components may be manufactured in one job because to the ability to generate several pieces at once.	Some materials with complicated shapes call for supports during construction.

Table 1: Advantages & Disadvantages of 3D printing.

2.4 3D printing technologies classification.

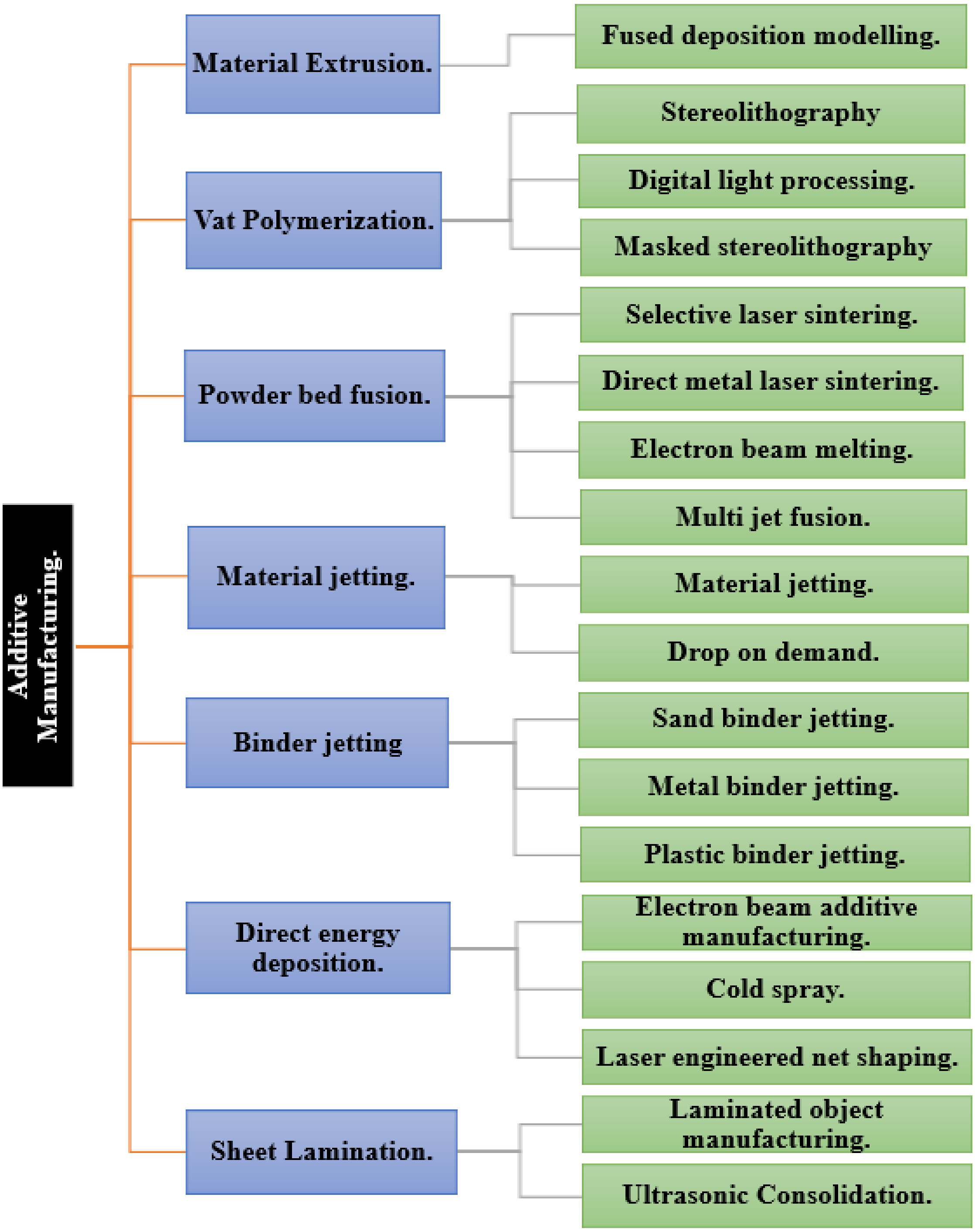


Fig1: Additive manufacturing classification

2.5 Fused deposition modelling

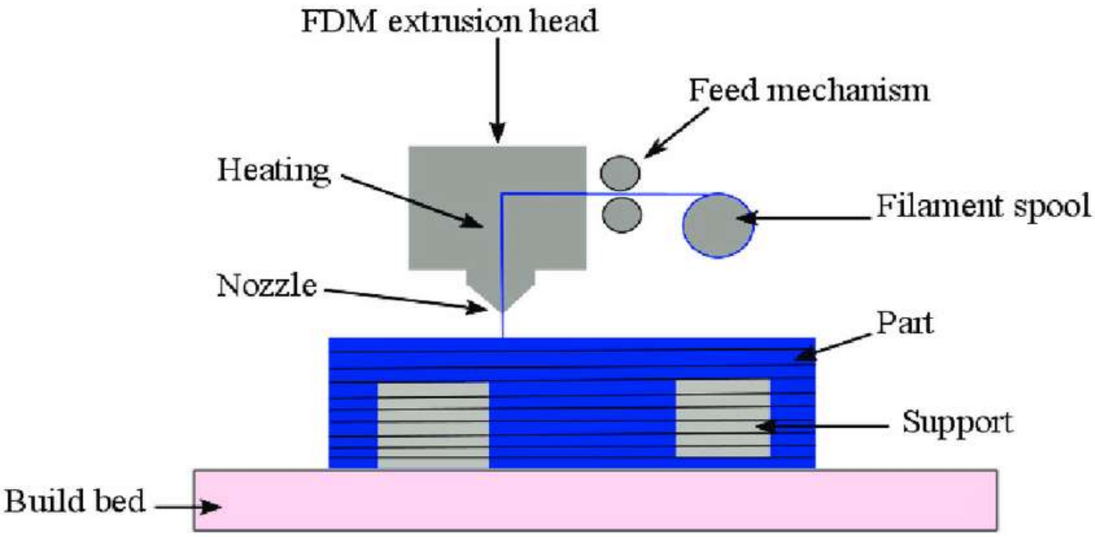


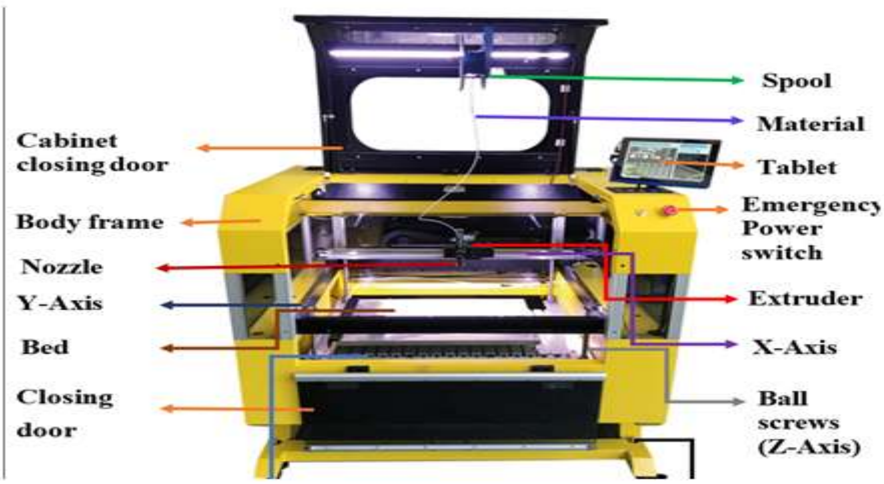
Fig2: Schematic diagram of Fused deposition modelling.

Globally, the most widely used and reasonably priced 3D printing technique is material extrusion equipment. They may be known to you as FDM, or fused deposition modelling. FFF, or fused filament fabrication, is another name for them.

Typically, a spool of filament is put into the extrusion head of the 3D printer and fed through to a printer nozzle. When the printer nozzle reaches the required temperature, a motor pushes the heated filament through the nozzle, melting it. The extrusion head is subsequently moved by the printer in accordance with predetermined coordinates, depositing the liquid material onto the build plate, where it cools and hardens. When a layer is finished printing, it moves on to the next layer. Repeating this cross-section printing technique, layer by layer, results in a completely formed item. It may occasionally be essential to build support structures depending on the geometry of the item, for instance, if a model includes steep overhanging areas. FDM is employed in 3D printed structures made of clay or concrete, desserts made of chocolate, organs made of living cells ejected from a bio gel, and so on. A 3D print of practically anything can be produced if it can be extruded.

2.6 Hydra 16A machine parts

Fig3: Schematic diagram of Hydra 16 A machine



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2.7 Review of Previous work

Adjustments can be made to the processing parameters to produce a part that can meet the demands of the application for which it is designed. But parameter modifications vary from machine to machine, and different advantages come with different settings. The process parameters have a considerable impact on the qualities of components made with FDM, according to the literature. Among the described works, Chacón et al[3] 's investigation of the effects of process variables on the mechanical characteristics of FDM-made PLA structures used in additive manufacturing. With sample orientation, they concentrated on variances in properties. They discovered, among other things, that ductility often declines with rising feed rate and layer thickness. Mohamed et al[4] 's investigation also looked into how process variables affected the dynamic mechanical performance of PC-ABS parts made using the FDM method. They found that layer thickness, air gap, and number of contours had the most effects among other processing factors. The effects of air gap, road/raster width, model temperature, material colour, and raster orientation on the tensile and compressive characteristics of ABS materials generated by the FDM process were investigated by Ahn et al. [5]. Their analysis showed that the mechanical characteristics of FDM-produced items appear to be parameter-dependent and anisotropic (display better characteristics in the deposition direction of the filaments). They also noted that raster orientation and air gap had a significant impact on the material's mechanical characteristics. In their study of the effects of layer thicknesses (200, 300, and 400 m) and raster angles (0, 30, and 45), Wu et al. [6] found that both variables had a comparable impact on the tensile, compressive, and flexural characteristics of 3D-printed poly ether ether ketone (PEEK) material. Research on the optimization of the mechanical characteristics of PEEK material in terms of process parameters was conducted by Deng et al. [7]. According to the study, printing at a speed of 60 mm/s, using a layer thickness of 0.2 mm, a temperature of 370 °C, and a filling ratio of 40% will yield the best mechanical qualities. Casavola et al. [8] investigated the impact of raster angle (30, 45, 0/90, and 0 only) on residual stresses that result from the process' fast heating and cooling in ABS objects made using FDM. Their research showed that components constructed with a raster angle of 30 have a larger residual stress, making them the worst configuration; in contrast, parts built with a raster angle of 45 have the lowest residual stress, making them the best configuration. Research on the effects of layer thickness, component orientation, raster angle, raster width, and air gap on the tensile property of ABS parts manufactured using FDM technology was conducted by Onwubolu and Rayegani [9]. According to their research, the best set of parameters to improve the tensile qualities of the components include a thin layer, a negative air gap, a narrow raster, and a high raster angle. Bagsik et al. [10] investigated how the build direction affected the tensile and compressive characteristics of ULTEM 9085 material manufactured using the FDM process while using a default raster orientation. They came to the conclusion from their analysis that the edge build direction provides more tensile strength than the flat and upright build directions. Additionally, their investigation demonstrated that, as opposed to the other two construction orientations, the section constructed in the upright (Z) direction has the maximum compressive strength. Bagsik and Schöppner [11] expanded upon their research by taking other factors into account, including raster angle (0, 30 and 45), build orientation (flat, edge, and upright), raster width (thin and thick), and raster-to-raster and raster-to-perimeter air gap (negative and positive). They conducted their experiment to see how these factors affected the tensile property of the same material made using the same FDM process. Their research revealed that employing a negative raster air gap, the best tensile strength was obtained for all construction orientations. Their research also revealed that employing thick filaments for both edge and upright construction orientations might increase the tensile capabilities. However, by using a thinner filament, the tensile property for items created in flat build orientation might be enhanced. Research on the impact of construction factors on the compression property of ULTEM 9085 generated by the FDM process was also conducted by Motaparti et al. [12]. They used a complete factorial design experiment to conduct their inquiry, which took into account three factors (build direction, raster angle, and air gap) and two types of specimens (solid and sparse). They came to the conclusion that the material's compressive yield strength is strongly influenced by the interplay between two factors, build direction and raster angle. The effect of process variables (layer thickness and printing speed) on the mechanical characteristics of 3D-printed ABS composite was also researched by Christiyan et al. [13]. They concluded from their analysis that low printing speed and thin layers produced the material's maximum tensile and flexural strengths. The effects of parameters, build direction, raster angle,

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and negative air gap on the flexural characteristics of ULTEM 9085 produced by the FDM process with solid- and sparse-build styles were also studied by Motaparti et al. [14]. Their research showed that a vertical build direction (edge) might provide a greater flexural yield strength than a horizontal build direction.

III. CHAPTER 3EXPERIMENTATION

3.1 Design of ASTM D638 specimen

Polylactic acid (PLA) material is used to print the test specimens. Specimens were printed using Fused deposition modelling technique using Hydra 16A 3D printing machine at AMS-India Pvt Ltd Bangalore.Two mechanical tests i.e., tensile and flexural were chosen to perform the experiment. All the tensile test specimens were printed as per ASTM D638 standard and all flexural test specimens were printed as per ASTM D790 standard dimensions.

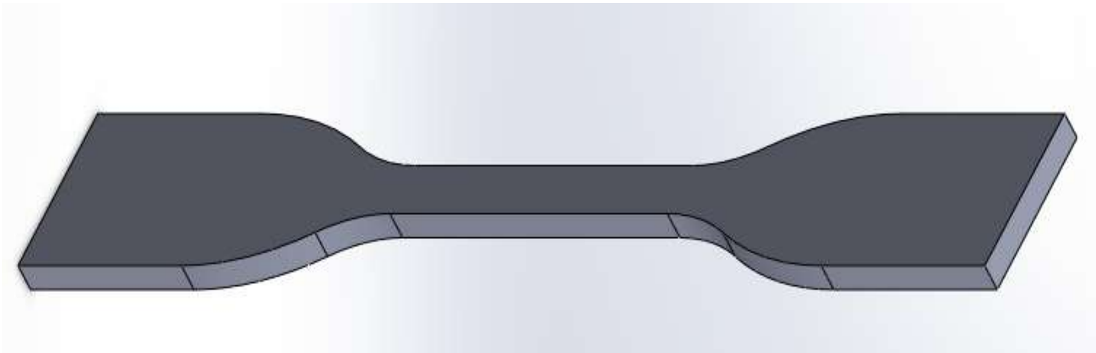

Fig4: Isometric view of the ASTM D638 test specimen

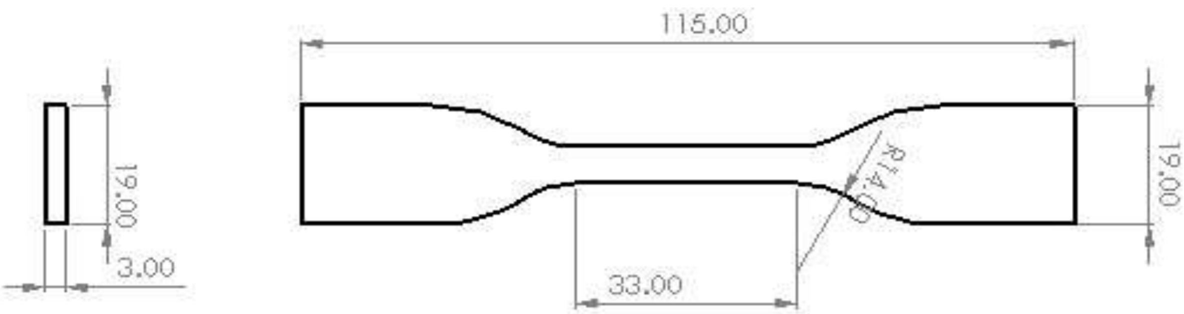

Fig 5: 2D view of the ASTM D638 test specimen

The test specimens were designed using solid works. Figure 4 shows the isometric view of the ASTM D638 test specimen and figure 5 shows the2D view of the ASTM D638 test specimen. All the dimensions are in mm.

3.2 Design of ASTM D790 specimen

Fig 6: Isometric view of ASTMD790 specimen

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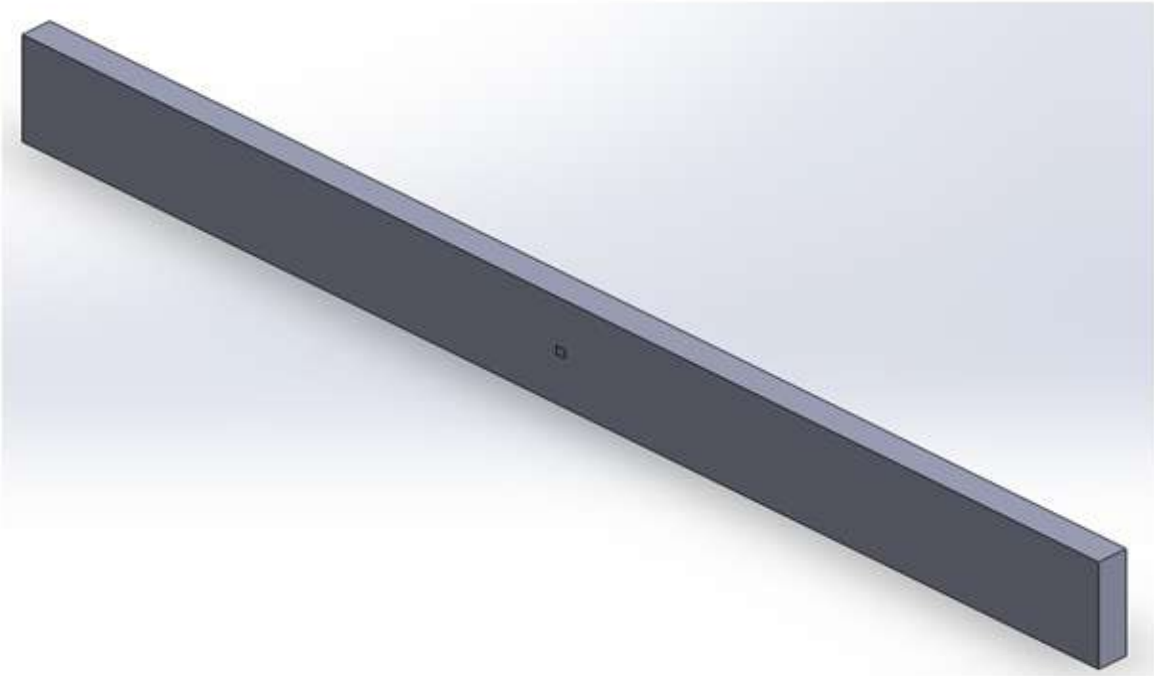

Fig 6: Isometric view of ASTMD790 specimen

Figure 6 represent the isometric view of ASTM D790 flexural test specimen and figure 7 represent the corresponding 2D view of the specimen. All the dimensions are in mm.

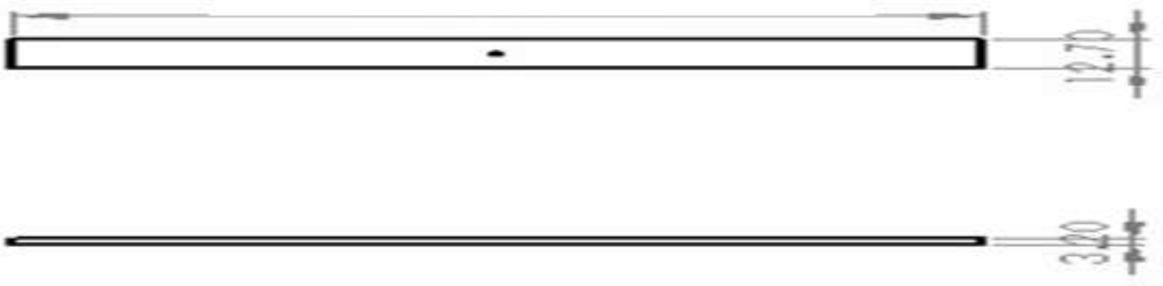

Fig 7: 2D view of ASTM D790 specimen

3.3 Combination of Printing Parameters

Once the specimen is designed, file is saved in the step format. Now 3D model of the specimen is ready and it has to be sliced. Slicing is done using Prusa slicing software where the printing parameters like layer thickness(mm), print speed (mm/sec) and number of contours of the specimens are given. Total seven specimens were printed with different combination of three parameters: layer height, print speed and number of contours. They are as follows:

Table 2: Combination of printing parameters

Sl. Number	Layer height (mm)	Print speed (mm/sec)	Number of contours
Specimen 1	0.20	20	4

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Specimen 2	0.25	20	4
Specimen 3	0.30	20	4
Specimen 4	0.20	20	4
Specimen 5	0.20	30	4
Specimen 6	0.20	40	4
Specimen 7	0.20	20	2
Specimen 8	0.20	20	4
Specimen 9	0.20	20	6

The above table shows the different combination of parameters that are used to print the specimens for both tensile as well as flexural tests. It was observed that parameters of category 1 i.e., layer height (mm) = 0.20, print speed (mm/sec) = 20 and number of contours = 4 are overlapping with the category 4 and category 8. Hence these two categories were dropped from the analysis. The final analysis is done only on remaining 7 categories.

After slicing of the part is completed, a G-code of the part is generated automatically. This G-code is fed into the 3D printing machine. The printing machine will begin to print the material in the predefined path. It will take to print specimen. Time depends upon the size and complexity of the specimen. Average time taken to print the ASTM D638 and ASTM D790 specimens on Hydra 16A machine was around 45 minutes for each specimen respectively.

Fig 8: 3D printed ASTM D638 specimens

Figure 8 shows the final 3D printed specimens of ASTM D638 specimens. Total 27 specimens were printed for tensile test. In each category three samples were printed in order to send the best finish or the one which has nice finish with no cracks or voids for testing purpose.

Fig 9: 3D printed ASTM D790 specimens

Figure 9 shows the final 3D printed specimens of ASTM D790 specimens. Total 27 specimens were printed for flexural test. In each category three samples were printed in order to send the best finish or the one which has nice finish with no cracks or voids for testing purpose.

Tensile test of ASTM D638 specimens were carried out at B.M.S. College of Engineering Bangalore. Flexural test of ASTM D790 specimens were carried out at Jyothy Institute of Technology Foundation Bangalore.

3.4 Tensile test of ASTM D638 specimen

Figure 10 shows the fixing of tensile specimen in the MTS testing machine at at B.M.S. College of Engineering Bangalore. One end of the specimen is fixed and load is applied gradually from the other end. Stress values were noted down at all the stages. This procedure was carried out for all the remaining specimens.

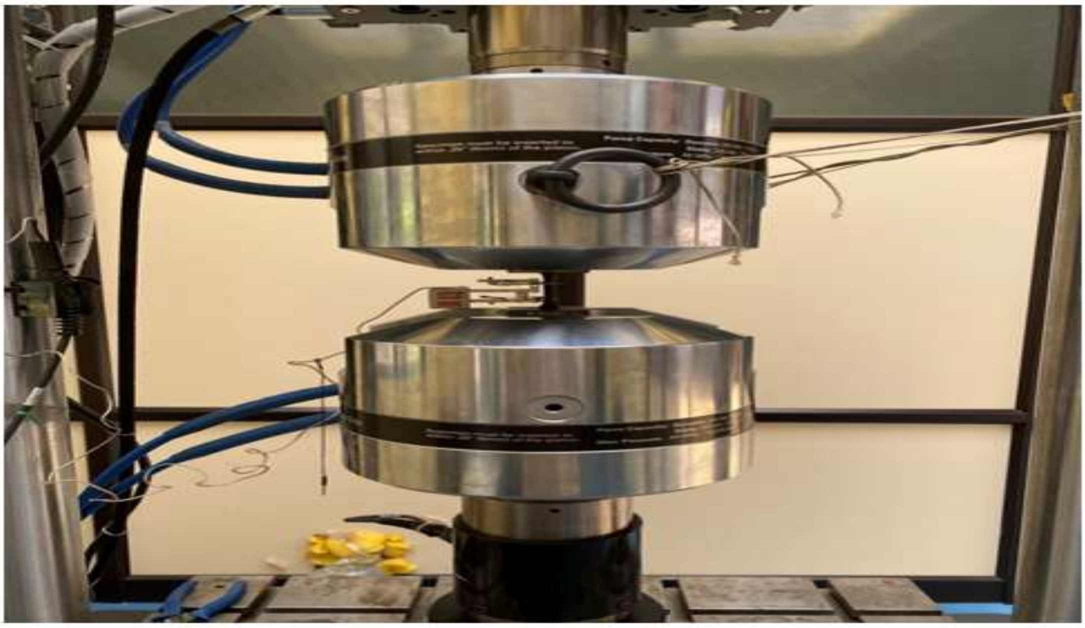

Fig 10: Testing of tensile specimen

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3.5 Flexural test of ASTM D790 specimen

Figure 11 shows the demonstration of testing of flexural specimens at Jyothy Institute of Technology Foundation Bangalore. The specimen is placed on two supports at both ends separated by a distance of 80mm. Load was applied at the center. This test is conducted till the specimens fails. The corresponding stresses were recorded. Same procedure is carried out for all the specimens.

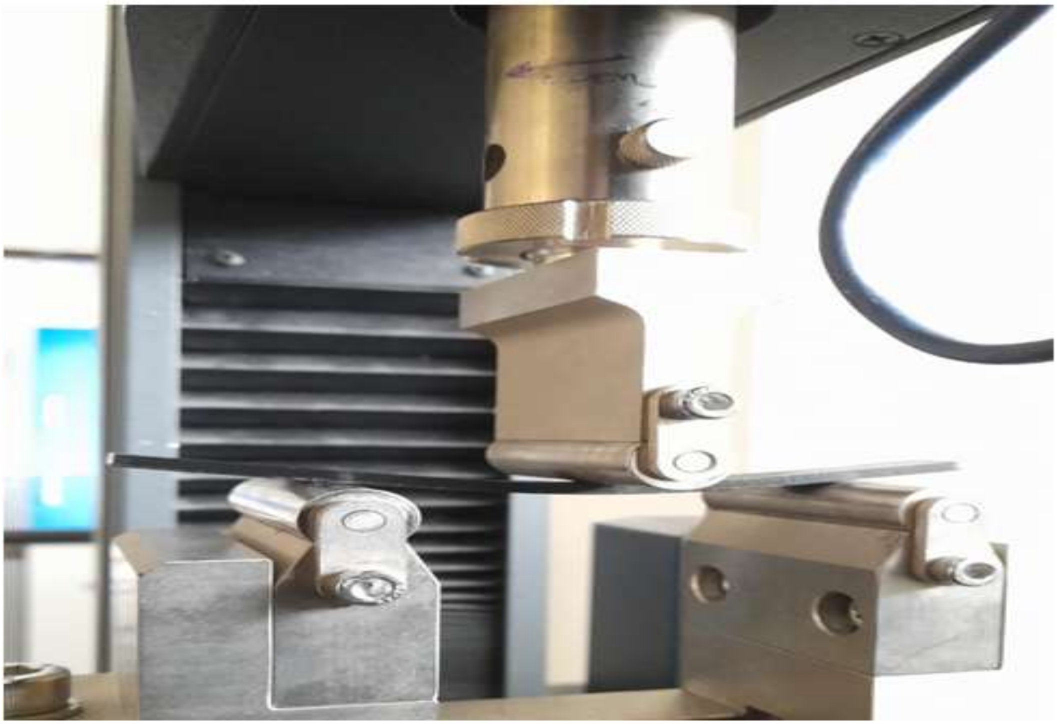

Figure 11: Testing of Flexural specimen

Simulation of both ASTM D638 and ASTM D790 test specimens were carried out using Ansys workbench to make a comparative study on the parameters of 3D printed specimen. The results are as below.

3.6 Simulationresults of the ASTM D638 & ASTM D790

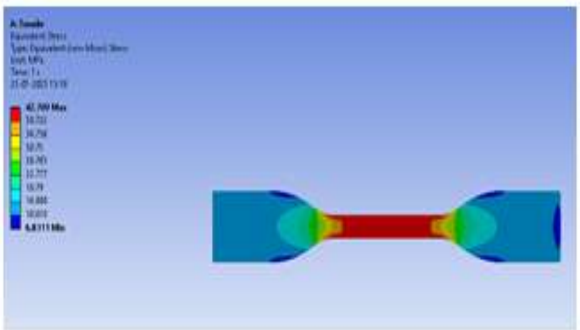

Fig 12: Tensile specimen 1

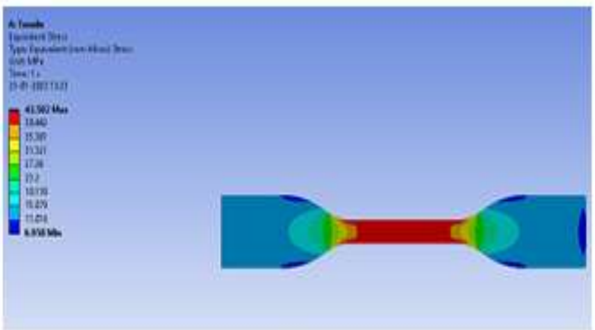

Fig 13: Tensile specimen 2

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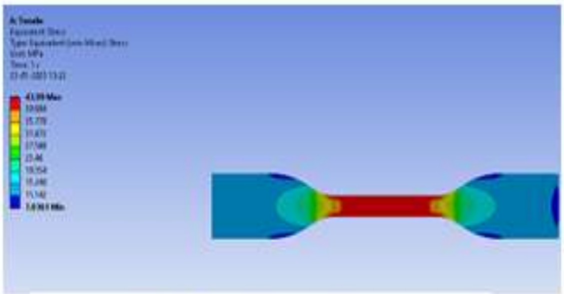
Fig 14: Tensile specimen 3

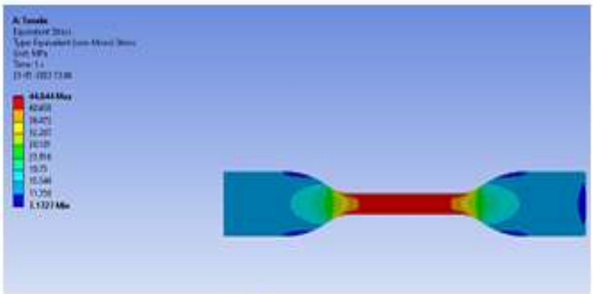
Fig 15: Tensile specimen 5

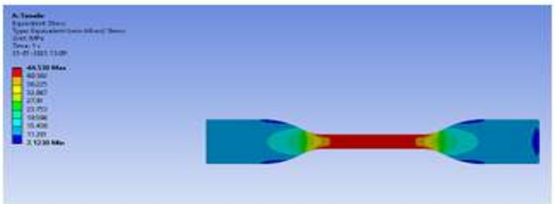
Fig 16: Tensile specimen 6

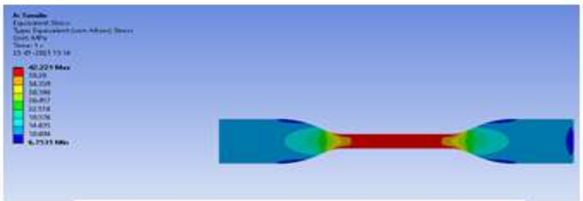
Fig 17: Tensile specimen 7

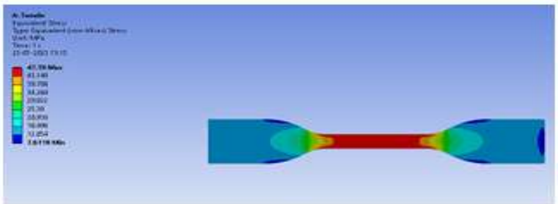
Fig 18: Tensile specimen 9

Fig 19: Flexural specimen 1

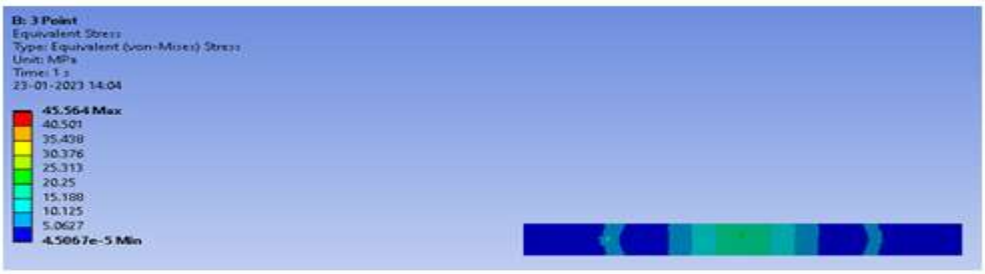

Fig 20: Flexural specimen 2

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Fig 21: Flexural specimen 3

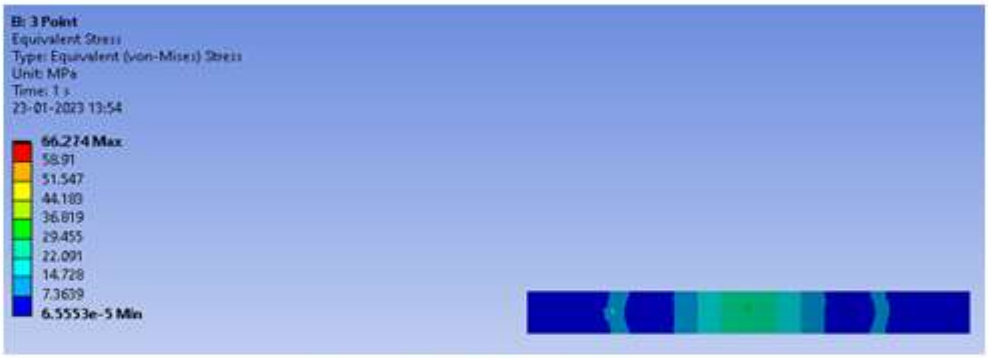

Fig 22: Flexural specimen 5

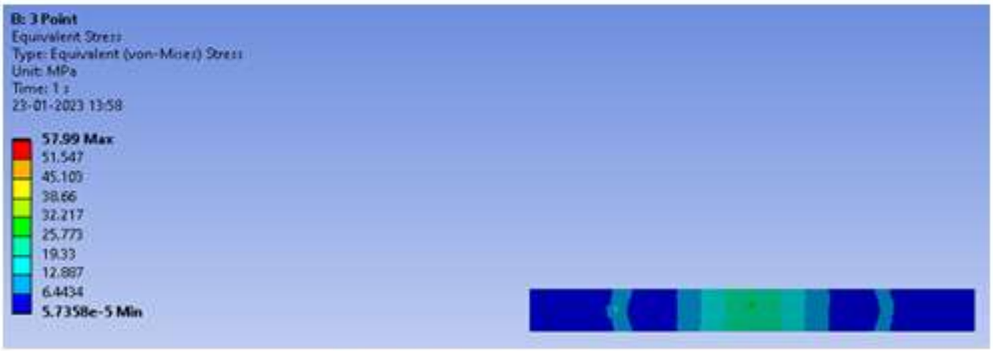

Fig 23: Flexural specimen 6

Fig 24: Flexural specimen 7

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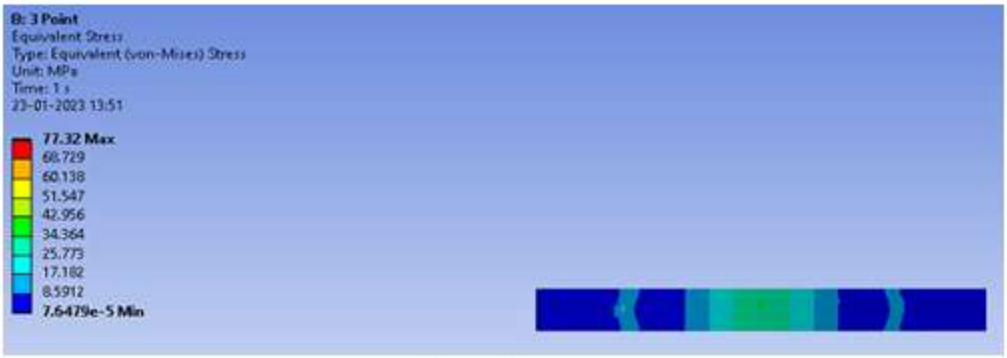

Fig 25: Flexural specimen 9

IV. CHAPTER 4 RESULTS AND CONCLUSIONS

4.1 Experimental results of ASTM D638 specimens

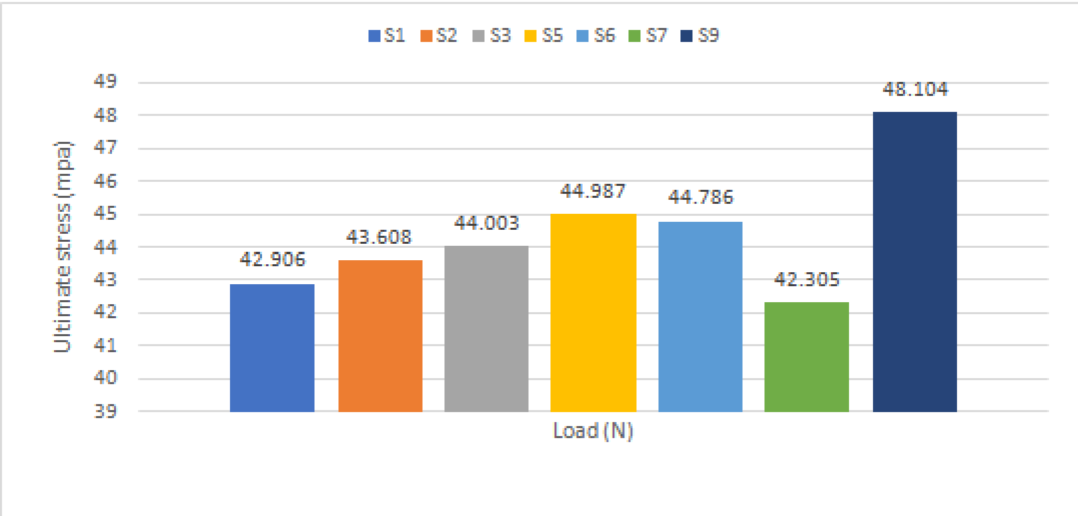

Fig 26: Bar graph of Ultimate stress vs Load (Tensile)

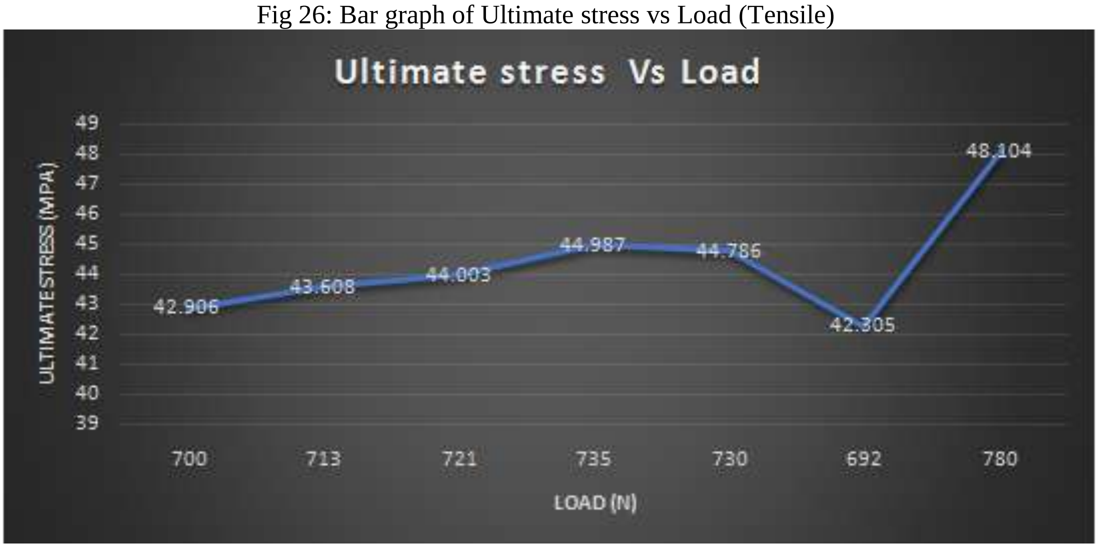

Fig 27: Line chart of Ultimate stress vs Load (Tensile)

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Figure 26 shows the bar representation of Ultimate stress vs Load of tensile specimens. Figure 27 shows the line chart representation of Ultimate stress vs Load of tensile specimens. It was observed that as the load is increasing the corresponding stress value is also increasing. In case of specimen 7, there is dip in the stress value. The printing parameters of specimen 7 are layer thickness (mm) = 0.20, print speed (mm/sec) = 20, number of contours = 2.

4.2 Experimental results of ASTM D790 specimens

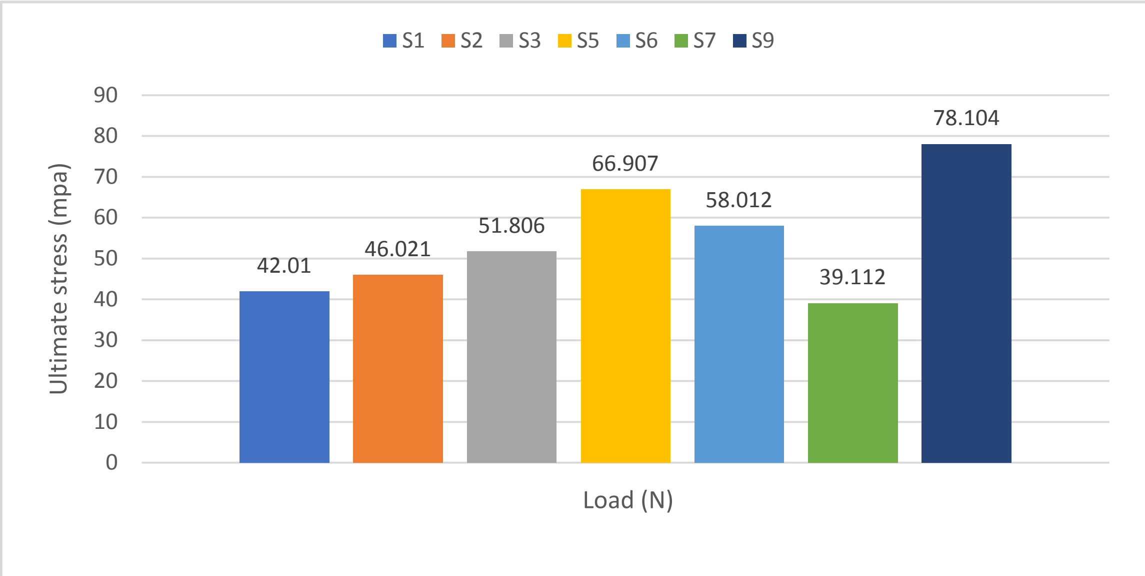

Fig 28: Line chart of Ultimate stress vs Load (Flexural)

Figure 28 shows bar graph of Ultimate stress vs Load of ASTM D790 flexural test specimens. Figure 29 is another way to check the relationship between the Ultimate stress vs load using line chart. This chart gives us the trend line. As seen in previous case of tensile specimens, here also there is a linear relationship between stress and load. At specimen 7, there is a dip in the trend and the corresponding parameters are as follows: layer height(mm) = 0.20, print speed (mm/sec) = 20 and number of contours=2.

Fig 29: Line chart of Ultimate stress vs Load (Flexural)

4.3 Comparison of Experimental values vs Simulation results (Tensile)

Sl. No	Load (N)	Experimental Values Ultimate stress(mpa)	Simulation results Ultimate stress(mpa)	Error rate
Specimen 1	700	42.906	42.709	0.45%
Specimen 2	713	43.608	43.502	0.24%
Specimen 3	721	44.003	43.99	0.02%
Specimen 5	735	44.987	44.844	0.31%
Specimen 6	730	44.786	44.539	0.55%
Specimen 7	692	42.305	42.221	0.20%
Specimen 9	780	48.104	47.59	0.11%

Table3: Comparison of Experimental values vs Simulation values(Tensile)

4.4 Comparison of Experimental values vs Simulation results(Flexural)

Sl. No	Load (N)	Experimental Values Ultimate stress(mpa)	Simulation results Ultimate stress(mpa)	Error rate
Specimen 1	30	42.01	41.421	1.4%
Specimen 2	33	46.021	45.564	0.99%
Specimen 3	37	51.806	51.086	1.4%
Specimen 5	48	66.907	66.274	0.94%
Specimen 6	42	58.012	57.99	0.03%
Specimen 7	28	39.112	38.66	1.16%
Specimen 9	56	78.104	77.32	1%

Table4: Comparison of Experimental values vs Simulation values(Flexural)

Table 2 and 3 shows the comparison of experimental values and simulation values of both tensile ASTM D638 and flexural ASTM D790 specimens. It was observed that the error rate is below 2%.

4.5 Conclusion

After going through all the results, it was observed that the layer height and number of contours are directly proportional to the tensile and flexural strength of the 3D printed specimen. As the we increase layer height and number of contours the load bearing capacity of the specimen also increases where as print speed is inversely proportional to the tensile and flexural strength of the specimen. Among all these number of contours has highest influence on the tensile and flexural properties of the material. Out of all categories the highest tensile stress of 48.104 (N/mm^2) at 780 (N) and flexural stress of 78.104 (N/mm^2) at 56(N) was found on the 9^{th} category and the corresponding combination of parameters are: layer height: 0.20 (mm), print speed (mm/sec) and number of contours = 6.

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