Investigation on Tensile and Compression Properties of 3D Printed PLA Material for Various Infill Percentage

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ABSTRACT: This work aims to study the effect of process parameters such as infill percentage by keeping other parameters like printing temperature, nozzle diameter, layer height, top and bottom layer thickness, print bed temperature constant during preparation of the test specimens on mechanical properties of FDM printed parts. In the present project, specimen is made with PLA material having different infill percentages which is in turn tested for its mechanical properties like tensile, compression and impact strength. The results are compared with each other various combinations. Thus, this project is conducted to get the average of the strength and mechanical properties. One variable at a time approach has been adopted to carry out the work.

i.INTRODUCTION

3D printing, is a type of nontraditional Additive Manufacturing (AM) technology. It is a process of joining materials to make objects from 3D model data, usually layer upon layer. The product is designed in CAD software, which is then exported to a 3D printer. 3D printing provides a various customization in product design and can even print parts, which cannot be manufactured by any traditional manufacturing processes. Complex and intricate components can be manufactured with substantial reduction in manufacturing time, costs and material wastage. 3D printing technology has been around since two decades, but in the past couple of years it has ascended into a new manufacturing revolution. Earlier, known as Rapid Prototyping (RP), the process was mostly limited to building prototypes and test products. It has evolved over a period of time into a matured process for being able to fabricate end-user products in various industries. The concept of AM involves building a part from the microscale to the macroscale. AM is representative of a step in human evolution, as we transition from making products by forging or cutting away to making products by adding material—a method that is closer to natural processes. The most obvious advantage of AM over traditional manufacturing technologies is its capability to handle very complex shapes, and particularly internal shapes. Another advantage of AM is its ability to save material, as no excess material is wasted in AM its use is particularly relevant for precious materials. The other unique advantages of AM, such as its use of gradient materials and its ability to combine different materials into a single structure. These characteristics cannot be obtained by simply replacing the conventional manufacturing process with AM, as this transition is a disruptive change in ideology and methodology from "subtracting" to "adding." The piece by piece addition of a material carries many new variables that will actively or passively affect the final product, including the usage of a single or multiple types of materials, the usage of the same or different conditions in terms of temperature, pressure, or environmental situation and how many chemical elements are present.

ii.LITERATURE SURVEY

Mayur D Pawar, Raghavendra Joshi (1) "Study On Mechanical Properties Of 3D Printed PLA Material for Various Infill Percentage". This paper focuses on In the present project, specimen is made with PLA material having different infill percentages which is in turn tested for its mechanical properties like tensile, compression and impact strength. The results are compared with each other various combinations. Thus, this project is conducted to get the average of the strength and mechanical properties. One variable at a time approach has been adopted to carry out the work.

Todd letcher.et.al These two people together researched about the material properties of the PLA with an entry level 3D printer. From this we came to know that how the specimen is created according to ASTM standards and its grain structure with various mechanical tests.

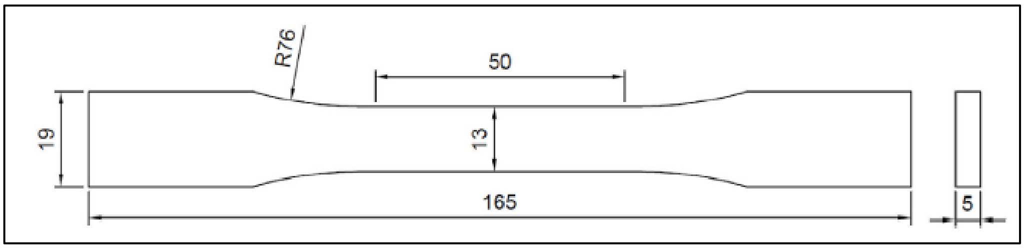
Chris.et.al They studied the samples of 3D printed materials produced with different infill structures and infill percentages to guide the mechanical design of the 3D printed objects for better mechanical properties and better strength. From this we have come to know, what samples should be produced according to the ASTM standards, and an idea of how the sample might behave under various mechanical testing.

Surendra.et.al They both studied and experimented about the PLA material and 3D printing and how the specimen will behave when it is produced under FDM 3D printer and tested for various mechanical properties. From this we came to know how the specimen will behave under 3D printer of different operational process other than that of standard process.

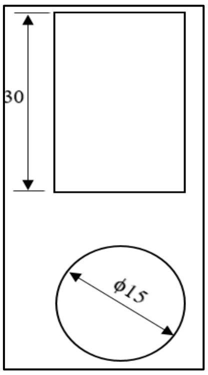
iii. SELECTION OF PRINTING MATERIALS

Various printing parameters are available in CURA slicing software like layer height, base top and wall thickness, printing and bed temperature, Infill percentage and infill shapes, angle of print ect.

Among all the printing variables based on the literature survey, in the present project printing parameters are printing temperature in degree coleus, infill shape and percentage is selected. All the three parameters are Printing temperature is from 200° C. Infill percentage varying from 20% to 100% in the step of 20% infill. In most of the literature work has been carried for infill percentage only for higher percentage. Here an attempt is made to study the effect of lower infill percentage.



a. Dimensions of tensile test sample as per ASTM D638.



b. Dimensions of compression test sample as per ASTM D285.

PRINTING MATERIAL

The material used in the manufacture of the specimens is as discussed below. Properties of PLA materials used in 3D printing process is mentioned in Table 3.1. Table. 3.2 shows printing time and amount of material used for printing each test specimen. The parameters selected for this project viz. printing speed, nozzle temperature, infill density, pattern will be changing according to brain literature review.

Table.3.1. shows the properties of PLA Material.

Mechanical Property	Value
Yield strength	60 MPa
Elongation at break	6%
Tensile modulus	3600 MPa
Flexural strength	83 MPa
Flexural modulus	3800 MPa

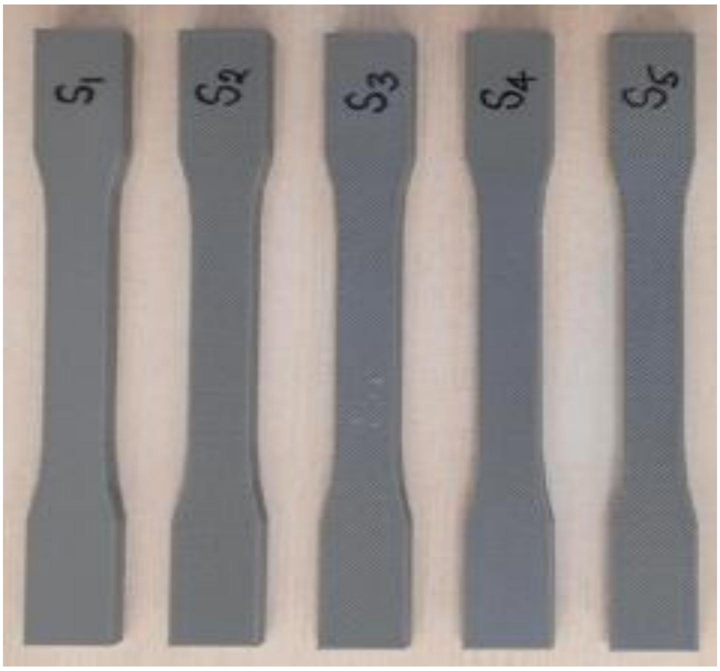
Mechanical Property	Value

Table. 3.2. Material used and printing time.

Sl. No	Infill Percentage (%)	PLA material consumed (gms)	Length of PLA material consumed (mt)	Printing time (min)
1	20	9	2.98	57
2	40	11	3.74	65
3	60	13	4.51	74
4	80	16	5.28	81
5	100	18	6.03	110

3D PRINTED TEST SPECIMENS

All 3D printed test specimens is as shown in fig a, b. represents tensile and Compression test specimens respectively in various infill percentage starring from 20% and go's until 100% in the steps of 20%.



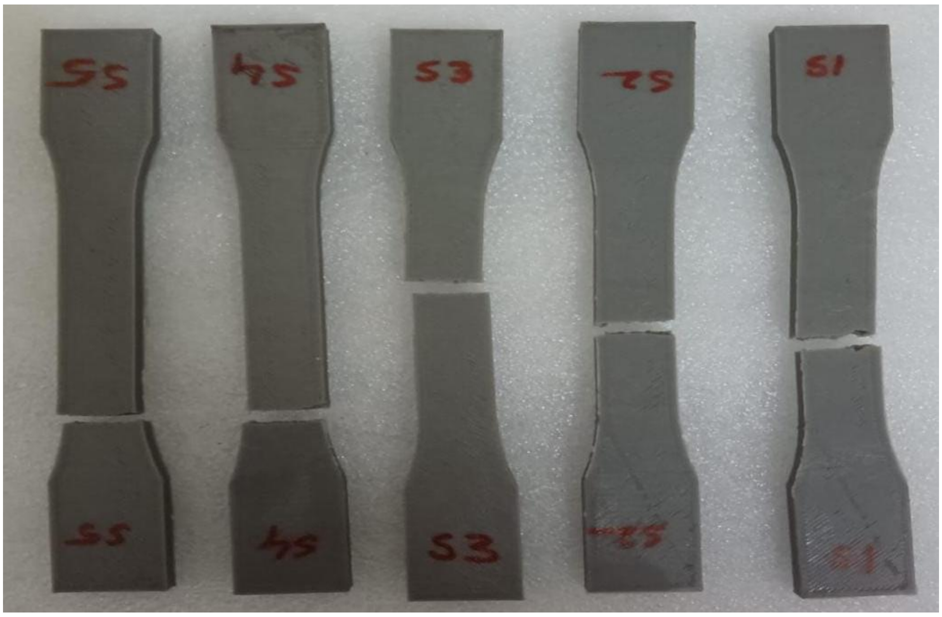
a. Tensile test specimens.

b. Compression test specimens.

Fig: Actual 3d printed test specimens.

BROKEN TEST SPECIMENS

The following section represents the test specimen after conducting tensile and compression test.



a. Broken specimen of Tensile

b. Broken specimen of Compression

iv.RESULTS

Fig. 1.1, 1.2 and 1.3 represents the results obtained for tensile test specimen in terms of peak load, % of elongation, Break Load, UTS and Youngs modules respectively.

Table. 1.1 Result of Tensile test.

Sl. No	Sample ID	Infill Percentage (%)	Peak load (N)	% Elongation	Break Load (N)	UTS (N/mm^2)	Youngs Modulus (N/mm^2)
1	S1	20	284.00	4.10	186.77	8.17	199.62
2	S2	40	537.00	3.66	347.35	15.43	421.58
3	S3	60	585.00	3.68	428.35	16.81	457.15
4	S4	80	623.00	5.52	520.83	18.39	560.76
5	S5	100	686.00	4.45	563.55	20.57	649.84

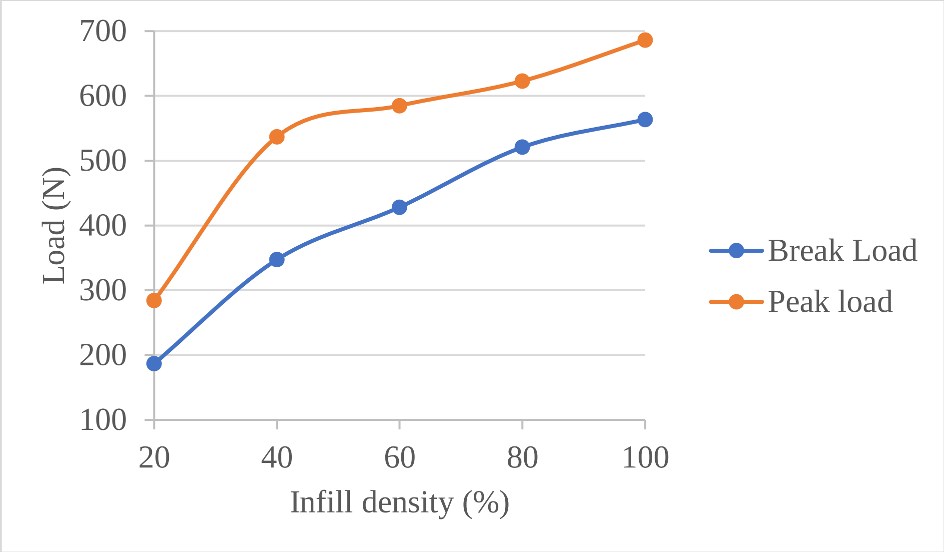


Fig. 1.2. Variation of Break and Peak load in N with respect to infill density

Fig 1.2 shoes the variations of break load and peak load of test specimens. For the figure it is clear that as the infill percentage increases, load baring capacity also increases for the test specimen. Both break load and peak load represented the similar trend.

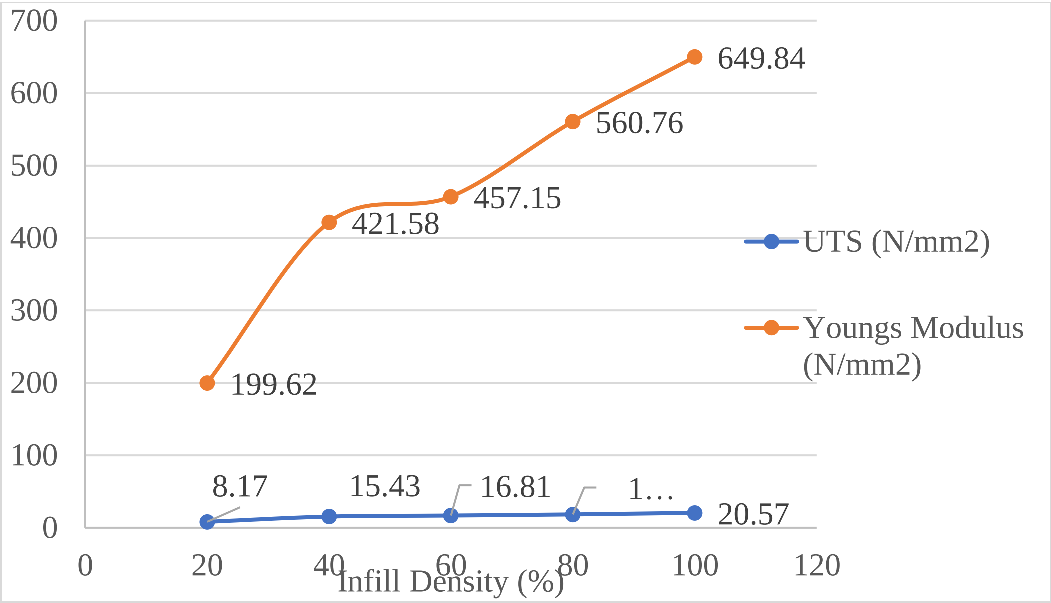


Fig. 1.3. Variation of UTs and Youngs modules in N/mm^2 with respect to infill density

Fig. 1.3 shoes the variations of UTS and Young's Modules with respect to infill density. From the figure it is evident that, variation of UTS is not much for the infill percentage but variation of Youngs modules is much evident. This is due to enhanced load baring capacity for denser test specimen. It is also observed that, Yourg's modules is not much varied for infill of 40 and 60 %. This trend may be due to not much difference in the filling of the material.

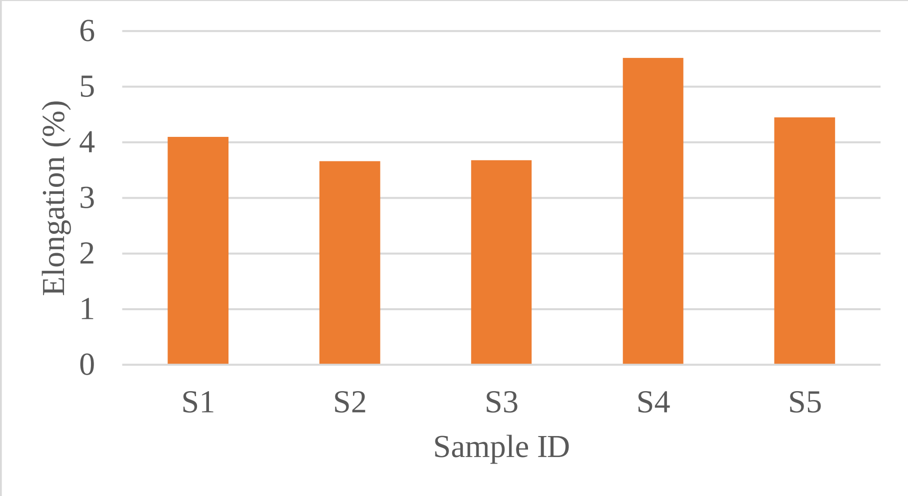


Fig. 1.4. % of elongation with respect to Sample ID

Fig. 1.4 Represents the trend that S4 test specimen having 80% infill percentage produces the better results in terms of tensile property. Initially the elongation was reduced as the percentage increases and is followed till 60%\infill percentage later the percentage elongation was increased to highest value.

Table 2.1 Results of Compression Test.

Sl. No	Sample ID	Infill Percentage (%)	Peak load (N)	% Compression	Break Load (N)	Compressive strength (N/mm^2)
1	S1	20	428.00	24.25	20.57	3.37
2	S2	40	982.00	22.01	23.76	7.75
3	S3	60	993.00	14.78	32.04	7.84
4	S4	80	1173.00	12.56	38.68	9.26
5	S5	100	1919.00	9.00	42.02	15.14

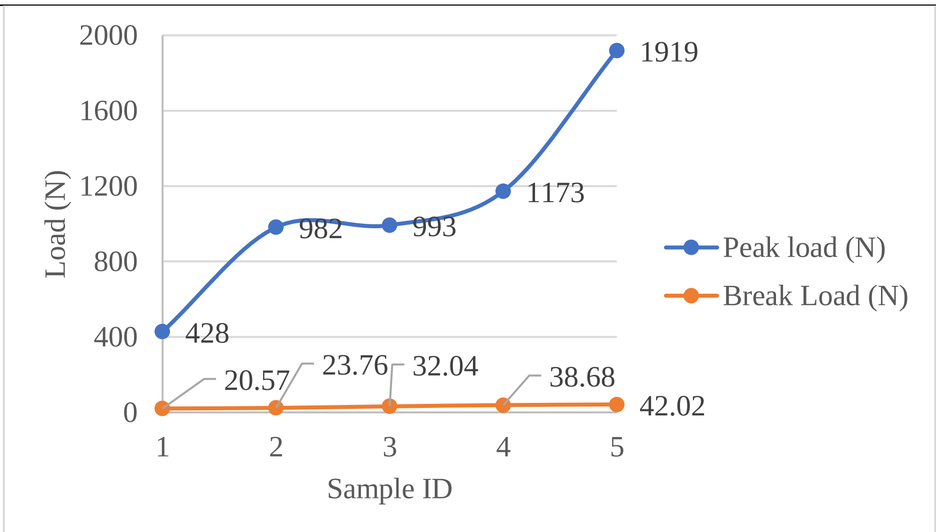


Fig. 2.1 Variation of Peak Load and Break Load with respective to Sample ID

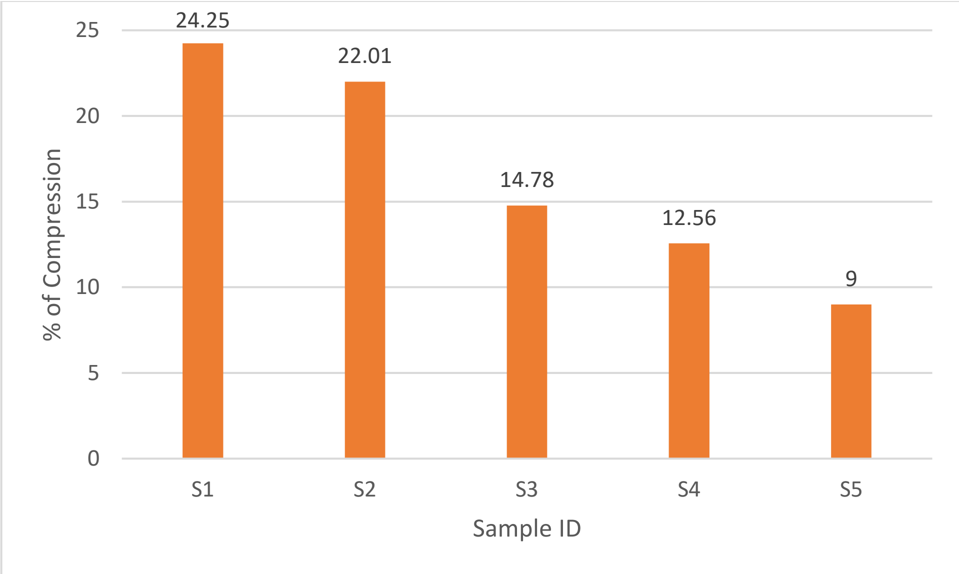


Fig. 2.2. Percentage of Compression for different sample ID

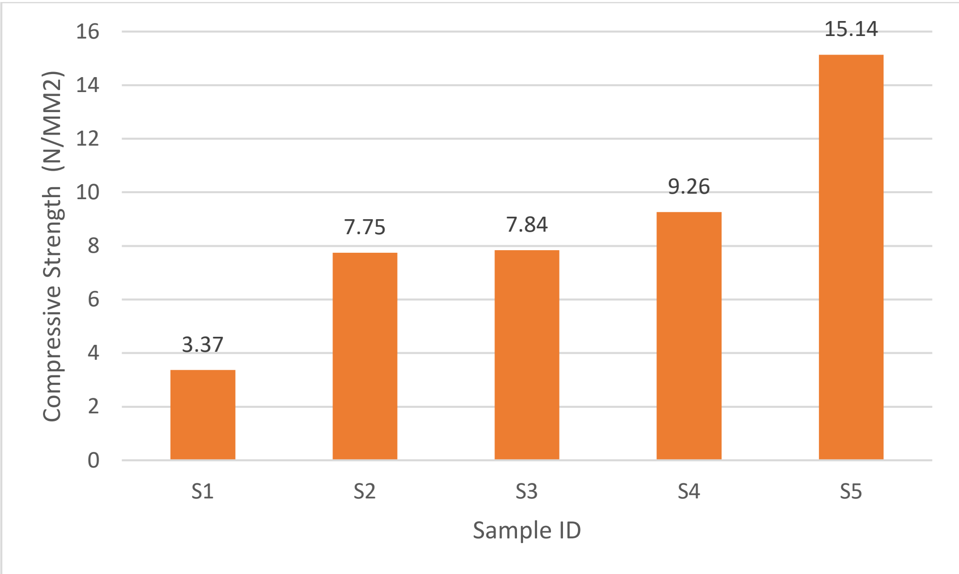


Fig. 2.3 Compression strength for different Sample ID

Compressive testing shows how the material will react when it is being compressed. Compression testing is able to determine the material's behavior or response under crushing loads and to measure the plastic flow behavior and ductile fracture limits of a material. For the compression properties, Table. 2.1. represents the numeric values of Peak load in N, % of compression, Break load in N and compressive strength in N/mm^2.

Fig. 2.1,2.2 and 2.3 represented the nature of results for the test specimens when subjected to compressive load. Simpler trends have been observed during compression test as that of tensile results for peak load and break load. The reason may be same for this trend as that of tensile test. However, the result was completely revers in terms of percentage of compression. This trend is observed due to the higher infill percentage the load baring capacity of the material also increases, Hence, shows that as the infill percentage is lower, it is easily comprisable than 100 % packed.

V. CONCLUSION

In this project, we have successfully investigated the influence of diverse processing parameters on the 3D printing of PLA test specimen. Test specimens were printed for different infill pattern by keeping other parameters same.

The following are the conclusions obtained from the experimental results: Among the variables like printing time, length of raw material, weight of raw material and test results for various infill percentage for PLA material following conclusion is drawn,

- ➢ Based on the printing parameter, it is observed that raw material is consumed around 9 gms for 20% infill and 18 grms for 100% infill, printing time is 57 min and 110 min respectively for 20 and 100% infill. Material consumed is 2.98 mt and 6.03 mt respectively for 20% and 100% infill.
- ➢ With respect to impact strength, break load is least for 20% and highest for 100% but at 40% the rate of increase of break load is higher compared to other percentage of infill. Same trend with peak load as well but at 80% infill the peak load is almost similar to 100% infill. Percentage of elongation is highest for 80% infill than compared with all other infill percentage. Almost similar results is observed in compression and impact test as well.
- ➢ With this we can conclude that 80% infill percentage is optimum to use for any application of PLA material as this consumes less material in terms of weight, length and also printing time with high percentage of elongation and strength.

VI. REFRENCES

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