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Effect of Infill Pattern and Layer Thickness on Mechanical Properties of the FDM Printed ABS Specimens

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ABSTRACT: This paper represent variations in mechanical properties like strength, toughness, stress by varying design parameters like layer thickness & infill pattern of FDM (fused deposition method) 3D printed sample. In this project we are performing test like tensile flexural and charpy for the infill pattern variation (honeycomb, diamond, triangular) and for layer thickness (100µ, 200µ, 300µ) total of 27 samples. We analyzed data collected from this tests. This project is aimed to find the suitable infill pattern and layer thickness to manufacturing the product in FDM for different application. Despite the numerous work on the printability of various type of polymers there is dearth in understanding the role of mechanical parameters of printed part. The purpose of this work is to make available much require data for analysis of 3D printed parts.

KEYWORDS: Fused deposition method, three dimension printing, tensile, flexural, layer thickness, infill pattern, ABS (acrylonitrile butadiene styrene).

I. INTRODUCTION

Traditional manufacturing method lacks in many aspect in producing geometry of product. Especially, balancing the cost and techniques used to produce complicated geometries. To overcome such limitation of traditional manufacturing. Scientist focusing on investing new manufacturing techniques. In 1984 scientist name Chuck Hull invented 3D printing which is very convenient in producing complicated geometries with such a good accuracy. Even after 36 years of invention most of people in the world is not familiarize with it. Various parameter related to 3D printed technology which affect strength of 3D printed object need to be known. Most commonly use 3D printing process. Fused deposition method which is used to print thermoplastic material is the area where work is need to be done so as to understand FDM process parameter to guide mechanical design.

Some recent work on fused deposition method is reviewed. Tainyun Yon [1] Studies tensile failure of FDM specimen by varying printed angles and layer thickness. Ankita Jai singhsheoron [2] proposed review on current research on FDM printed objects parameter which enhancing part quality, mechanical properties build time etc. V Durga Prasad Rao[3] tested FDM printed tensile specimen for variation FDM parameter like print temperature, layer thickness, infill pattern etc. on poly lactic Acid (PLA). Also Ei EI Cho [4] investigation influence of layer thickness and infill pattern on mechanical strength of PLA material. All current research include PLA as testing material. Also the variation parameters which are selected are not contributing much to help in guiding mechanical design. Also generally researcher focusing only on tensile behavior of FDM printed object.

According to interpretation of knowledge in this field we think that FDM parameters like infill pattern and layer thickness contribute more in guiding mechanical design. Using infill pattern material reducing without reducing strength can be obtained. So we are using infill pattern which are very much common in all slicing software and their geometries are easy to understand. Also the layer thickness variation not only contribute to strength but also the quality of FDM printed object. We are performing tensile, bending and charpy test to understand strength according to respective variation, our aim is to provide data of tensile, bending strengths and strain energy so as manufacturer understand which infill pattern should be used with particular layer thickness to get desired strength & toughness using ABS material which has much advantages compare to other thermoplastic material.

II. STANDARD FOR TESTING

Specimen of the testing is created by utilizing 3D printing machine. The sample should be planned by utilizing computer aided design programming and should be changed over to STL record for the printing reason. Inventor Autodesk computer aided design programming is utilized to plan the example utilizing the standard that has been decided for the testing. There are three kinds of example that should be delivered for the testing, which are tensile

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specimens, flexural specimens. All the examples are created by 3D printer as per the detail as appeared in Table 1. The particular depends on the assessment of most extreme determination of the machine to deliver fine 3D printing item.

Parameters	Printer specification (accucraft 250 plus)
Material Nozzle diameter	ABS 0.2mm
Nozzle temperature Temperature of bed ^{0}C	260-270 100
Infill Infill type(print orientation)	50% Honeycomb, diamond, triangular
Print speed	40-60mm/s
Layer thickness	100 micron, 200 micron, 300 micron
Build orientation	horizontal
Load capacity	2 KN

Principles are the records which characterize necessity for items and how they are being tried. Material testing standard is utilized as rule on the most proficient method to direct material testing and what are the prerequisite to be followed so as to get the testing result. In plastic material testing, there are a few principles that can be utilized, which are ASTM, English, European and ISO standard of testing. For the most part, ISO standard is indistinguishable from different guidelines, for example, English (BS) and European (CEN). This closeness may include the sort of example and size, state of the example and testing, technique for material testing and furthermore testing machine determination. It gives the advantages to the client to allude to any perceived standard report. Generally, this indistinguishable standard can be perceived by double or triple numbered framework, for example, BS EN ISO XXX. BS EN XXX, and BS ISO XXX.

ASTM standard is broadly utilized as standard for material testing particularly in ventures and furthermore for research purposes. This standard is perceived worldwide as an innovator in the turn of events and conveyance of intentional agreement norms, which is created by the World Exchange Association Guideline. As it were, this is the world norm for material testing that is utilized to locate the crucial data, for example, material properties that should be demonstrated as solid material. In enterprises, this standard offers advantages to the producer to complete test as to guarantee their items are first rate and can offer top notch items to their clients. It has been picked as the alluded norm in this examination to test material that is utilized to deliver the 3D model.

There are two sorts of test include in this exploration, which are tensile and flexural. Both of these tests are utilized to research the mechanical impact on material properties of ABS and PLA material. The tests use ASTM standard as testing rule. The most significant testing prerequisites are the accessibility and capacity of the machine that will be utilized ready to satisfy the necessity of the norm.

All the tests are run multiple times for each example, which are multiple times higher than the necessary number of example of each test. This is because of the repeatability factor, which is significant in deciding the closeness of the estimation to concur with one another. An estimation which is profoundly repeatable will in general give esteem which is exceptionally near one another. Moreover, the measurement of vulnerability particularly the standard deviation figuring is significant so as to watch the dispersion of the estimation around the mean worth. The lower the standard deviation, the lower the vulnerability and accordingly it makes more trust in the testing results which will in general have higher information dependability.

III. TENSILE TEST STANDARD

Tensile test is led so as to decide the power expected to break the example and to decide the expansion to which the example prolongs until the limit. This kind of testing is normally utilized for material quality assessment reason, which to decide the material capacity to withstand burden or powers in tensional condition. There are assortments of tensile test that are utilized in mechanical testing. Most normal tensile tests are strain, ductile attachment, tractable shear, pliable get, tensile pulling, pliable weakness and pliable drag. These kinds of test utilize a similar guideline; wherein they are completed until the material arrives at disappointment. The main contrasts are the example size or shape and holding position utilized during the test.

By doing tensile test, rigidity, tensile strain, yield point and modulus of flexibility can be resolved. Tensile pressure is the tensile power per unit region of the first cross area inside the check length of the example at some random second. Pliable strain can be characterized as the expansion long per unit unique length of the measure. Other than

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that, pliable test can likewise decide the relationship of tractable anxiety of the material. Normally, tensile test produces Pressure Strain bend chart of the tried example to quantify modulus flexibility of material.
For this exploration, General Testing Machine is utilized to test the ductile properties of the material. This machine can convey up to 10 KN of testing power with demonstrated unwavering quality as agreement to ASTM D638.
This test is directed by ASTM D638 standard as testing rule. ASTM D638 is one of the most well-known plastic quality particulars and spreads the tractable properties of unreinforced and strengthened plastics. The idea of this testing is by pulling the testing material so as to decide the conduct of the material that responds to the ductile powers. At the end of the day, this standard is utilized to decide the plastic material conduct under tensional stacking condition. The example size for the testing, which is designated "canine bone" is set up as per the norm. At that point, it follows by setting up the example on the machine for testing. To set up the example on the machine, the example should be grasped at each end and pulled separated. The example should be handle cautiously because of weak properties, which can make the harm the example. Much of the time, the grasps (jaws) that hold the example by applying clasping power continually making harm the example particularly at or close to the jaws.
Before the test starts, the widespread testing machine should be set up as indicated by the boundaries that are required by the norm. The boundaries that should be set up on the machine are length and width of the center part of the example and speed of testing. The length and width of the center part of the example are 6 mm and 4 mm individually and the machine should be run at 5 mm/min of testing speed. After all the boundaries have been arranged and the example is clipped, the test is run until the example breaks or cracks. The analysis of malleable test utilizing UTM testing machine will naturally create Pressure Strain outline of the example. The crude information, for example, applied force, time and elongation of the testing example are recorded and modulus elasticity can be determined.

IV. FLEXURAL TEST STANDARD

Flexural test is a mechanical test, which is led to decide the flexural properties of the testing material. There are three kinds of flexural test, which are three-point, four-point and basic cantilever stacking. For plastic material, the basic kind of flexural test is three-point flexural testing technique. It is directed to decide the flexural impact on material properties under three-point stacking condition. This kind of strategy is pertinent to plastic material because of the most elevated or greatest curve pressure happens under the stacking blacksmith's iron, which is appropriate for homogenous material, for example, plastic.
By doing flexural test, the flexural quality, flexural strain and modulus of flexibility in bowing can be resolved. Flexural quality is the measure of pressure or power the material can withstand to oppose bowing disappointment. As such, it is the measure of worry before the material yields due to flexural stacking condition. Flexural strain can be characterized as the strain that is created due to flexural stress, which causes an addition of material from its unique length. Generally, this test can decide the connection between flexural anxieties of material by creating the Pressure Strain chart. This chart can be utilized to decide the modulus of flexibility for bowing or flexural. Flexural modulus is the proportion of worry to strain flexural disfigurement, which can be resolved from the slant of a pressure strain bend.
In this examination, the trial is directed by ASTM D790 standard. This standard includes testing of plastic material on three-guide stacking condition all together toward decide the flexural properties of the material.
The strategy of this test requires example arrangement concurring ASTM D790 standard. For the thermoplastic expulsion material, the example size is 127 mm by 12.7 mm by 3.2 mm. At that point, it follows by setting up the help length for the material arrangement on the machine. As per the norm, the help length to-profundity of the pillar proportion is 16:1. By alluding to the profundity of the example, the standard help length that should be set up for the arrangement of the material is 51.2 mm. This testing technique utilizes the strain pace of 0.01 mm/min dependent on ASTM D790.

V. TENSILE TEST SPECIMEN

They are two kinds of example that are utilized, which are "dog bone" and "dam bell" shape example. For the ISO standard, the "dog bone" example as appeared in Fig. 1 is favored for expulsion and trim thermoplastic material and the standard is appeared in Table 2.

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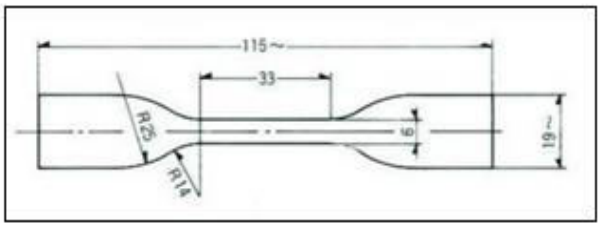

Fig. 1 Tensile test specimen

Standard	Dimension (mm)				
	Length	width	thickness	Throat width	Gauge length
ASTM D638(type IV)	115	19	4	6	25

Table 2

VI. FLEXURAL TEST SPECIMEN

They are two guidelines of example size for flexural trial of plastic material, which are ASTM D790 and ISO 178 principles. For the ASTM D790 standard, the example size is 127 mm by 12.7 mm by 130 mm. This example size is chosen due its appropriateness for thermoplastic and embellishment material as appeared in Fig. 3 for flexural test standard.

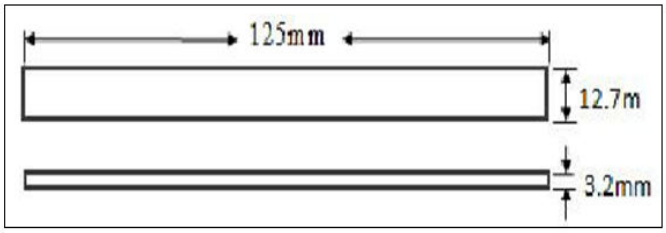

Fig. 2 Flexural test specimens

Standard	Dimension (mm)				
	Length	width	thickness	Throat width	Gauge length
ASTM D790	125	12.7	3.2	4	20

Table 3

VII. RESULTS AND CONVERSATION

For ABS material tensile test and flexural test is conducted to find the change in mechanical properties. The tensile test is set up by utilizing 3D printing strategy as per Type IV ASTM D638 standard for ABS. The tensile test is directed to watch the material conduct on tensional stacking. By doing tensile test, material properties, for example, elasticity, yield quality and stress disappointment of the ABS materials can be resolved. The samples condition before the tensile test and flexural test and after the tensile test and flexural test are appeared in figs.3 and figs4. Respectively.

Fig. 3 Tensile test specimens before testing

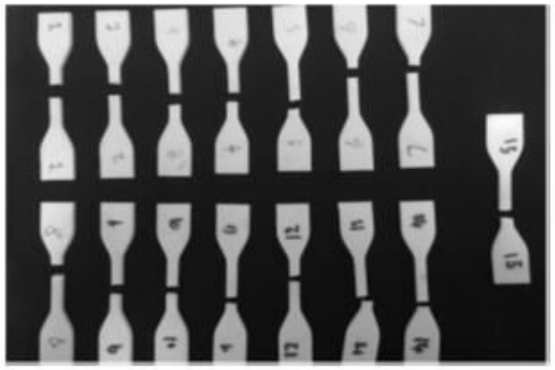

Fig.5 Tensile test specimens after testing

Fig.4 Flexural test specimens before testing

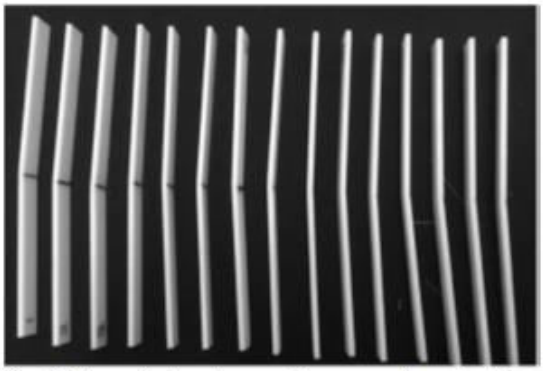

Fig.6 Tensile test specimens after testing

Data and result for tensile test

Jobs	Testing	Infill pattern	Layer thickness	Tensile strength	Maximum load	Breaking elongation	Weight	Weighted strength
1	Tensile	Honeycomb	100	27.19	736.568	4.9	4.69	16009.25
2	Tensile	Honeycomb	200	31.791	861.224	4.6	4.51	19465.72
3	Tensile	Honeycomb	300	33.101	896.7	9	4.97	18391.69
4	Tensile	Diamond	100	31.053	841.232	5	4.87	17608.32
5	Tensile	Diamond	200	31.404	850.738	4.4	4.98	17590.56
6	Tensile	Diamond	300	35.177	952.952	4.7	5.12	18972.83
7	Tensile	Triangular	100	28.177	763.322	5.1	5.01	15531.06
8	Tensile	Triangular	200	33.44	906.01	5	5.08	18180.27
9	Tensile	Triangular	300	34.801	942.76	5	5.33	18030.38

Data and result for flexural test

jobs	testing	Infill pattern	Layer thickness	Flexural strength	Peak load	Peak deformation	weight	Weighted strength
1	Flexural	Honeycomb	100	45.275	80.36	4.3	3.8	2155.7
2	Flexural	Honeycomb	200	48.753	86.534	5	3.75	2352.27
3	Flexural	Honeycomb	300	59.962	106.428	5.3	4.13	2626.86
4	Flexural	Diamond	100	52.756	72.03	4.7	3.96	1854.16
5	Flexural	Diamond	200	72.567	99.078	5.9	4.11	2457.34
6	Flexural	Diamond	300	62.005	110.054	6.1	4.25	2639.66
7	Flexural	Triangular	100	46.49	82.516	4.5	4.11	2046.47
8	Flexural	Triangular	200	52.563	93.296	4.6	4.28	2222.03
9	Flexural	Triangular	300	62.557	111.034	5.7	4.41	2566.54

VIII. GRAPHICAL COMPARISON

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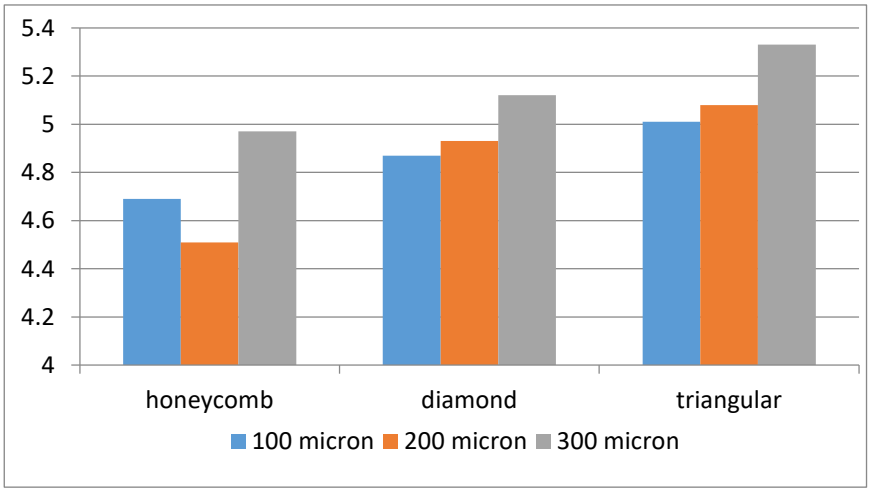
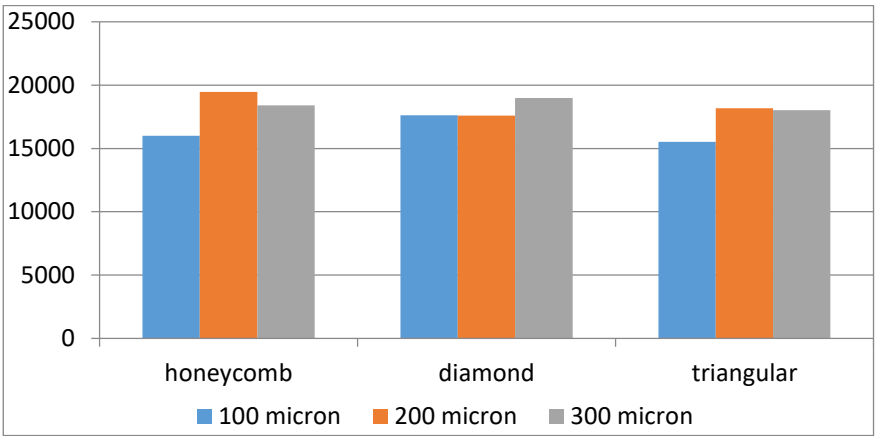
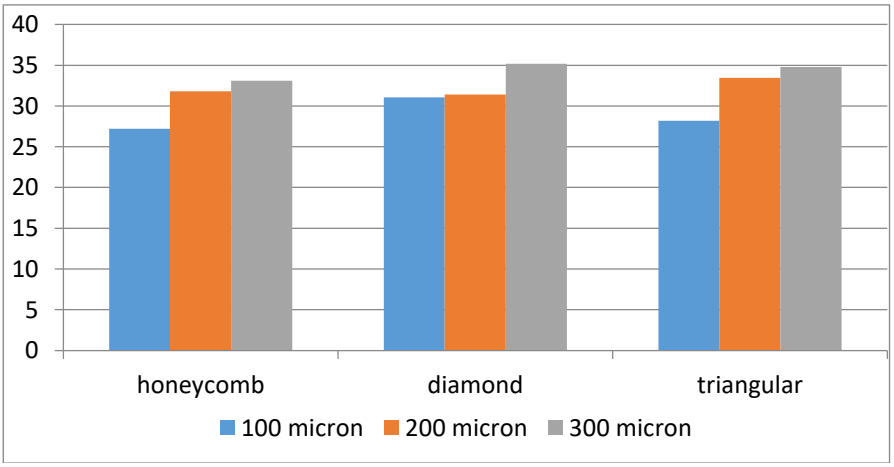
1. ANALYSIS OF TENSILE TEST



Weight comparison



Weighted strength comparison



Maximum tensile load comparison

2. Analysis of flexural test

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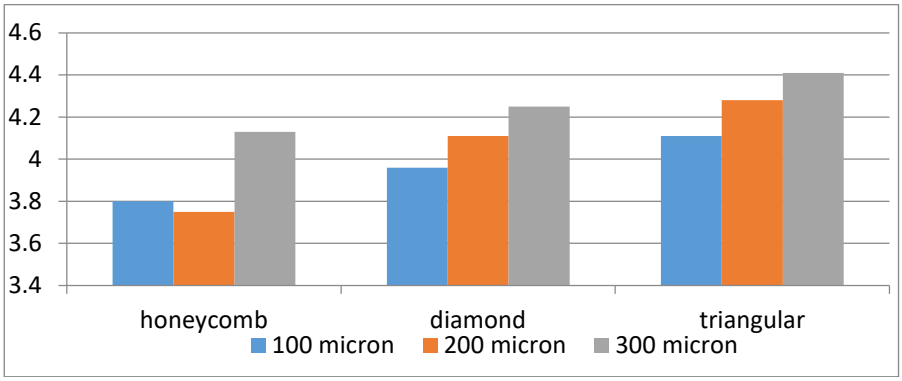
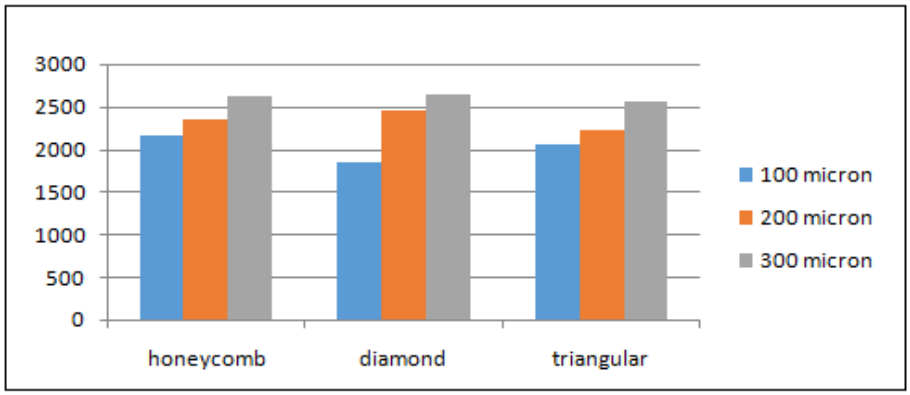
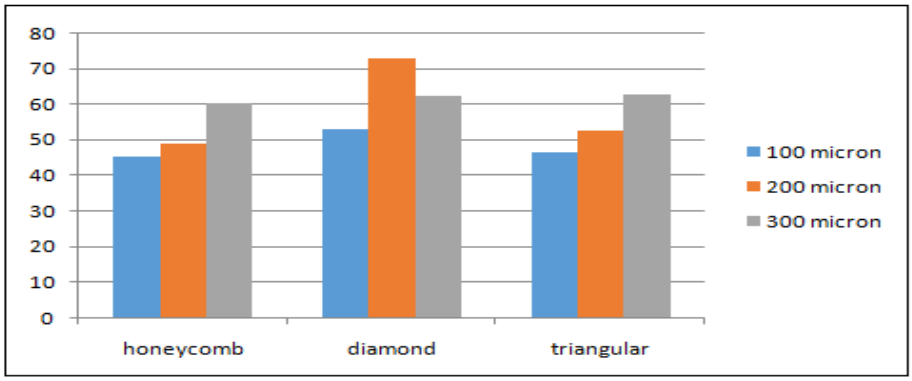


Weight comparison



Weighted strength comparison



Maximum flexural load comparison

IX. CONCLUSION

The 3D printing innovation has been generally utilized in delivering geospatial imaging printed item. Materials that are utilized in 3D printing can be as fiber, powder or sheet. The kinds of material are relying upon the 3D printer procedure, applications and their properties. The vast majority of the broadly utilized material are PLA and ABS. Hence, this section examines about the mechanical properties of these materials. Two sorts of test are conveyed to decide their mechanical properties, which are malleable and flexural tests. Tensile test is led so as to decide the power expected to break the example and to decide the augmentation to which the example prolongs until the limit. Then, flexural test is completed to decide the measure of pressure or power the material can withstand to oppose bowing disappointment the testing examples are created by utilizing 3D printer into 'dog bone' and 'dumb shell' shapes by alluding to ASTM D638, ISO 527 and ASTM D970 norms. . 9 specimens are prepared for each test. The tensile test result show that honeycomb infill pattern with 200 layer height having greater weighted strength and in maximum tensile load comparison diamond infill pattern with 300 layer height give superior result. The flexural test result show that diamond infill pattern with 300 layer height having greater weighted strength and in maximum tensile load comparison diamond infill pattern with

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200 layer height give superior result. The information regarding the mechanical properties of plastic polymers that are produce using 3D printing technique can become useful in fabricating printed products for geospatial imaging applications.

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