

Experimental Investigation for Mechanical Properties of Solidified Polylactic Acid Parts Produced by Fused Deposition Modeling

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ABSTRACT: 3D Printing is a layered manufacturing process that builds prototypes by depositing material in layered from using heaters. 3D printing also known as additive manufacturing. 3D printing is a process for producing a physical object from a 3-dimensional digital model, typically by many successive thin layer of a material. It bring a digital object (CAD presentation) to physical from by layer by layer material. Prototypes made by 3D Printing are widely used in product development as they can be used for product testing. Prototype should have a very good mechanical properties for functional performance as well as aesthetics. The mechanical properties in 3D Printing depends upon different process parameter namely, Layer Thickness, Nozzle Diameter, Part Bed Temperature, Speed of Deposition, Raster Angle of Deposition, Raster Width and Length of the parts. In this present work, an attempt has been made to improve the mechanical properties namely, Impact Strength, Hardness of prototypes of Solidified PolyLactic Acid (PLA) parts fabricated using Fused Deposition Modelling process of 3D Printing. The parameters selected for this study are layer thickness, Raster width & Travel Speed.

KEYWORDS:- 3D printing, Polylactic Acid, Hardness, Impact strength, Shear strength, Layer thickness, Nozzle Travel speed, Nozzle diameter, Raster width

I.INTRODUCTION

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object. 3D printing enables you to produce complex (functional) shapes using less material than traditional manufacturing methods.

Antonio Lanzotti, Marzio Grasso, Gabriele Staiano, Massimo Martorelli, (2015) [1] investigate the main impact of each process parameter on mechanical properties and the effects of interactions. The use of a response surface methodology allowed the proposition of an empirical model which connects process parameters and mechanical properties.

Isabelle Anderson (2017) [2] investigate the 3D printing with recycled PLA is a viable option. With the recycled filament, tensile strength decreased 10.9%, shear strength increased 6.8%, and hardness decreased 2.4%. The tensile modulus of elasticity was statistically unchanged. Although the average mechanical properties before and after recycling were similar, there was more variability in the results of the recycled filament.

K. G. Jaya Christiyan, U. Chandrasekhar, K. Venkateswarlu (2016) [3] investigate the 0 orientation, 38 mm/s printing speed, and 0.2 mm layer thickness resulted maximum flexural strength, as compared to all other specimens.

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The improved flexural strength was due to the lower layer thickness (0.2 mm) specimens, as compared with other specimens made of 0.25 and 0.30 mm layer thicknesses.

Guoying Dong, Yunlong Tang, Dawei Li, Yaoyao Fiona Zhao (2018) [4] investigate the experiments to understand the tensile property of 3D printed fiber reinforced composite material. The fiber orientation, the volume fraction, and the position of fiber are considered. The elastic modulus, yield strength, and the ultimate tensile strength have been calculated based on experimental results. ASTM D3039 standard was followed in the tensile test.

1.1 Working principal of Fused Deposition Modeling

Fused Deposition Modeling is a 3D printing process that uses a continuous filament of a thermoplastic material. This is fed from a large coil, through a moving, heated printer extruder head. Molten material is forced out of the print head's nozzle and is deposited on the growing work piece. The head is moved, under computer control, to define the printed shape. Usually the head moves in layers, moving in two dimensions to deposit one horizontal plane at a time, before moving slightly upwards to begin a new slice. The speed of the extruder head may also be controlled.

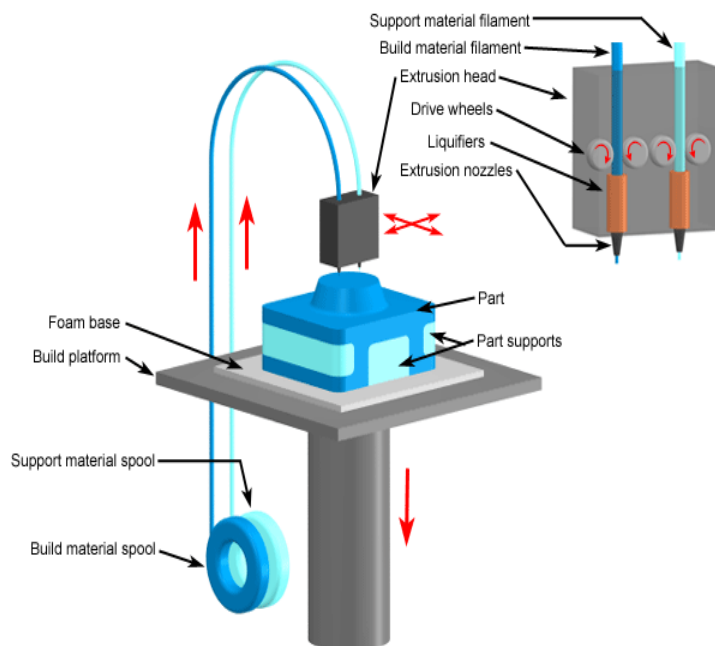


Fig 1: Fused Deposition Modeling

II. SELECTION OF MATERIAL AND PARAMETER

In 3D printing, one of the most widely used material is Polylactic Acid (PLA), which has gained wide popularity because of its high strength, Durability, Light Weightless, Ready availability and a less tendency to warp. Polylactic Acid (PLA) is a biodegradable and bioactive thermoplastic aliphatic polyester derived from renewable resources. As PLA material has many functional properties like toughness and strength. With PLA 3D printer is able to fabricated fully functional part. So PLA is selected as built materials.

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2.1 process parameter

For selected three parameters namely layer thickness, Travel speed and Nozzle diameter and three levels selected, which is shown in Table.

Table 1: Processing parameter and Levels

Parameter	Level		
	(-1)Level	(0) Level	(1) Level
Layer thickness (mm)	0.1	0.2	0.3
Travel Speed (mm/sec)	40	45	50
Raster width (mm)	0.4	0.5	0.6

2.2 Fabrication of specimen

The CAD model is designed in creo software and converted to .STL format.

Specimens are fabricated at 3D cubic company at 39- Babrik Industrial Estate, Katargam, Ashwini Kumar Rd, GIDC, Surat, Gujarat 395008

Main Feature

- Build Volume:- 350 L x 350 W x 350 H mm
- Layer Resolution Height:- 0.60 to 400 microns
- Filament Dia.:- 1.75mm

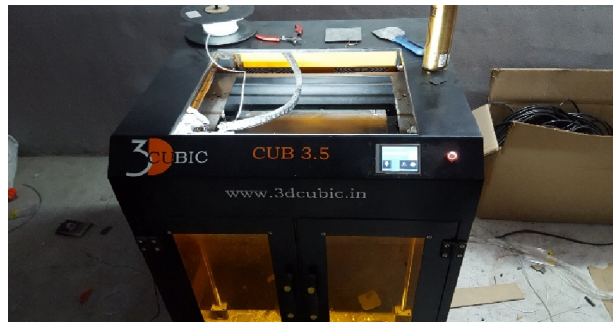


Fig 3: CUB 3.5 (3D printer)

III. EXPERIMENT TESTING

Experimental testing are performed at CIPET : INSTITUTE OF PLASTICS TECHNOLOGY (IPT) @ AHMEDABAD Plot No. 630, Phase-IV, GIDC, Vatva, Ahmedabad, Gujarat 380038

Impact strength test performed on impact strength testing instruments. Impact strength is determined on TINIUS OLSEN instrument according to ASTM D 6110 testing standard. Capacity of TINIUS OLSEN is 25 J. In Impact testing to attach the striking tip on the pendulum and the specimen clamp in the base of the unit. And then the release the pendulum so the striking tip is strike with the specimen and break it the specimen.

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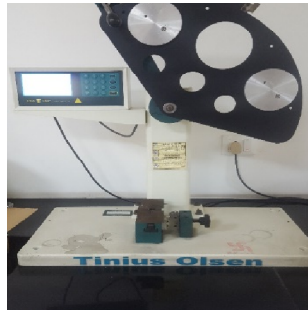


Fig 5: Impact strength testing machine

Hardness test is determined as per ASTM D 785 testing standard. In Hardness test the specimen will be fixed in with the pressing tip and then the release the lever or gear. At that time in which there are 60kg load will be applied during 15 second on the specimen.



Fig 6: Hardness testing machine

- This table is shows that the result of the Impact strength and hardness test.

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Table 2: Experiment testing result

Run Order	Layer Thickness (mm)	Travel Speed (mm/sec)	Raster Width (mm)	Impact strength (kJ/m ²)	Hardness (HRC)
1	0.2	45	0.5	4.33	113.5
2	0.3	50	0.4	2.83	102
3	0.2	40	0.4	3.498	113
4	0.2	40	0.5	2.66	104
5	0.1	45	0.4	2.74	115.5
6	0.2	50	0.5	2.77	115
7	0.1	40	0.5	3.4984	113
8	0.3	45	0.5	2.64	95.5
9	0.1	40	0.4	3.519	116
10	0.1	50	0.6	2.852	103.5
11	0.3	40	0.4	2.6805	108.5
12	0.3	45	0.6	2.6708	103.5
13	0.2	50	0.6	2.630	104.4
14	0.3	50	0.5	2.821	104
15	0.2	45	0.4	3.665	112.5
16	0.1	50	0.4	2.8317	115
17	0.1	45	0.5	4.2473	117
18	0.3	50	0.6	2.6404	109
19	0.2	40	0.6	2.7610	114.5
20	0.3	40	0.5	2.6805	102.5
21	0.1	50	0.5	2.8014	111
22	0.3	45	0.4	2.5903	122
23	0.2	50	0.4	3.4776	105

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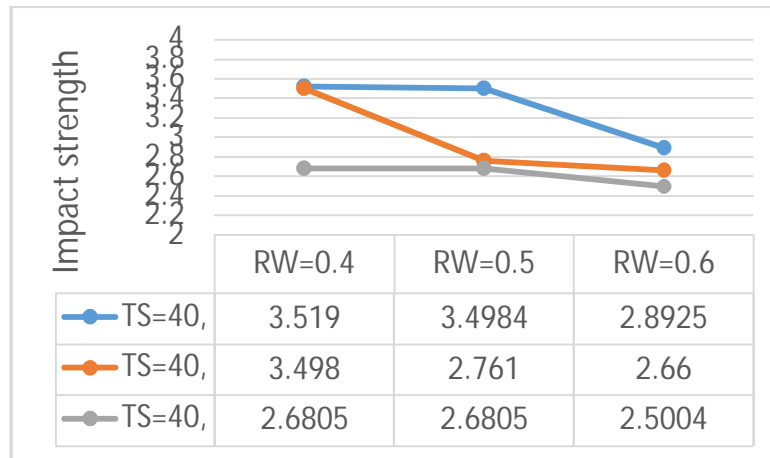
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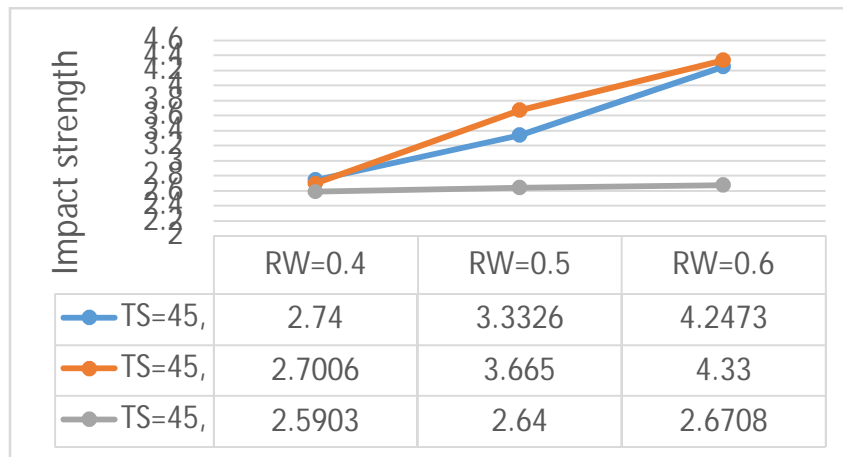
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IV. RESULTS AND DISCUSSION

From the result of this experiment we get the this type of graph and we can show that the result of the Impact strength and Hardness.



It is seen that as the raster width increases, the impact strength is decreased. For travel speed of 40 mm and layer thickness of 0.1 mm and raster width of 0.4 mm, a maximum result of impact strength is obtained.



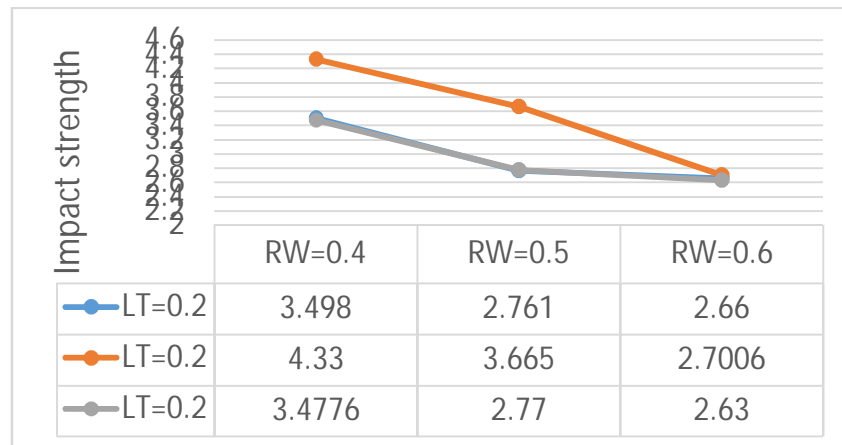
It is seen graph shows raster width increases then the impact strength will be increases at travel speed 45 mm/sec and layer thickness 0.3 mm. And raster width is 0.6 mm and layer thickness is 0.2 mm so this combination we get the maximum result of impact strength at travel speed 45 mm/sec.

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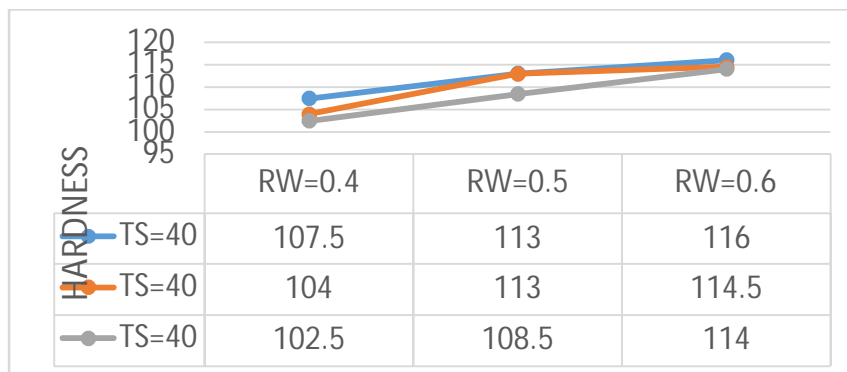
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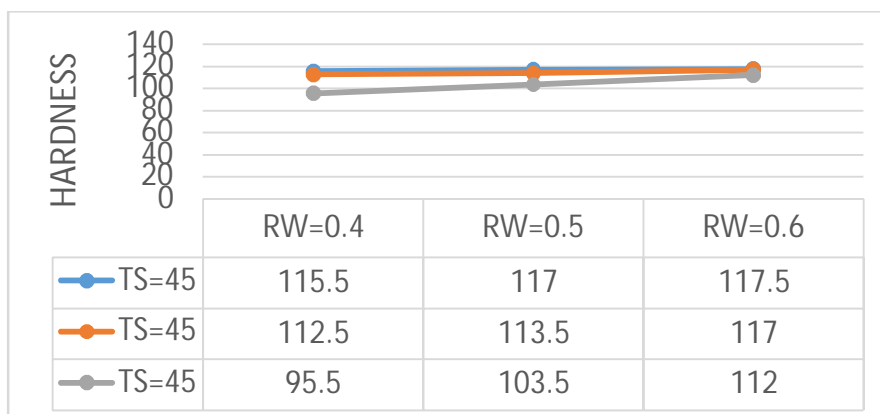
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Graph shows the raster width will be increases then the impact strength is decreases on the layer thickness of 0.2 mm constant.



In this graph presented that hardness will be increases when raster width increases at travel speed is 40 mm/sec.



In this Graph shows that raster width will be increases then the hardness will be increases on the travel speed is 45 mm/sec is constant.

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V. CONCLUSIONS

In present study the specimen were fabricated by the PLA material and mechanical testing for this specimen like Impact strength and Hardness. So that the conclusion are as follows:

1. When the layer thickness will be increases then the impact strength will be decrease.
2. And the raster width will be increases then the Hardness of the specimen will be increase.

REFERENCES

1. Antonio Lanzotti, Marzio Grasso, Gabriele Staiano, Massimo Martorelli, "The impact of process parameters on mechanical properties of parts fabricated in PLA with an open-source 3-D printer" (2015) Rapid Prototyping Journal, Vol. 21 Issue: 5, pp.604-617, <https://doi.org/10.1108/RPJ-09-2014-0135>
2. Isabelle Anderson "Mechanical Properties of Specimens 3D Printed with Virgin and Recycled Polylactic Acid" (2017) Volume 4, Number 2 Mary Ann Liebert, Inc. DOI: 10.1089/3dp.2016.0054
3. K. G. Jaya Christiyan, U. Chandrasekhar, K. Venkateswarlu "Flexural Properties of PLA Components Under Various Test Condition Manufactured by 3D Printer" (2016)
4. Guoying Dong, Yunlong Tang, Dawei Li, Yaoyao Fiona Zhao "Mechanical Properties of Continuous Kevlar Fiber Reinforced Composites Fabricated by Fused Deposition Modeling Process"(2018) 774-781
5. Narendra Kumara,*, Prashant K. Jain, Puneet Tandon, Pulak Mohan Pandey "The effect of process parameters on tensile behavior of 3D printed flexible parts of ethylene vinyl acetate (EVA)" (2018) 317-326
6. Kyle Raney, Eric Lani, Devi K.Kalla "Experimental characterization of the tensile strength of ABS parts manufactured by fused deposition modeling process" (2017) 7956-7961
7. Gokulakrishnan Jothibabu, Saravana Kumar Gurunathan, "Surrogate Based Sensitivity Analysis of Part Strength due to Process Parameters in Fused Deposition Modelling" (2018) 772-778
8. Ashu Garg and Anirban Bhattacharya, "An Insight to the Failure of FDM Parts under Tensile Loading: Finite Element Analysis and Experimental Study", International Journal of Mechanical Sciences, <http://dx.doi.org/10.1016/j.ijmecsci.2016.11.032>
9. Sharma R, Singh R, Penna R, Fraternali F, Investigations for mechanical properties of Hap, PVC and PP based 3D porous structures obtained through biocompatible FDM filaments, Composites Part B (2017), doi: 10.1016/j.compositesb.2017.08.021.
10. Jasgurpreet Singh Chohan, Rupinder Singh, Kamaljit Singh Boparai "Mathematical modelling of surface roughness for vapor processing of ABS parts fabricated with fused deposition modelling" (2016) 161-169
11. Michael Dawoud, Iman Taha, Samy J. Ebeid "Mechanical behaviour of ABS: An experimental study using FDM and injection moulding techniques" (2016) 39-45
12. Vishwas.M,Basavaraj.CK "Studies on Optimizing Process Parameters of Fused Deposition Modelling Technology for ABS" (2017) 10994-11003