Parametric Optimization and Evaluation of mechanical properties of ABS using FDM

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ABSTRACT

This work deals with mechanical property analysis of ABS material of different infill percentages (100%,80%,60%,40%,20%) which was fabricated by 3D printing. The material used is biodegradable. Modeling was done by using Solid Works as per ASTM Standards. The model is changed. STL format and fabricated by Ender 3D printing machine. After fabrication, the tensile and compression tests are done in a Universal testing machine. The Hardness Test on Rockwell Hardness TestMachine and the surface test are done using a Surface Roughness testing machine. By comparing all experimental test results, the property which closely matches the experimental result is 80% infill percentage specimens also having good stability like 100% infill material. From the results obtained, it can be concluded that we can -reduce the material deposition.

KEYWORDS: - ABS, FDM, UTM, Hardness, Surface Roughness

INTRODUCTION

It is a 3D Printing process that uses a continuous filament of thermoplastic material. The material is fed from a large spool through a moving heated printer extruder head and is deposited on growing work

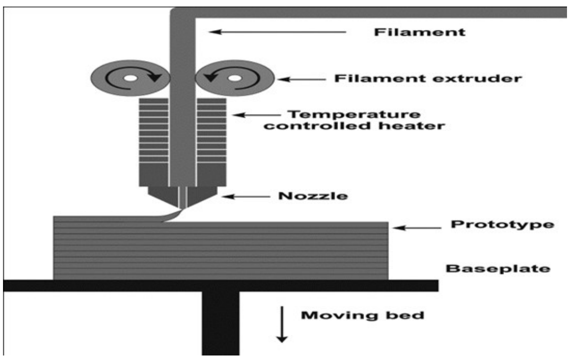


Fig 1 FDM

The principle of the FDM is based on surface chemistry, thermal energy, and layer manufacturing technology. The filament (spool) material is melted in a specially designed head, whichextrudes the model. As it is cooled and thus solidifies to form the model. The model is built layer by layer like the other RP system. Parameters affecting the system's performance and functionalities are material column strength, material flexural modulus, material viscosity, positioning accuracy, road widths, deposition speed, volumetric flow rate, tip diameter, envelope temperature, and part geometry. Contemporary thermoplastics exhibit large deformations, making them ideal for impact resistance in engineering applications. [1] However, their material behavior is complex due to strain rate and temperature influences.[2]Deriving constitutive models for amorphous thermoplastics' strain rate and pressure-dependent behavior is a focus of theoretical studies, but further investigation is needed.[3,4] Semi-analytical material models are increasingly used to predict thermoplastic mechanical response under stress states,[5]such as random rubber particles in ABS, enhancing toughness and preventing craze initiation.[6] This study investigates the mechanical response of ABS amorphous thermoplastic under tension, compression, and three-point bending at different deformation rates. [7]It examines the effect of test speed on ABS yield stress and the pressure dependence effect on material behavior. The study utilizes Mat-SAMP-1, a semi-analytical model developed for polymers, to handle various loading cases[8].

Material: ABS

It has been selected as a popular material from renewable resources to produce economically. ABS has been recorded as the second-highest consumption of plastic in the world. It is also called bioplastic. ABS is mostly widely used as Plastic filament in 3D Printing.

Fig 2 ABS material in the form of filament

Table.1. Properties of ABS

S.no	Properties	Values
1	Technical name	Acrylonitrile butadiene styrene
2	Chemical formula	$(C_8H_8\cdot C_4H_6\cdot C_3H_3N)_n$
3	Melt temperature	157-170˚C
4	Typical injection molding temperature	178-240˚C
5	Heat deflection temperature	49-52˚C
6	Tensile strength	61-66 Mpa
7	Flexural strength	48-110 Mpa
8	Specific gravity	1.24
9	Shrink rate	0.37-0.41 %

ROCKWELL HARDNESS

The Rockwell test is rapid and simple in operation and may be used on thinner specimens, and very soft to very hard materials. It is essentially used to determine the hardness of finished parts, plastic sheets or parts, etc. Here we used [1] th Ball Intender to find the hardness. The experiment is done at our college laboratory. The machine is Rockwell hard. The test report is furnishedbelow

SURFACE ROUGHNESS

Here we obtain Ra, Rq, and Rz values by checking the surface at various places of specimens.

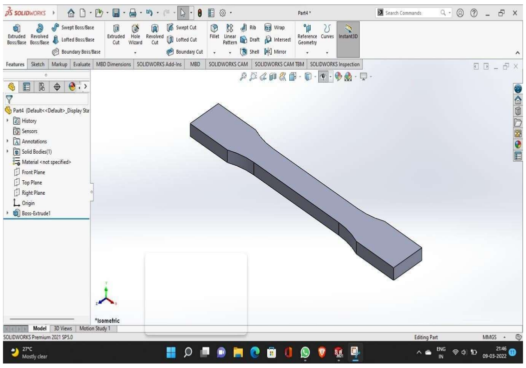
Fig 3 Surface Roughness, Hardness & UTM

UTM

When force is applied on both sides of the specimen it gets broken into two pieces in the middle as shown in Fig.3 The tensile test values are recorded for each specimen with graph sheets. Later all five specimens are compared with each other to state which one is better or poor in mechanical properties

DESIGN & EXPERIMENT:

The methodology of the project starts with choosing the ABS material in the form of filament. Firstly, the material is selected and it is installed in FDM 3D printer and set to the required settings once the material is inserted in the nozzle of the 3D printer. The STL file of the required component is loaded into the printer and the machine is set to print. Here we are printing the Specimens with different infills density and infill designs in an orientation. We print one set of specimens which are for the tensile test consisting of 5 specimens and another set consisting of 5 specimens for the compression test. Once the printing of specimens is done and those specimens are performed Surface Test, to check the surface and in the next step the specimens are performed a Hardness test on a Rockwell hardness machine to ensure the hardness of the specimen printed through the FDM technique. Now these specimens are tested for tensile test in UTM and later another set of specimens is performed compression test on the same UTM. Now we observe each specimen's data and compare it with each other and conclude which specimen is good and bad based upon the data interpreted from experimentation. In the first step of the experiment, we design the CAD file (FISHBONESTRUCTURE) with the required dimensions as shown in the below figure



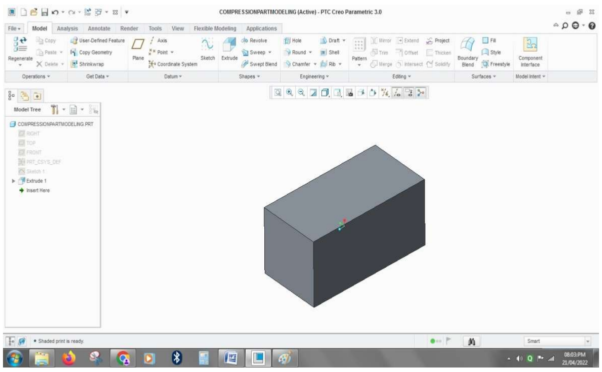


Fig-4 Tensile & Compression Specimen

Table: -2 Required parameters of fish bone structure specimen

parameters	Total lines	Filament needed (mm)	Layer count	Time required
20	7648	2865	30	31m.38s
40	10164	3629	30	36m.32s
60	12250	3971	30	36.54s
80	14824	4732	30	42m.3s
100	17896	5918	30	59m.42s

Table: - 3 Required parameters of cuboidal block specimen

parameters	Total lines	Filament needed (mm)	Layer count	Time required
20	3099	718	63	8m.48s
40	4416	973	63	10m.28s
60	5892	1228	63	12m.57s
80	7374	1481	63	14m.35s
100	8742	1731	63	25m.50s

Later this filament is inserted in FDM 3D Printer to manufacture the components. TheSTL file is imported into 3D printing software called “Cura 3.0”. In this software, we modify the component as per requirements like orientation, Infill density, Infill density, and time required per specimen. Here the STL file is converted into G-code which is updated according to user interest and copied into the 3D printer’s memory card.This memory card is inserted into a 3D printer and the machine is set to start. Before starting to print the Printer is set to nozzle temperature which is 210˚C it is used for heating the nozzle. The filament is inserted into the nozzle. After all the preprocessing is done the machine is started. The filament is converted into a liquid paste and prints the specimens from bottom to top as shown in the figure.

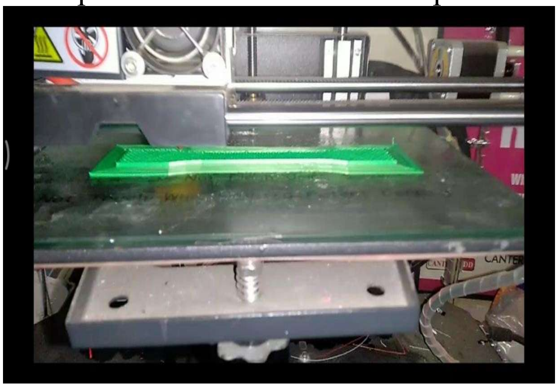


Fig- 5 Printing of specimens using FDM

In this way Five specimens with 0˚ angle orientation, with different infills density, and infills design as shown in below fig.6

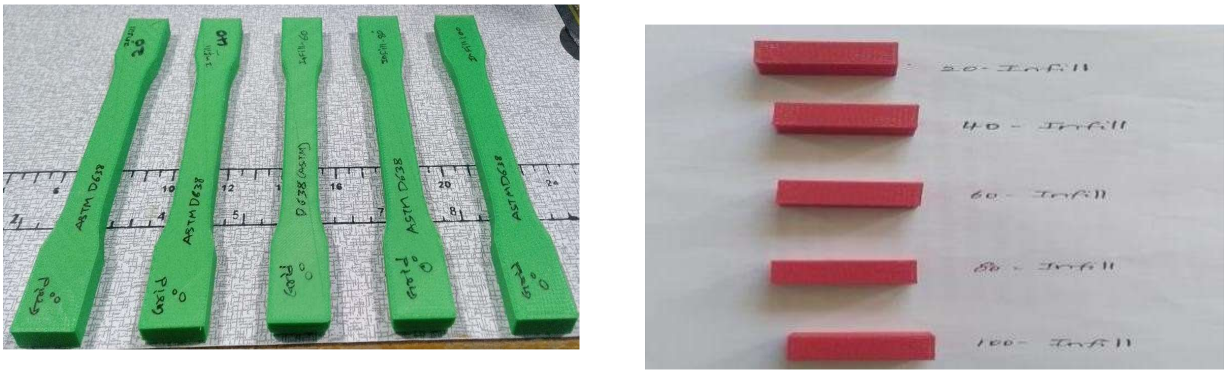


Fig 6 specimens with different infill Percentages

Fig 7: Testing on UTM, Hardness & Surface Roughness

Table: - 4 Comparison table of cuboidal structure specimens

S NO	INFILL	COMPRESSION	SURFACE TEST			HARDNESS
			Ra	Rq	Rz	
1	20%	24.85	3.75	4.90	16.3227	7.79667
2	40%	26.98	7.100	8.988	35.183	14.166
3	60%	34.31	3.988	4.990	18.675	32
4	80%	40.23	15.393	20.188	80.182	31
5	100%	45.20	17.02	22.927	87.315	45.33

Table: - 5 Comparison table of fish bone structure specimens

S NO	INFILL	UTM TEST			SURFACE TEST			HARDNESS
		YIELD N	BREAK N	MAX N	Ra	Rq	Rz	
1	20%	10.63	11.08	11.08	3.994	5.013	20.74	7.9667
2	40%	5.18	12.48	12.48	2.953	3.902	18.535	14.166
3	60%	14.93	15.71	15.71	5.176	6.880	30.888	32
4	80%	17.02	17.86	17.86	4.067	5.275	23.203	31
5	100%	31.23	32.63	32.33	10.246	12.987	51..325	45.33

CONCLUSION

This paper discusses the mechanical properties of FDM 3D-printed ABS components, focusing on tensile and compression testing. The strongest specimens were found at a 0º raster orientation with 80% infill density. Low infill speed increased strength by providing longer deposition time. Infill design parameters, such as layer thickness, deposition speed, density, pattern, and width, impact the mechanical properties of the 3D printed specimen. Higher infill density leads to better tensile and compression strength, while lower infill density and higher layer width decrease strength. Higher infill density increases stiffness and modulus elasticity. By SEM analysis 80 infill having no clogs and peel off are there and also no voids when compare with other infill percentages.

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