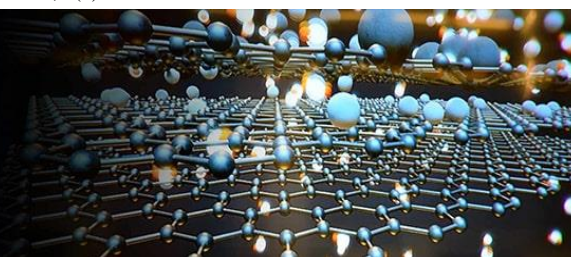


International Journal of Materials Science



E-ISSN: 2707-823X
P-ISSN: 2707-8221
IJMS 2023; 4(2): 34-38
Received: 13-05-2023
Accepted: 19-06-2023

Vaibhav Kulkarni
Assistant Professor,
Department of Mechanical
Engineering, MIT-World
Peace University, Pune,
Maharashtra, India

Sakshi Shinde
Student, Department of
Mechanical Engineering, MIT-
World Peace University, Pune,
Maharashtra, India

Samruddhi Shinde
Student, Department of
Mechanical Engineering, MIT-
World Peace University, Pune,
Maharashtra, India

Effect of variation of process parameters on printed component using FDM technology

Vaibhav Kulkarni, Sakshi Shinde and Samruddhi Shinde

DOI: <https://doi.org/10.22271/27078221.2023.v4.i2a.34>

Abstract

FDM technology also known as a fused deposition technology is a solid based 3D printing techniques used to create prototypes and working models. It mainly uses PLA and ABS as the printing material. For the experimentation purpose, we printed two bushes, with PLA as the printing material but changing the process parameters for both the prints. The CAD model of the bush was drafted in Solid works Software and the slicing process of the model for printing purpose was performed in Cura Software which is compatible with Ultimaker 3D printers. The main objective was to print a bush with same material but different process parameters and compare the results obtained.

Keywords: FDM, PLA, ABS, infill pattern and density

Introduction

Additive Manufacturing otherwise referred as 3D printing Rapid Prototyping or Generative Manufacturing, was first introduced in 1987. The fundamental principle with regard to additive manufacturing is layer by layer construction of a three-dimensional CAD model using suitable printing process in accordance to the application.

FDM Technology

FDM (Fused Deposition Modelling) technology is a solid based printing process used for making physical models by adding successive layers of material with minimal wastage. It is an additive manufacturing process which is exactly opposite to the convectional subtractive manufacturing process. This process creates 3D models using a thermoplastic or composite material filament. The plastic filament is fed through an extruder nozzle where it is melted and the layer is selectively deposited layer by layer on a heated glass plate which is used as a building platform. It works by melting and extrudes a thermoplastic filament through a nozzle on the base of the ultimaker. The nozzle of the ultimaker has 3 movable axes i.e., X, Y. The printer's axis moves along the Z- axis while nozzle travels along X and Y axis, in order to create successive layers which in turn helps creation of complex, custom designed objects. The material used for printing is usually PLA, ABS, PETG, TPU etc. The nozzle temperature can vary from 180 degree to 250 degree or maybe higher. As the melted material is extruded onto the built platform, it quickly cools and solidifies, adhering the layer beneath it. For some of the complex designs the printer creates a support structure below the empty space. These supports are nothing but scaffolds which are printed alongside the object to prevent sagging or misshaping during printing. Once all the layers are printed, the object is completed. Depending on the design and material used, post processing steps like removing support structures if any, sanding, etc., if necessary, in order to achieve the desired finish.

Corresponding Author:
Vaibhav Kulkarni
Assistant Professor,
Department of Mechanical
Engineering, MIT-World
Peace University, Pune,
Maharashtra, India

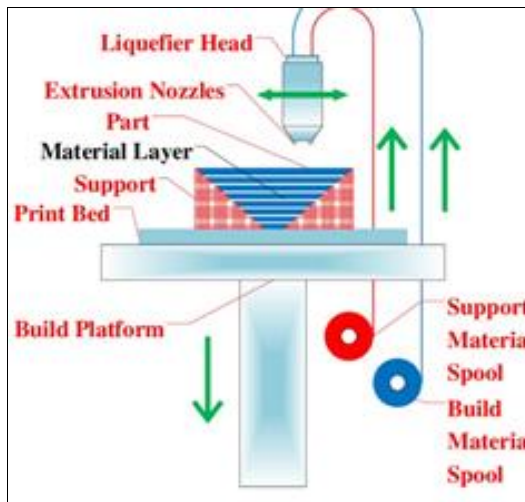


Fig 1: FDM Technology

Printing Process

3D printing of a model involves various steps like:

Step 1: Part Design in Solidworks

The primary step in the process of 3d Printing is the modelling of the part to be printed using 3D modelling software such as Catia, Pro-E, Solidworks, etc. For our experiment we used Solidworks 2021 3D Modelling Software to design our model i.e., the Bush. Required dimensions of the part to be printed for example the height, inner and outer diameters of the bush are decided in the design stage.

Step 2: Saving the Design in .stl format

The file designed is to be saved as .stl format (Standard Tessellation Language) as this file format is supported by many software packages. (STL) is the global format for 3D printing files.

Step 3: Opening file in Slic3r and Export G-code

The model's (.stl) file is opened and further is sliced using the CURA Software, so as to set the parameters such as scaling of the model, layer height, object density etc. As a result of this, a G-code for the object is generated and saved for further references.

Step 4: Importing the G-code file and Printing

The file created is then saved to a pen drive and programmed into the ultimaker 2+.

Step 5: After printing

After printing the object the model undergoes post processing such as filing, sanding, drilling if any defects are to be corrected.

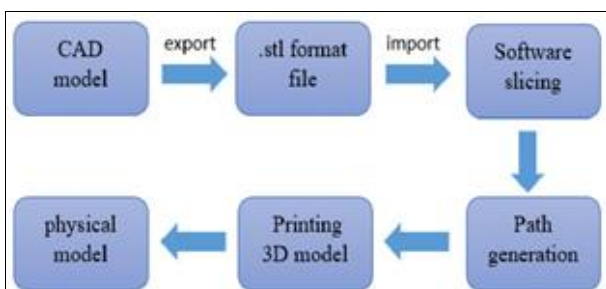


Fig 2: FDM Printing Process

Material

FDM makes use of various types of materials prominent being PLA and ABS. The various materials used are:

PLA (Polylactic Acid)

PLA is amongst the most commonly available and the easiest material used in FDM. Since it is biodegradable, rigid and strong, it is used for concept modelling. The disadvantage of this material is that it is brittle and less resistant to heat and chemicals.

ABS (Acrylonitrile Butadiene Styrene)

Manufactured from the monomer Acrylonitrile, 1,3-Butadiene and Styrene, ABS is a frequently used material which is known for its toughness and durability [5]. This material is mainly used for functional prototyping but requires a heated bed for printing and ventilation.

PETG (Polyethylene Terephthalate Glycol)

PETG is mainly used for snap-fit components and is compatible with lower printing temperatures. It is chemical resistant and has high transparency.

Nylon

Nylon being strong, durable, lightweight, tough and partially flexible, it is mainly used for functional prototyping and wear resistant parts. This material is very complex to print in FDM.

Table 1: Mechanical Properties of the Material [5, 6]

Properties	PLA	ABS	PETG	Nylon
Tensile Strength	59 MPa	2.96-43 MPa	53 MPa	100 MPa
Flexural Strength	106 MPa	2400 MPa	70 MPa	150 MPa
Density	1.24 g/mL	1.14 g/mL	1.27 g/mL	1.17 g/mL
Elongation At Break	7%	10-50%	130%	120%

Cad Model

Bush: A bush is one of the most common mechanical elements which finds its applications in most of the heavy-duty machines, mechanical components, cars, etc. It is mainly used as a mechanical fixing between two moving parts or at fixing points to attach various assemblies with one another. They are used to connect moving arms, pivot points etc. in the suspension system of vehicles.

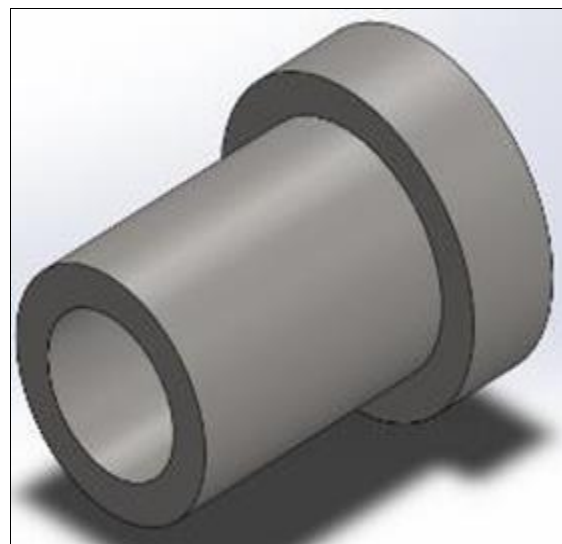


Fig 3: Bush Model

Experimental Setup

Assembly of FDM Printer

For experimental purpose, we used Ultimaker 2+ printer which is a FDM based printer. The main parts of the Ultimaker 2+ printer is:

- Build Plate:** The Ultimaker 2+ uses a glass build plate as a heated building platform which moves down in Z-axis as the printing is done layers.
- Print Head:** During the printing process, the print head provides motion to the nozzle in X and Y direction. The nozzle is interchangeable for different printing sizes.
- Print Head Cable:** The wires used for the print head fans, the heater and the temperature sensor are present in the print head cable.
- Bowden Tube:** The tube which guides the filament from the feeder to the print head is known as the Bowden Tube.
- Glass Build Plate:** The glass build plate is the print surface.
- Display:** The small but efficient display shows several menu options and provides information about your print.
- SD Card Slot:** An SD card is used to start a print.

- Spool Holder:** A spool of material is placed on the spool holder before loading it into the feeder. The spool holder can turn the spool during printing.
- Feeder:** The feeder uses a gear mechanism which helps in feeding the material to the print head.

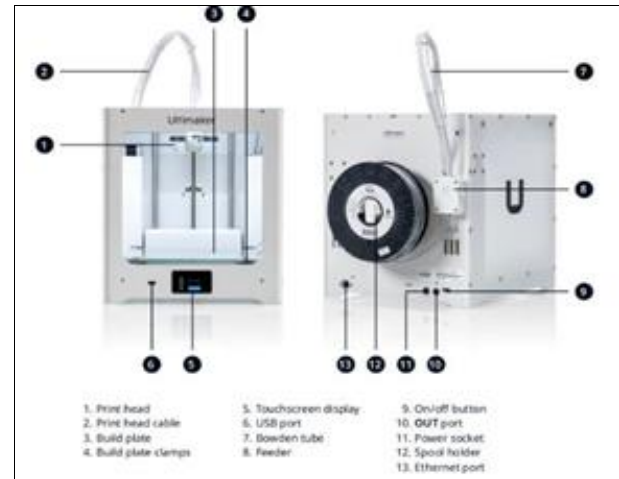


Fig 4: Ultimaker 2+ Printer

Table 2: Specifications of Ultimaker 2+

Parameters	Specifications
Building Volume	223 mm x 223 mm x 205 mm
Layer Resolution	20-200 microns
Filament Diameter	2.85 mm
Nozzle Diameter	0.4 mm (default), 0.25 mm, 0.6 mm, 0.8 mm
Accuracy	12.5 / 12.5 / 5 micron
Printing temperature of the nozzle	180 – 260 °C
Speed	Print: 30 mm/s – 300 mm/s Travel: 30 mm/s – 350 mm/s
Print Surface	Heated glass build plate
Dimensions	342 x 357 x 388 mm
Weight	11.3 kg
Software	UltiMaker Cura

Cura Interface

Cura is an open source, simple and powerful 3D slicing software used for printing models in Ultimaker printers. Available under LGPLv3 license, this software accepts .stl, .3MF and .obj 3D file formats for 3D printing the models. The software has a feature to select the printer nozzle and also allows to open multiple models on printing bed.

G-code for Bush Model

```

;START_OF_HEADER
;HEADER_VERSION:0.1
;FLAVOR:Griffin
;GENERATOR.NAME:Cura_Bush
;GENERATOR.VERSION:5.0.0
;GENERATOR.BUILD_DATE:2022-05-17
;TARGET_MACHINE.NAME:Ultimaker S5
;EXTRUDER_TRAIN.0.INITIAL_TEMPERATURE:200
;EXTRUDER_TRAIN.0.MATERIAL.VOLUME_USED:6301
;EXTRUDER_TRAIN.0.MATERIAL.GUID:506c9f0d-e3aa-4bd4-b2d2-23e2425b1aa9
;EXTRUDER_TRAIN.0.NOZZLE.DIAMETER:0.4
;EXTRUDER_TRAIN.0.NOZZLE.NAME:A A 0.4

```

```

;BUILD_PLATE.TYPE:glass
;BUILD_PLATE.INITIAL_TEMPERATURE: 70
;BUILD_VOLUME.TEMPERATURE:28
;PRINT.TIME:2381
;PRINT.GROUPS:1
;PRINT.SIZE.MIN.X:125.491
;PRINT.SIZE.MIN.Y:102.879
;PRINT.SIZE.MIN.Z:0.2
;PRINT.SIZE.MAX.X:181.974
;PRINT.SIZE.MAX.Y:136.948
;PRINT.SIZE.MAX.Z:24.95
;END_OF_HEADER
;Generated with Cura_SteamEngine 5.0.0 T0
M82 ;absolute extrusion mode G1 F2700
E-6.5
;LAYER_COUNT:100
;LAYER:0 M107
M204 S429
M205 X20 Y20
G1 F600 Z2.2
G0 F1928.6 X179.406 Y128.961 Z2.2 G0 X176.893
Y132.095
M204 S1000
;TYPE:SKIRT G1 F600 Z0.2 G1 F2700 E0

```

G1 F900 X176.019 Y132.895 E0.01783
 G1 X175.378 Y133.415 E0.03025 G1
 X174.418 Y134.104 E0.04803 G1
 X173.721 Y134.545 E0.06045 G1
 X172.682 Y135.118 E0.0783 G1
 X171.938 Y135.472 E0.0907
 G1 X170.839 Y135.918 E0.10855 G1
 X170.055 Y136.183 E0.121 G1 X168.916
 Y136.494 E0.13877 G1 X168.107
 Y136.664 E0.15121 G1 X166.931
 Y136.839 E0.1691 G1 X166.119
 Y136.912 E0.18137 G1 X164.938
 Y136.948 E0.19915 G1 X164.097
 Y136.923 E0.21181 G1 X162.917
 Y136.816 E0.22964 G1 X162.115
 Y136.695 E0.24185 G1 X160.958
 Y136.452 E0.25964 G1 X160.163
 Y136.236 E0.27203 G1 X159.043
 Y135.858 E0.28982 G1 X158.276
 Y135.547 E0.30228 G1 X157.203
 Y135.036 E0.32016 G1 X156.486
 Y134.641 E0.33248 G1 X155.486
 Y134.011 E0.35027 G1 X154.808
 Y133.524 E0.36283 G1 X153.886
 Y132.775 E0.38071 G1 X153.638
 Y132.548 E0.38576 G1 X152.661
 Y133.349 E0.40478 G1 X151.979
 Y133.839 E0.41741 G1 X150.979
 Y134.469 E0.4352 G1 X150.262
 Y134.864 E0.44752 G1 X149.189
 Y135.375 E0.4654 G1 X148.422
 Y135.686 E0.47786 G1 X147.302
 Y136.064 E0.49565 G1 X146.507
 Y136.28 E0.50804 G1 X145.35 Y136.523
 E0.52583 G1 X144.536 Y136.645
 E0.53822 G1 X143.356 Y136.75

E0.55605 G1 X142.533 Y136.774
 E0.56844 G1 X141.352 Y136.739
 E0.58622

To be continued...

G1 X141.214 Y125.704 E987.65874
 G1 F1671.9 X140.458 Y125.498 E987.67337 G1
 F1679.6 X139.693 Y125.178 E987.68878 G1
 X138.966 Y124.728 E987.70468
 G1 F1675.7 X138.306 Y124.182 E987.72063 G1
 F1671.9 X137.786 Y123.615 E987.73499 G1 F1675.7
 X137.325 Y122.97 E987.74976 G1 F1695.2 X136.944
 Y122.264 E987.76455 G1 F1691.2 X136.649
 Y121.422 E987.78103 G1 F1668 X136.49 Y120.597
 E987.79674
 G1 F1645.4 X136.45 Y119.834 E987.81121 G1
 F1652.9 X136.49 Y119.011 E987.82674
 ;TIME_ELAPSED:2381.427618 G1 F2700
 E981.32674
 M204 S3000 M107
 M82 ;absolute extrusion mode M104 S0
 M104 T1 S0
 ;End of Gcode

Observations

During the experimentation process, we printed the model using PLA during both the prints. We changed the process parameters to observe the variations in the print quality. For both the prints, we scaled the model to 125% so as to increase the size of the model.

For Print A1

For the first print of the model, the infill pattern provided is triangular with infill density 60%. The time required for printing was 18mins.

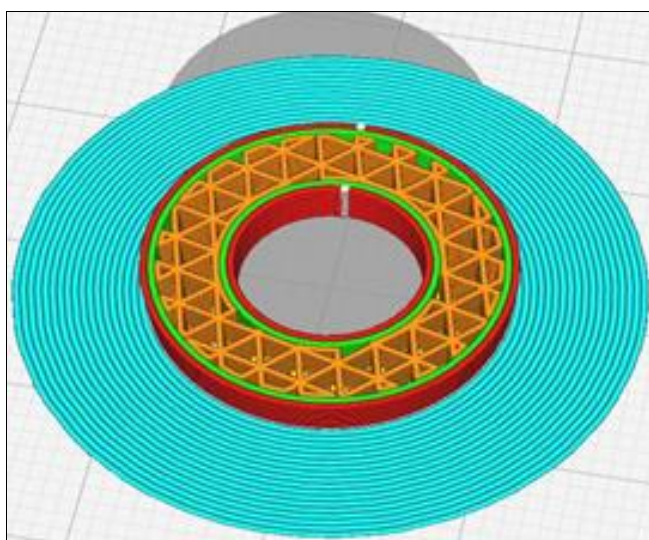


Fig 5: Triangular Infill Pattern for lower part

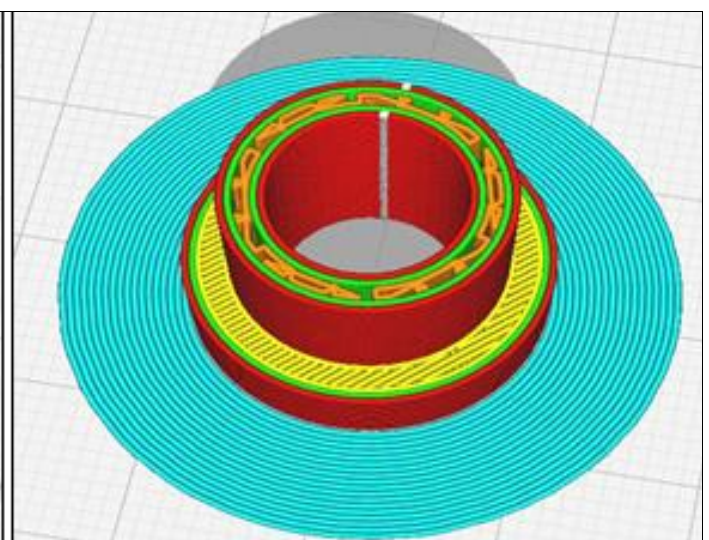


Fig 6: Triangular Infill Pattern for upper part.

For Print A2

For the first print of the model, the infill pattern provided is

gyroid with infill density 50%. The time required for printing was 17mins.

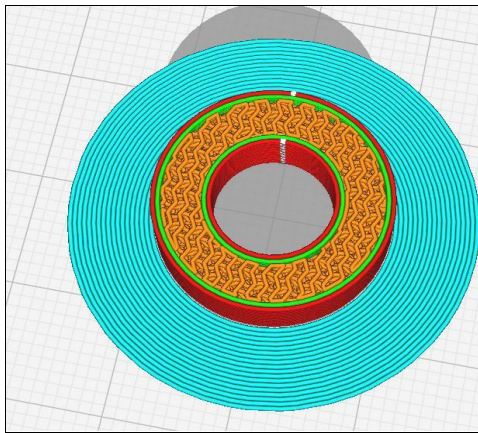


Fig 7: Gyroid Infill Pattern for lower part

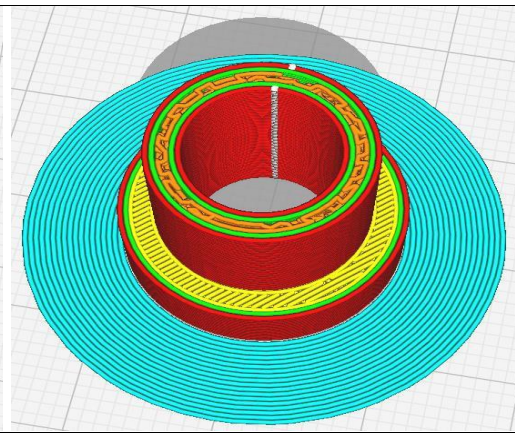


Fig 8: Gyroid Infill Pattern for upper part

Process parameters table

Table 3: Process parameters table

Parameters	A1	A2
Material	PLA	PLA
Scale	125%	125%
Layer Thickness	0.25 mm	0.3 mm
Wall Thickness	0.8	0.8
Density	60%	50%
Infill Pattern	Triangle	Gyroid
Final Printing Temperature	195	185
Brim Width	7	6
Time Required	18 minutes	17 minutes
Weight	4 g	4 g

Results

Bush A1



Fig 9: Bush A1

Bush A2



Fig 10: Bush A2

Conclusion

3D printing is one of the most effective rapid prototyping tools used in industry now a days. Various techniques have been developed so far. From the experiment, we conclude that slight change in process parameters can affect the printing rate and printing quality. For the first bush, the layer thickness was less than the second bush. More the layer thickness, lesser the time required to print, poor the surface finish. Also, the infill density for the first bush is more than that for the second bush. Lower the infill density, lower the time required for printing. The gyroid pattern is more closely packed than the triangular pattern and hence the second bush is denser than the first one.

References

1. Ruben Bayu Kristiawan, Fitriani Imaduddin, Dody Ariawan, Ubaidillah, Zainal Arifin. A review on the fused deposition modeling (FDM) 3D printing: Filament processing, materials, and printing parameters, *Open Engineering*. 2021;11:639–649.
2. Vinod Surange G, Punit Gharat V. 3D Printing Process Using Fused Deposition Modelling (FDM), e-ISSN: 2395 -0056, p-ISSN: 2395-0072.
3. Andrei Danut Mazurchevici, Dumitru Nedelcu, Ramona Popa. Additive manufacturing of composite materials by FDM technology: A review, *Indian Journal of Engineering & Materials Sciences*. 2020 Apr;27:179-192.
4. Kianoush Haghsefat, Liuting Ting. Research status and development trend of 3D Printing and Additive manufacturing technology.
5. Mehtab Alam, Mohd Anas. Improving the Strength of Acrylonitrile Butadiene Styrene Filament Used in the 3D Printer: A Review.
6. Ali Zolfagharian, Mohammad Reza Khosravani, Kif Kaynak. Fracture Resistance Analysis of 3D-Printed Polymers.
7. Dudek P. FDM 3D Printing Technology in Manufacturing Composite Elements, 58.
8. Katarzyna Bryll, Elżbieta Piesowicz, Paweł Szymański, Wojciech Ślącza, Marek Pijanowski. Polymer Composite Manufacturing by FDM 3D Printing Technology, *MATEC Web of Conferences* 237 D2ME; c2018.