

3D Printing Process

Using Fused Deposition Modelling (FDM)

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Abstract - Fused Deposition Modelling (FDM) is an Additive Manufacturing Technology for printing 3D objects layer by layer. The main purpose of the research is to develop a low cost 3D Printer using easily available materials and conventional methods for fabrication which can be used to print objects confined within 300 x 250 x 300 (in mm) Printing Area. Many Industries uses traditional methods for developing prototype for analysis rather than using technologies like 3D printing because it is expensive.

After thorough market survey, we came to a conclusion that 3D Printers available in the Indian market are priced around Rs. 50,000 to 60,000 due to type of supporting material used. Initially we designed our 3D Printer completely in 3D Modelling Software SOLIDWORKS and analysed each part and selected readily available material appropriately so as to develop a cost effective printer. Main objective of research is to develop a printer which is cost effective and to encourage manufacturers to adopt the method of 3D Printing.

Key Words: AM, FDM, PLA, ABS, CAD

1. INTRODUCTION

3D printing (or additive manufacturing, AM) is any of various processes used to make a three-dimensional object. [1] In 3D printing, additive processes are used, in which successive layers of material are laid down under computer control. These objects can be of almost any shape or geometry, and are produced from a 3D model or other electronic data source. A 3D printer is a type of industrial robot. 3D printing in the term's original sense refers to processes that sequentially deposit material onto a powder bed with inkjet printer heads. More recently the meaning of the term has expanded to encompass a wider variety of techniques such as extrusion and sintering based processes. Technical Standards generally use the term additive manufacturing for this broader sense. [1].

1.1 How FDM Works

3D printers that run on FDM Technology build parts layer-by-layer from the bottom up by Heating and Extruding thermoplastic filament. The process is simple:

- **Pre-processing:** Build-preparation software slices and positions a 3D CAD file and calculates a path to extrude thermoplastic and any necessary support material.
- **Production:** The 3D printer heats the thermoplastic to a semi-liquid state and deposits it in ultra-fine beads along the extrusion path. Where support or buffering is needed, the 3D printer deposits a removable material that acts as scaffolding.
- **Post-processing:** The user breaks away support material away or dissolves it in detergent and water, and the part is ready to use.

FDM Benefits

- The technology is clean, simple-to-use and office-friendly
- Supported production-grade thermoplastics are mechanically and environmentally Stable
- Complex geometries and cavities that would otherwise be problematic become practical with FDM technology

FDM, a prominent form of rapid prototyping, is used for prototyping and rapid manufacturing. Rapid prototyping facilitates iterative testing, and for very short runs, rapid Manufacturing can be a relatively inexpensive alternative. FDM uses the thermoplastics ABS, ABSi, polyphenylsulfone (PPSF), polycarbonate (PC), and Ultem 9085, among others. These materials are used for their heat resistance properties. Ultem 9085 also exhibits fire retardancy making it suitable for aerospace and aviation applications. FDM is also used in prototyping scaffolds for medical tissue engineering applications. [4]

1.2 Polylactic Acid (PLA)

We have used 3D Printing filament as Polylactic acid or polylactide (PLA, Poly) which is a biodegradable thermoplastic aliphatic polyester derived from renewable resources, such as corn starch (in the United States), tapioca roots, chips or starch (mostly in Asia), or sugarcane (in the rest of the world). In 2010, PLA had the second highest consumption volume of any bioplastic of the the world. [14] The name "polylactic acid" does not comply with IUPAC standard nomenclature, and is potentially ambiguous or confusing, because PLA is not a polyacid (polyelectrolyte), but rather a polyester. [3]

The skeletal formula for PLA is as shown below

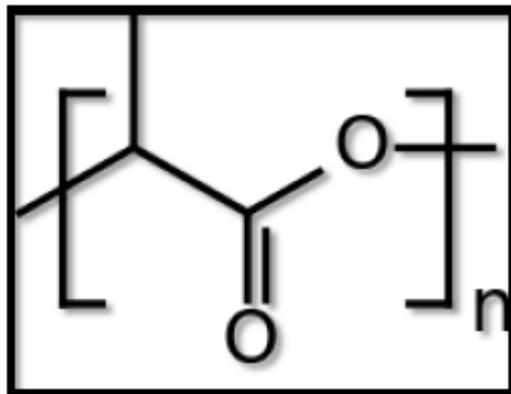


Figure 1: Skeletal Formula for PLA

2. Complete Design and Fabrication of 3D Printer

Complete design of 3D Printer was made taking into consideration the printing area. Fabrication of frame and base along with the other supporting structure was made using low cost and light weight materials.

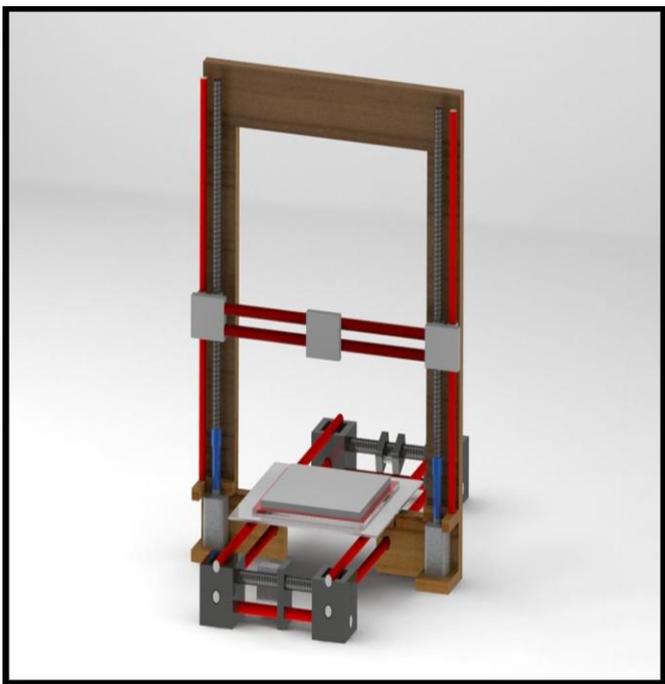


Figure 2: Complete design of 3D Printer

Table -1: part specification

SR.No.	PART NAME	SPECIFICATION	QUANTITY
1	Bolt	12 Inch ID	2
2	Nut	12 Inch OD	10
3	Linear Bearing	8 mm ID,15 mm OD	14
4	Timing Pulley	20 teeth,5 mm inner bore	2
5	Timing Belt	2 mm pitch	2
6	Radial Bearing	8mm X 20mm X 7mm	2
7	Rubber Bush	1 Inch X 1 Inch	4
8	Wooden Ply	250mm X 300mm	1
9	Adhesive Ghe	250 gm	1
10	Nails	2mm OD	50
11	Wooden Plank	35Inch X 40Inch	1
12	Smooth Rod	8 mm OD,5 Feet Length	1
13	Nema 17 motors	45 N.cm Torque	6
14	RAMPS	1.4 Pohnh Shield	1
15	Complete extruder set	0.4 Nozzle tip ID	1
16	Threaded screw	8 mm OD,450 mm Length	2
17	Arduino mega board		
18	Flange net	10 mm ID	2
19	SMPS power supply	12 V,20A	1
20	M-seal	250 gms	1
21	Connecting wire	(F-F)	20
22	Connecting wire	(M-F)	20
23	Limit switches	250 VDC	6
24	Two pin wire		7
25	PLA Spool	1kg	1
26	Acrylic Sheet	250mm X 300mm	1

Table 2: Cost Report

PARTICULARS	COST PER UNIT	QUANTITY	TOTAL COST
12 Inch bolt	25	2	50
Nuts	2.5	10	25
Linear bearing	114	14	1596
Timing pulley	198	2	396
Timing belt	198	2	396
Radial bearing	20	2	40
Rubber Bush	10	4	40
Ply	50	1	50
Fevicol	40	1	40
Nails	10	1	10
Wooden plank	400	1	400
Smooth rod	280	2	560
Nema 17 motors	619	6	3714
RAMPS	1735	1	1735
Complete extruder set	3658	1	3658
Threaded screw	80	2	160
Arduino mega board	1673	1	1673
M10 flange net	816	2	1632
20A Supps power supply	2479	1	2479
M-seal	85	1	85
Connecting wire (F-F)	4	20	80
Connecting wire (M-F)	4	20	80
Limit switches	40	6	240
Two pin wire	10	7	70
PLA Spool	1500	1kg	1500
Acrylic Sheet	100	1	100
TOTAL			20809

3. Printing Process

STEP 1: Part Design in Solidworks

There are various steps involved in the process of printing of a part or model using a 3D Printer. here all the steps involved in the printing process in our 3D Printer are explained in detail.

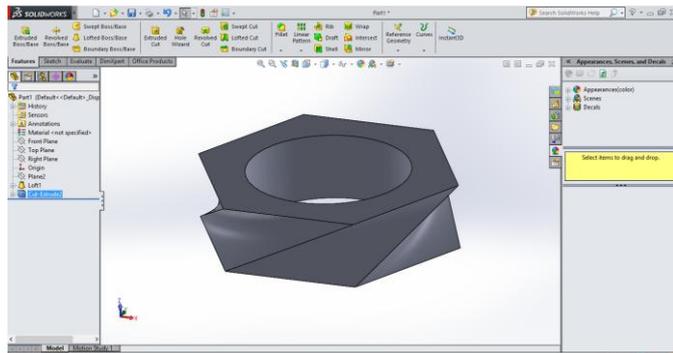


Figure 3: Part design in solidworks

The first and foremost step in the process of 3d Printing is to design the part or model to be Printed in any of the 3D Modelling Softwares such as Pro-E , Catia , Solidworks...etc.

- In our case we had used Solidworks 3D Modelling Software to design a part for example in this case a Twisted Hexagon with a circular cut in between.
- Required dimensions for the part to be printed is decided in the design stage for example the height of this hexagon is 15mm.

STEP 2: Saving the Design in .STL format

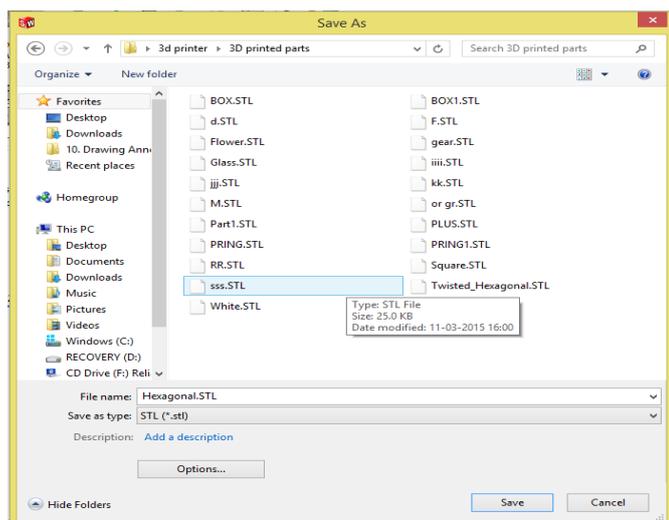


Figure 4: Saving the file in STL format

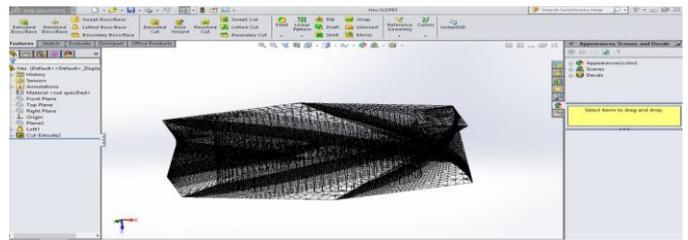


Figure 5: Unstructured Triangular surfaces

- The designed file is saved as .STL format (STereoLithography). This file format is supported by many software packages; it is widely used for rapid prototyping, 3D printing and computer-aided manufacturing.
- An STL file describes a raw unstructured triangulated surface by the unit normal and vertices (ordered by the right-hand rule) of the triangles using a three dimensional Cartesian coordinate system.

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

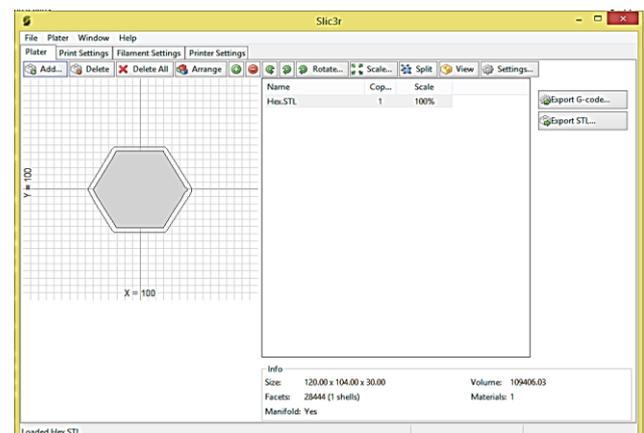


Figure 6: Slic3r Software

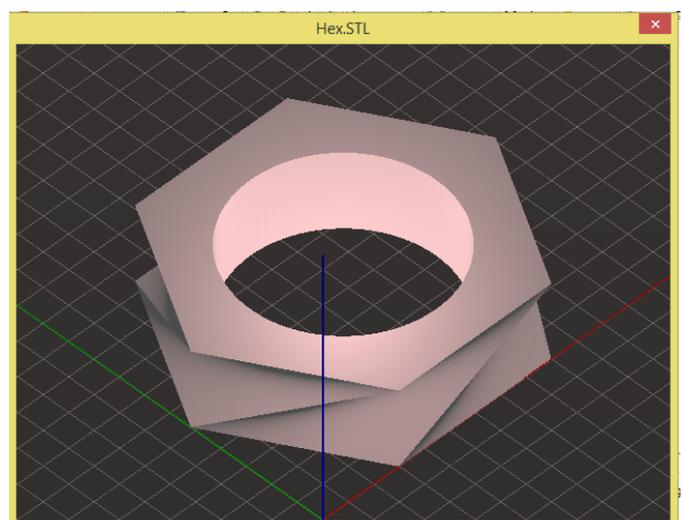


Figure 7: Part Print View

- The .STL file is opened in Slic3r Software where the view of the object or the position in which the object would be printed can be seen.
- After checking the view the G-code of the design in this case a Twisted Hexagon can be generated by clicking on the option 'Export G-Code'.

STEP 4: Importing the G-code file and Printing in Pronterface Software

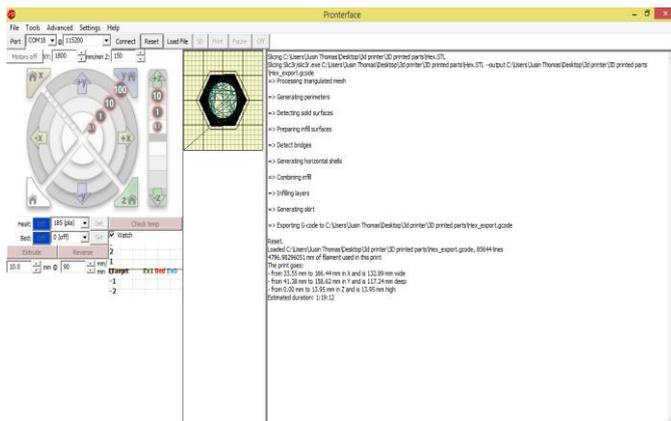


Figure 8: Pronterface Software

- The file created is then loaded in the pronterface which connects Arduino with the computer.
- From the pronterface software we can give print command. The Arduino mega will thus send command to the stepper motor & we get a 3D model.
- Figure above is a snap shot of pronterface software showing the wagon wheel through which the motions of the 3D printer can be controlled.

After printing:



Figure 9: Actual 3D printed object

3. CONCLUSIONS

The intention behind this research was to develop a low cost 3D Printer by using materials which are easily available and cost effective. We have been successful in reducing the cost to a considerable extent i.e about 10-15 %. The parts made in 3D design software are successfully imported in the printing software and the product obtained has the same dimension given during the design stage of the product i.e an accuracy close to 100%. We were able to successfully fabricate the 3D printer according to its virtual design proposed at reduced cost.

REFERENCES

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