

Design and Fabrication of Portable FDM 3D printer

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ABSTRACT:

3D printing is an additive manufacturing technique in which 3D objects are printed layer by layer until the model is complete, each layer is a thin cross-section of the part derived from the original CAD data. In this paper, we have focused on the design and fabrication of a portable and economical 3D printer using the FDM(fused deposition method) technique. In the FDM process we can use a wide range of materials such as ABS, PLA, and composites as well. By heating any of the filament material to its melting point and it is deposited layer by layer a 3D model is built.

3D printing significantly challenges mass production processes and supply chains in the future. This type of printing is predicted to influence industries, like automotive, medical, education, equipment, consumer products industries, and various businesses.

Keywords: 3D Printing, ABS, FDM, Rapid Prototyping.

1. INTRODUCTION:

Additive manufacturing is the formalized term for what used to be called rapid prototyping and what is popularly called 3D printing. The term Rapid Prototyping (or RP) is used in a variety of industries to describe a process for rapidly creating a system or part representation before final release or commercialization. In other words, the emphasis is on creating something quickly and that the output is a prototype or basis model from which further models and eventually the final product will be derived.

Users of RP technology have come to realize that this term is inadequate and does not effectively describe more recent applications of the technology. Improvements in the quality of the output from these machines have meant that there is a much closer link to the final product. Many parts are in fact now directly manufactured in these machines; so we cannot label them as "prototypes." So recently formed Technical Committee within ASTM International agreed that new terminology should be adopted. While this is still under debate, recently adopted ASTM consensus standards now use the term Additive Manufacturing.

The Basic principle of additive manufacturing technology involves, creating a three-dimensional Computer Aided Design (3D CAD) model, and then the part is fabricated using the information of CAD model. Thus this technology does not require process planning. 3D printing needs only some basic dimensional details and a small amount of understanding as to how the 3D printing machine works and the materials that are used.

In 3D printing technology the parts are made by adding material in layers; each layer is a thin cross-section of the part derived from the original CAD data. Obviously in the physical world, each layer must have a finite thickness to it and so the resulting part will be an approximation of the original data, the thinner each layer is, the closer the final part will be to the original.

1.1 Basic process of 3D printing:

3D printing process can be described and defined in the following steps:

➤ CAD Model Creation:

Initially, the item to be 3D printed is designed utilizing a Computer-Aided Design (CAD) software. Solid modelers, for example, CATIA, and SOLID WORKS have a tendency to represent 3-D objects more precisely than wire-frame modelers, for example, AutoCAD. This procedure is comparative for the majority of the Rapid Prototyping building methods.

➤ Conversion to STL Format:

The different CAD models use different methods to present solid parts. To have consistency, the stereolithography format has been followed as the standard of the 3D printing industry.

➤ Slice the STL File:

A preprocessing computer program is done which readies the STL format going to be built. Numerous programs are there, which permit the user to tweak the model. The preprocessing program cuts the Stereolithography model into numerous layers from 0.01 mm to 0.7 mm thickness, in view of the building method. The program likewise makes an auxiliary structure to

help the model amidst building. Sophisticated structures are bound to use auxiliary support.

➤ Layer by Layer Construction:

The fourth step is the actual construction of the part. Using one of various techniques RP machines build one layer at a time from polymers, or powdered metal. Building the part is mainly an automated process and the machine can largely carry on without supervision.

➤ Removal:

Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

➤ Post-processing:

Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation.

2. How FDM process work:

Fused Deposition Modeling (FDM) is an additive manufacturing process. In this process the thermoplastics; which constitute ABS (Acrylonitrile butadiene styrene), wax, and nylon were utilized. FDM uses a heating chamber (V6 J head hotend) to liquefy polymer that is fed into the system which is in the form of filament. The filament is pushed into the chamber by a MK8 Extruder left-hand arrangement and it is this pushing that generates the extrusion pressure.

Then, the 3D printer uses information from a CAD record to create the 3D item layer by layer. It is deposited at the bottom of the printer platform i.e the heatbed, where it solidifies. The next layer that is extruded which fuses with the layer below it, building the object from the bottom to top layer by layer. Most FDM printers first print the outer edges, then the interior edges, and lastly the interior of the layer which is either a solid layer or as a fill-in matrix. In some models, there are fragile 'overhangs' that will droop unless they are given some support.

FDM printers include a mechanism whereby these support structures (struts) are printed along with the object. They are later removed once the object is built complete. These struts are usually of the same material as the object. Some printers have a second extruder to specifically deposit soluble thermoplastic struts when there is a need to prevent the overhangs from drooping.

These struts may be of a different composition than the thermoplastic used for the 3D model. They are later dissolved by an appropriate solvent.

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
- Wide range of raw materials

FDM Limitation

- The main drawback to using this technology is the build speed
- FDM process can sometimes lead to problems with warping and minor shrinking

3. ABS (Acrylonitrile butadiene styrene)

We have used 3D Printing filament acrylonitrile butadiene styrene (abs) which is a thermoplastic. It is an amorphous polymer (These can be defined as **polymers** that do not exhibit any crystalline structures in X-ray or electron scattering experiments) comprised of three monomers, acrylonitrile, butadiene and styrene

ABS material properties.

1. Acrylonitrile provides chemical and thermal stability
2. Butadiene provides toughness and strength
3. Styrene provide glossy finish
4. Abs has low melting points
5. It also has high tensile strength

4. Design and Fabrication of 3D printer

We designed all the parts required for the assembly and dimensions were strictly taken from the internet as we didn't have the kit or manual to find out the original dimensions. Then all the parts are assembled in the Solidworks workbench to create the 3d printer assembly. Here are the real-life pictures, designed model of individual parts, and their working process

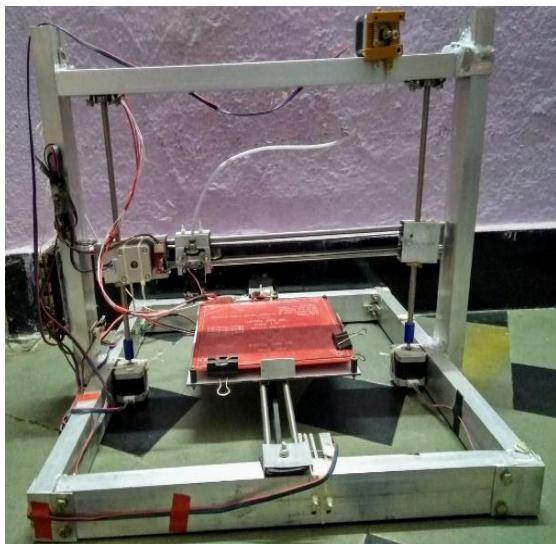


FIG. 1 (A) Fully assembled working 3D printer

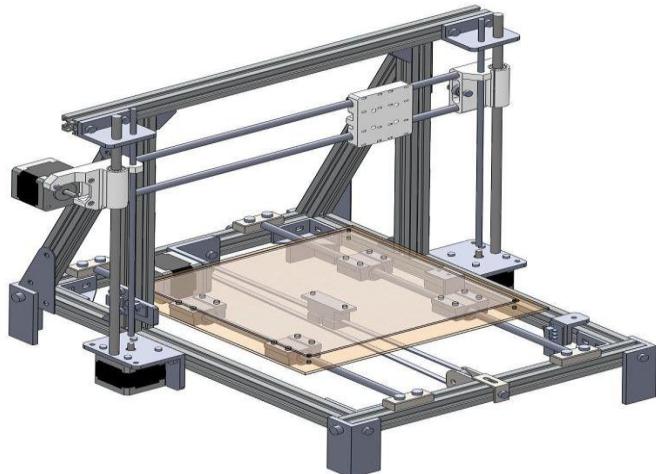


FIG. 1(B) CAD model of 3D printer

Table -1: Part specification

S.N O	PART NAME	SPECIFICATI ON	QUANTI TY
1	Arduino Mega 2560		1
2	Ramps 1.4		1
3	Stepper Motor Driver a4988		4
4	LCD 12864 Smart Controller		1
5	Nema 17 Bipolar Stepper motor	4.2Kg-cm	5
6	Flexible coupling	5*8mm	2
7	Trapezoidal screw with brass nut	8mm OD, 30cm length	2
8	Radial bearing	8*22*7mm	2
9	GT2 timing belt	2m	
10	Pulley		4
11	V6 J head hotend		1
12	SS Smooth rod	Dia 8mm, length 50cm	4
13	Linear bearing LM8UU		8
14	MK2B dual power heatbed		1
15	Mechanical Endstop		3
16	MK8 Extruder left hand		1
17	Power supply	12V 20A 240 W	1
18	ABS Filament	1Kg	1
19	Aluminum channel	160 kg	

Table-2: Cost Report

S.NO	PART NAME	Qty Rate	COST
1	Arduino Mega 2560	1*650	650
2	Ramps 1.4	1*250	250
3	Stepper Motor Driver a4988	4*90	360
4	LCD 12864 Smart Controller	1*800	800
5	Nema 17 Bipolar Stepper motor	5*500	2500
6	Flexible coupling	2*90	180
7	Trapezoidal screw with brass nut	2*350	700
8	Radial bearing	2*75	150
9	GT2 timing belt	2M*80	160
10	Pulley	4*100	400
11	V6 J head hotend	1*750	750
12	SS Smooth rod	4*125	500
13	Linear bearing LM8UU	8*75	600

14	MK2B dual power heatbed	1*750	750
15	Mechanical Endstop	3*90	270
16	MK8 Extruder left hand	1*250	250
17	Power supply	1*900	900
18	ABS Filament	1*1250	1250
19	Aluminum channel	160*6	960
		TOTAL	12,380

5. MECHANISM

5.1 X-axis Movement

Figure 2 shows the mechanism of Lateral movement. It consists of the pulleys, timing belt, carriage, cylindrical rods, and extruder nozzle (used in the FDM process) arranged as shown.

The rotary motion from the motor is converted into linear sliding motion and this linear motion is transferred by timing belt-pulley connection as shown. The extruder nozzle is the main printing part of the machine. For its movement in a horizontal direction, the carriage is provided. The extruder nozzle is mounted onto the carriage on one side, this may result in imbalance and failure of the machine. To avoid this, the carriage is mounted on two rods and designed for balance.

The carriage slides in the horizontal direction over these two cylindrical rods using linear bearings. These cylindrical rods are fixed rigidly with the help of end-stops. The timing belt is mounted on the pulley which is driven by the motor as shown in Fig-2.1 on one side and a support pulley on the other side.



Fig-2: X-axis assembly



Fig-2.1: Assembled X-end motor part

5.2 Y-axis Movement

Figure 3 shows the mechanism for the Y-axis movement. It consists of Carriage, Cylindrical Rods, Pulleys, and Timing Belt arranged as shown. The rotary motion of the motor is converted into linear sliding motion by timing belt-pulley connection as shown. These cylindrical rods are fixed rigidly to the frame. The timing belt is mounted onto the pulley which is driven by the motor on one side and a support pulley on the other side. The carriage is fixed to the lower timing belt of the loop, such that the belt movement results in the movement of the carriage. When the motor rotates in one direction, the carriages are connected to the lower belt in the loop moves from front to back or in the opposite direction depending on the motor orientation. The two motors should be in perfect synchronization for high-quality printing.

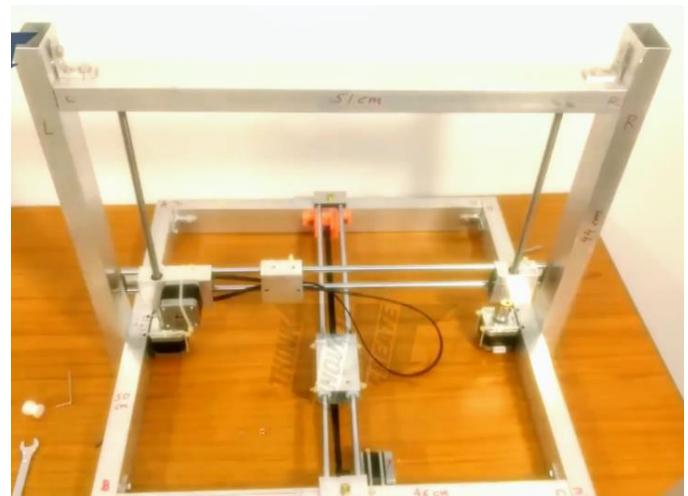


Fig-3: 3D printer frame with Y-axis and Z-axis

5.3 Z-axis Movement

Figure 3 shows the mechanism for the Z-axis movement. It consists of trapezoidal screw with brass nut, radial bearing, flexible coupling.

The rotary motion of the motor is transferred by rotating the leadscrews connected to the motor by using flexible coupling and brass nut.

The Z-axis moves the X-axis up and down the frame. The X-axis traverses the extruder left and right within the frame.

We will see from the figure, Z-axis is controlled by 2 stepper motor. It results in the precise movement of the Z-axis.

6. 3D printing Calibrated Cube

STEP 1: Part Design in NX 11

There are various steps involved in the process of printing 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.

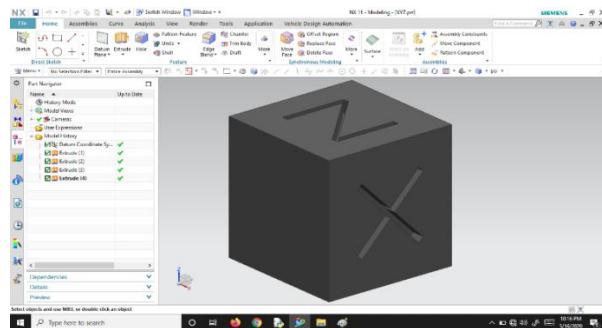


Fig-4: Model design in NX 11.0

Every 3D print begins as a 3D model generated in a modeling program. 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 Modeling Softwares such as Pro-E, NX 11.0, Catia, Solidworks...etc.

- In our case, we had used NX 11.0 Modelling Software to design a part for example in this case an XYZ Calibration cube.
- Calibration cubes are simple geometric shapes X, Y & Z written on it that help you fine-tune your 3D printer's settings. They enable you to achieve maximum precision and accuracy in your prints.

STEP 2: Saving the Design in .STL format

- The next step is to save the model file in .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.

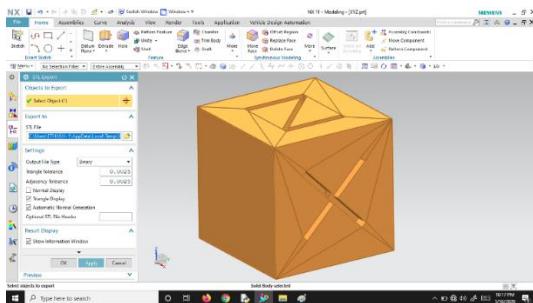


Fig-5: Saving the Design in .STL format

- STL files describe only the surface geometry of a three-dimensional object without any

representation of color, texture, or other common CAD model attributes.

- The main purpose of the STL file format is to encode the surface geometry of a 3D object. It encodes this information using a simple concept called "tessellation" (A process of tiling a surface with one or more geometric shapes especially triangles such that there are no overlaps or gaps).

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

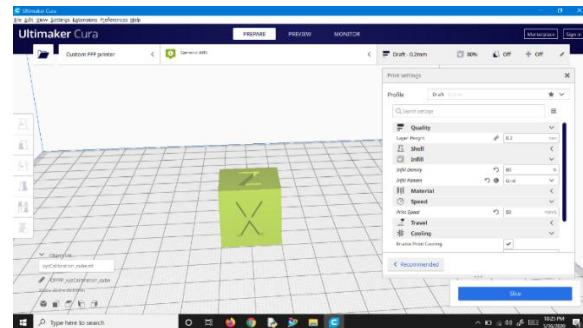


Fig-6: Ultimaker Cura Software

The .STL file is opened in Ultimaker Cura Software, Cura slices your models ready for print. You can do any changes required for a 3D

- printer using printer settings. We can change settings according to what we want to print by changing a few quality, infill, shell, and speed options.
- Then the G-code of the design is generated by clicking on the option 'Export G-Code'.

STEP 4: Importing the G-code file in G-code interpreter (Pronterface)

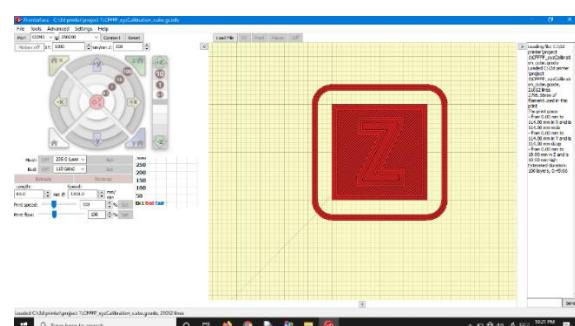


Fig-7: Pronterface Software

- The G-code file is then loaded in the pronterface software which connects Arduino with the computer.
- The G-code interpreter reads each line of the file that sends to actual signals to the motor for moving the devices symmetrically
- Firmware on a printer electronic platform will be integrated into hardware interpreter

7. Result

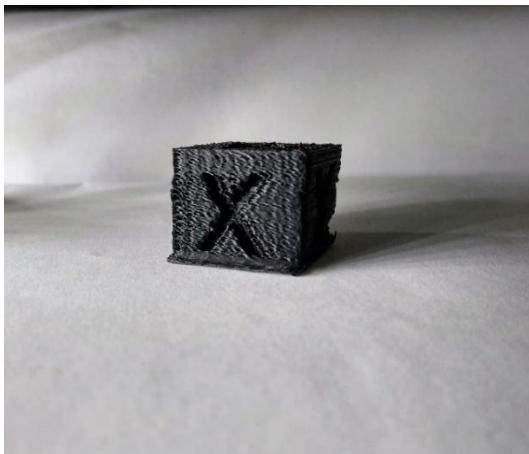


Fig-8: Actual 3D printed part

Table-3:- Machine Specifications

Build Volume	200mm*200mm*200mm
Method	Fused Deposition Modeling
Layer Resolution Height	100 microns
Number of Extruders	One
Machine Size	510mm*510mm*435mm
Machine Weight	5.1 kg
Power Supply	DC 12V, 30amp
Connectivity	USB, SD
Filament Diameter	1.75mm
Nozzle Diameter	0.25 mm
Filament Material	PLA, ABS, Thermoplastics
Print File Type	Gcode, STL, Obj

8. Future potential of 3D printing

1. It is predicted that dentistry has a great case for converting 80% plus of the means of production to an additive technology
2. Metal 3D printing will grow at a faster rate
3. A SmarTech analysis report estimates that composite 3D printing will grow into a nearly \$10 billion business within the next decade (Composites are lightweight, strong materials, highly sought-after in industries like aerospace, automotive, oil and gas and industrial goods).
4. Additive manufacturing is leading the way in the digital transformation of Industry 4.0. Rather than stocking a warehouse full of parts that consume mass quantities of space, Additive manufacturing condenses and converts the physical space into a digital file that can be stored.
5. The market for medical 3D printing, including materials, services, software and hardware, is currently estimated to be worth \$1.25 billion

6. The orthopedics 3D printing market was valued at \$691 million in 2018 and is predicted by SmarTech Analysis to grow into a \$3.7 billion market by 2027.

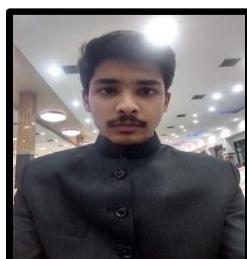
9. CONCLUSION:

This research aimed to build a portable 3D printer that has been successfully accomplished. The design of the frame is made robust and compact using aluminum sections. The material selected for the various elements are economical. The part printed has the same dimension given during the design stage. In this paper, we have also discussed some of the future potential, Considering the recent progress of the technology and these expert predictions, 3D printing is headed for a bright future of digital, smart manufacturing.

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