Build a Delta three-dimensional printer using Fused Deposition Modeling Technology and it's efficacy in various aspects

A DISSERTATION
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE
OF

MASTER OF SCIENCE

IN

PHYSICS

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CANDIDATE'S DECLARATION

We, YASH YADAV (2K21/MSCPHY/54) and GOPAL SAINI (2K21/MSCPHY/14), students M.Sc. (Physics), hereby declare that the project Dissertation titled "Build a Delta three-dimensional printer using Fused Deposition Modeling Technology and it's efficacy in various aspects" which is submitted by us to the Department of Applied Physics, Delhi Technological University. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi

Date: 31 May 2023

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CERTIFICATE

We hereby certify that the Project Dissertation titled "Build a Delta three-dimensional printer using Fused Deposition Modeling Technology and it's efficacy in various aspects " which is submitted by, YASH YADAV (2K21/MSCPHY/54) and GOPAL SAINI (2K21/MSCPHY/14), Department of Applied Physics, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the students under our supervision. To the best of our knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date: 31 May 2023

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YASH YADAV

GOPAL SAINI

CONTENTS

LIST OF FIGURES

Abstract

Three-dimensional printing is an additive manufacturing process that produces a physical object from a digital design by interacting mechanical power with digital intelligence. This additive manufacturing process works on the principal to lay down thin layers of material and fuse them to get the desired structure. Three-dimensional printers used nowadays are in developing phase and many challenges are associated with them such as the dimensions of Delta Three-dimensional printer are quite large especially its height, which cause unsuitability and vibration while operation. Error detection of Three-dimensional printers are also very difficult due to their complex structure. In this research work, a Hybrid Delta Three-dimensional printer is developed to overcome challenges / disadvantages of Three-dimensional printers.

The Hybrid Delta three-dimensional printer utilises a process of stacking and fusing layers of various materials to create three-dimensional objects. It can produce more complicated geometries than conventional three-dimensional printing technologies , is relatively quick, has low setup cost, and works with a enormous expanding range of materials . This developed Delta Three-dimensional printer has many advantages and will be used extensively in the engineering industry, its application includes prototyping and execute ideas into reality. In designing of Delta Three-dimensional printer, three stepper motor was used to move various parts of Delta Three-dimensional printer which provide more degree of freedom to our extruder to use all axis movement together to reduce time and cost.

CHAPTER-1

1. INTRODUCTION OF THREE - DIMENSIONAL PRINTER

The operation of Three-dimensional printers consists of lay down thin layers of material and then fuse the layers together, this operation is repeated till desired structure is obtained. In this research a Delta Three-dimensional printer is developed which has many advantages. It can produce more complicated geometries than conventional three-dimensional printing technologies, is relatively quick, has low setup cost, and works with a enormous expanding range of materials. Delta Three-dimensional printer has found a number of applications in engineering industry is commonly used in the engineering field, especially for prototyping. A hybrid Delta three-dimensional printer is developed to print computational design of structures formed by using finite element-based software like Fusion 360, Meshmixer, PowerMill, Unity, Adobe Dimension etc. Nowadays, the Cartesian Fused deposition modeling three-dimensional printer is market leading [1]. The major disadvantages of the board include (i) it takes a long time to print (ii) difficult to modify due to spatial restrictions (iii) there is no instant change of direction because only one axis is used at a time (iv) accuracy is constant (v) it cannot be altered, which making it ineffective for nano-printing. The Delta Three-dimensional printer is developed on three principles, (a) speeding up the printing process (b) making complicated structures more approachable (c) improving precision when creating nano-structures. [2] Section 2 depicts the construction of Delta Three-dimensional printer.

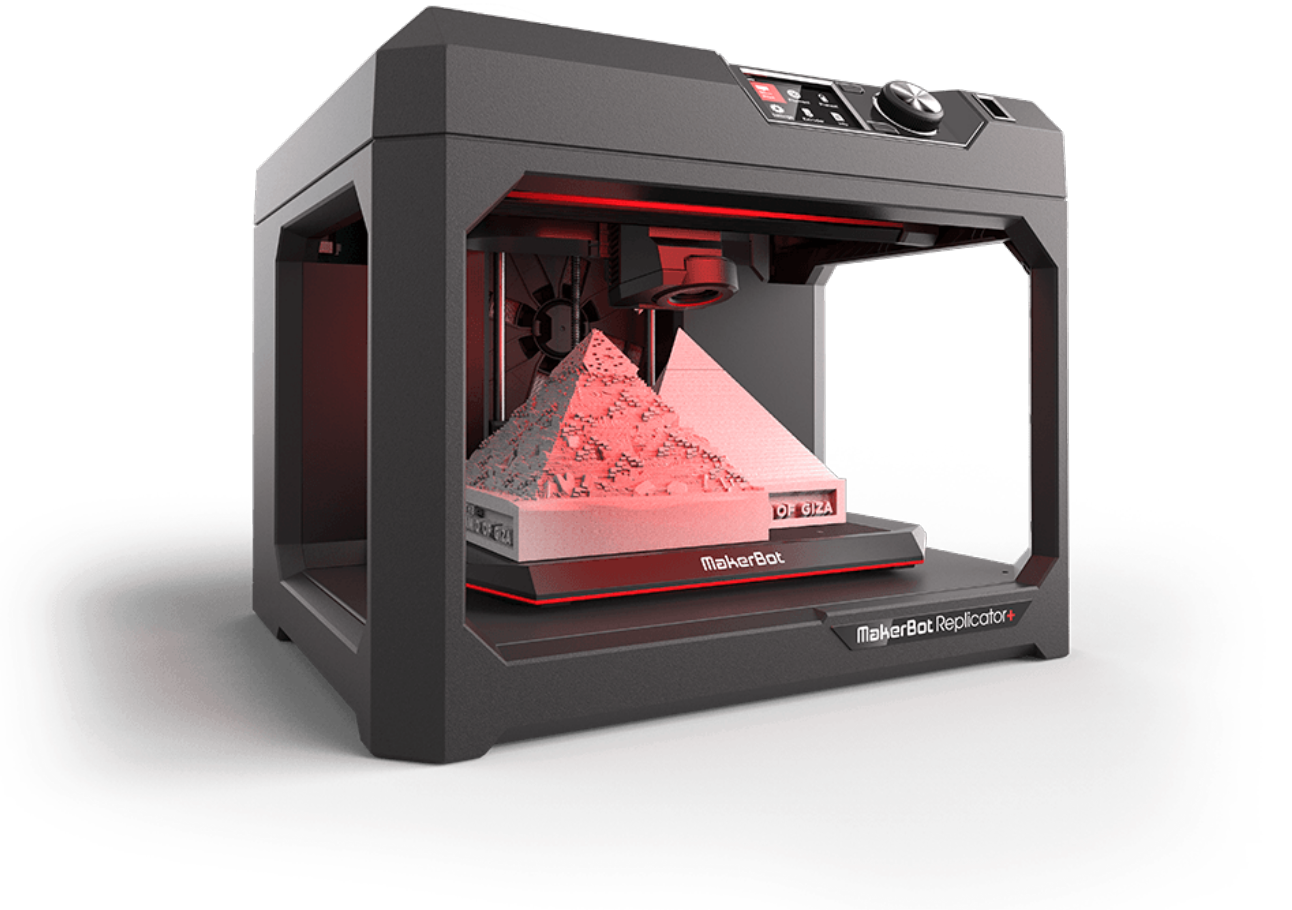


FIG 1 :-three-dimensional printer

1.1 Additive vs traditional manufacturing

Since the 1980s, additive manufacturing has emerged as a prominent method, leading to the conventional manufacturing methods developed and employed prior to that era being commonly known as traditional manufacturing. To distinguish between additive manufacturing and traditional manufacturing, we can classify all methods into three categories: additive, subtractive, and formative manufacturing.

1.1.1 Additive Manufacturing

Additive manufacturing constructs three-dimensional objects by progressively depositing and fusing layers of material.

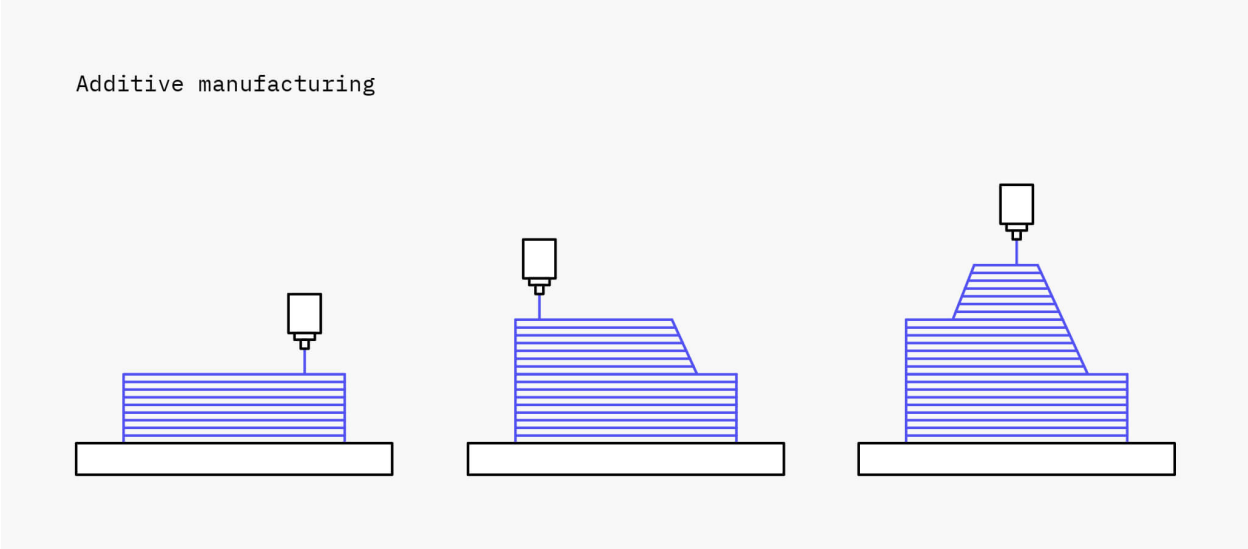


FIG 2 : Additive manufacturing

1.1.2 Subtractive manufacturing

Subtractive manufacturing, such as milling or drilling and turning, creates objects by removing material from a block of solid material.

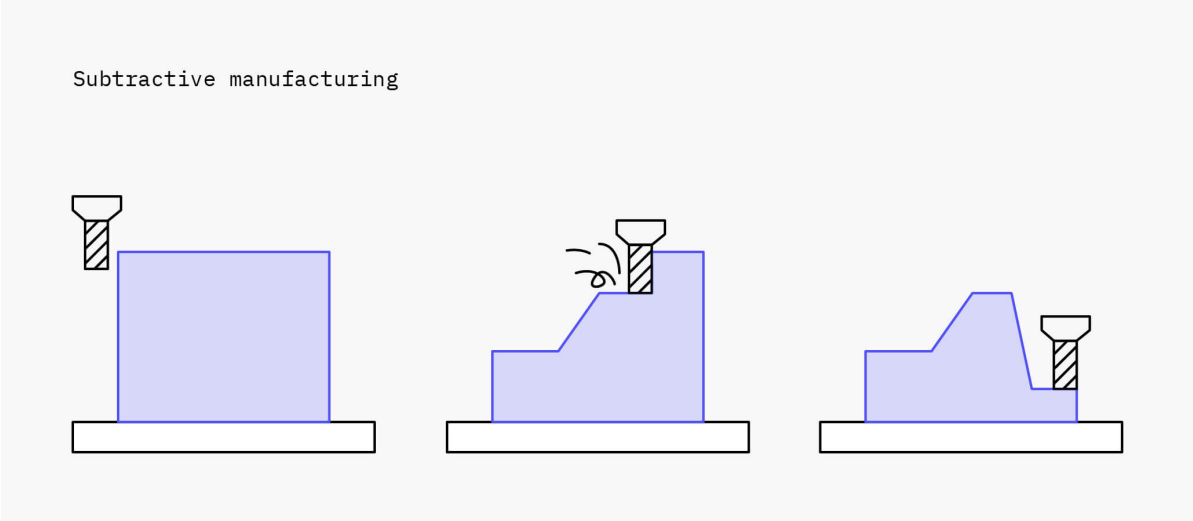


FIG 3 : Subtractive manufacturing

1.1.3 Formative manufacturing

Formative manufacturing, including techniques like injection molding and stamping, involves shaping materials by subjecting them to heat and pressure within a mold, resulting in the desired object's formation or molding.

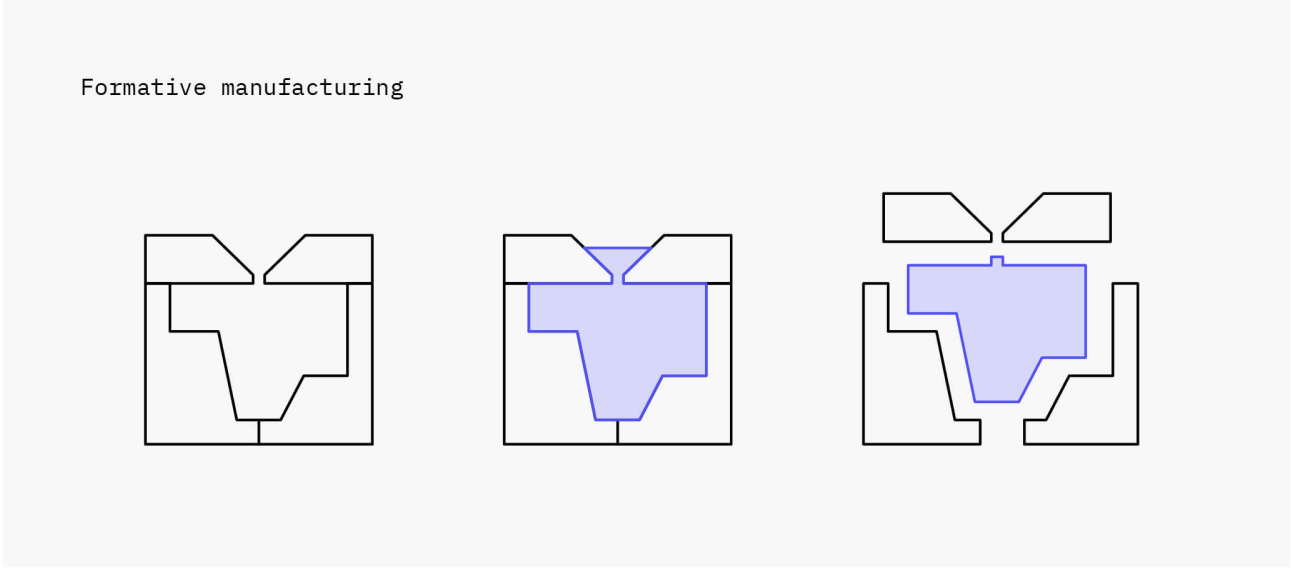


FIG 4 : Formative manufacturing

CHAPTER-2

2. Types of three-dimensional printer

The present and future of three-dimensional printer are very developing so it is very hard to distinguish between but still on basis or techniques used to fuse material to create structure. Three-dimensional printers can be classified into various types of processes:

1. **Vat Polymerisation:** In this process, a liquid photopolymer is cured using light.
2. **Material Extrusion:** This method involves depositing molten thermoplastic through a heated extruder.
3. **Powder Bed Fusion:** The process includes fusing powder particles together using a high-energy source.
4. **Material Jetting:** Droplets of a liquid photosensitive agent are deposited onto a powder bed and cured with light.
5. **Binder Jetting:** Liquid binding agent droplets are deposited onto a bed of granulated materials, which are then fused together.
6. **Direct Energy Deposition:** Molten metals are simultaneously stacked and deposited to fuse them together.
7. **Sheet Lamination:** Individual sheets of material are cut into shape and then laminated together.

2.1 Material Extrusion or Fused Deposition Modeling (FDM)

Material extrusion technologies involve the process of pushing a material through a nozzle onto a build plate, layer by layer. The most commonly utilized three-dimensional printing technology within material extrusion is Fused Deposition Modeling (FDM).

2.2 Types of Material Extrusion or Fused Deposition Modeling (FDM)

- Delta FDM Printers
- Cartesian FDM three-dimensional Printers
- Polar three-dimensional FDM Printers
- FDM three-dimensional Printing with Robotic Arms
- Hybrid three-dimensional printers

2.2.1 Delta FDM Printers

Fused Deposition Modeling (FDM) printers are a popular and widely used type within the three-dimensional printing market. They operate based on Cartesian coordinates. These printers feature a circular printing plate combined with an extruder fixed at three triangular points, which is why they are referred to as 'Delta' printers. Each of the three points can move up, down, left, and right independently, enabling the determination of the position and direction of the print head.

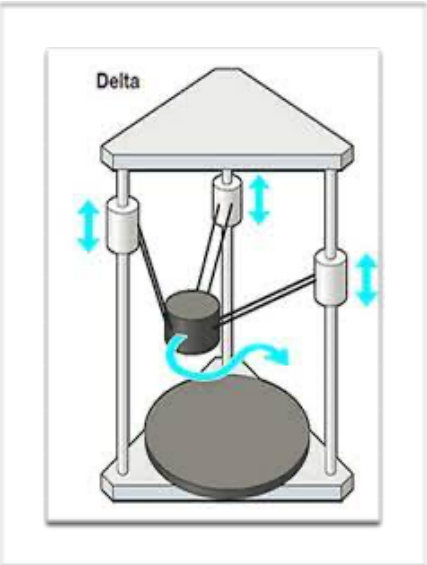
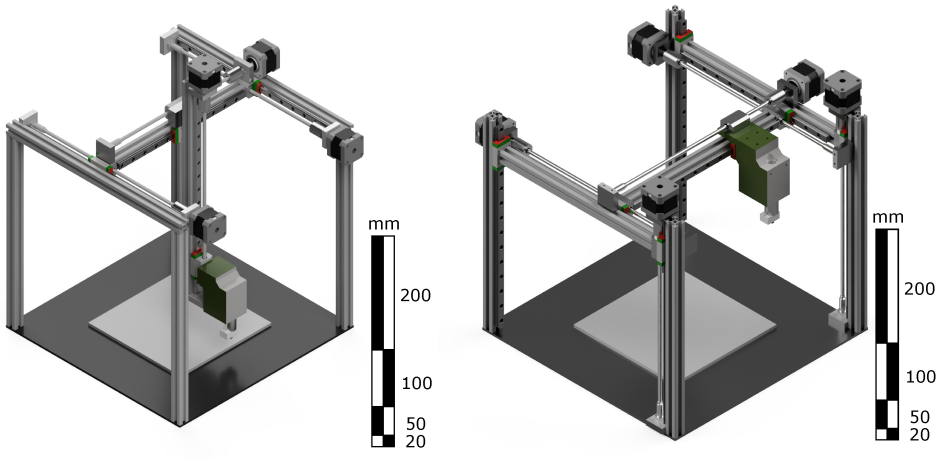


FIG 5 : Delta FDM Printers

2.2.2 Cartesian FDM three-dimensional Printers

The Cartesian 3D printers are the prevalent type of Fused Deposition Modeling (FDM) three-dimensional printers available in the market. Drawing inspiration from the Cartesian coordinate system in mathematics, this technology employs three orthogonal axes (X, Y, and Z) to accurately determine the positions and direction of the extruder. By adjusting the axes according to the desired dimensions, the extruder can be positioned along the X and Y axes, enabling movement in four directions.



(a) (b)

FIG 6: Cartesian FDM three-dimensional Printers

2.2.3 Polar three-dimensional printers

Polar three-dimensional printers differ from Cartesian printers in terms of their positioning mechanism. Instead of using X, Y, and Z coordinates, polar printers utilize an angle and length to determine the positioning. The coordinate system defines points on a circular grid rather than a square one. In this system, the base rotates and moves simultaneously while the extruder moves up and down. These printers are particularly well-suited for objects that have a spiral structure.

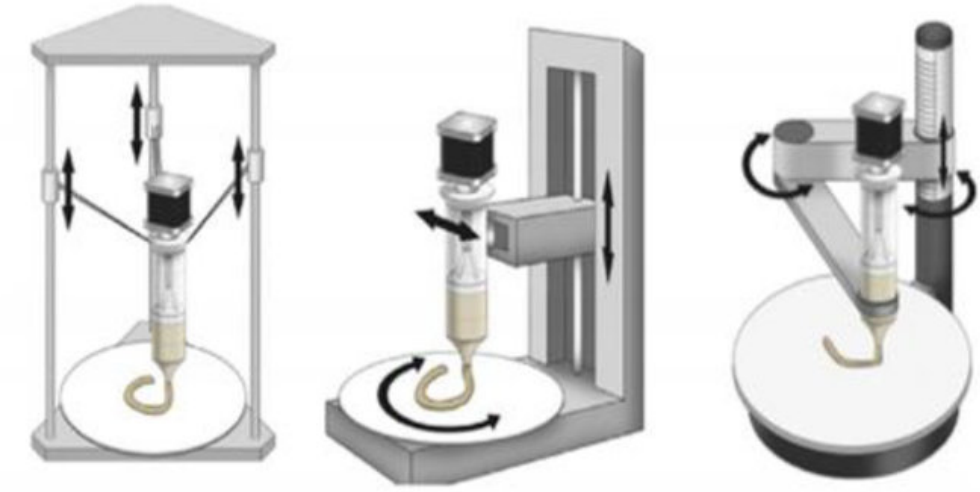


FIG 7: Polar three-dimensional printers

2.2.4 FDM three-dimensional Printing with Robotic Arms

Robotic arms are extensively employed in industrial production, particularly in large automotive plants, for the assembly of line components. On the other hand, three-dimensional printing has incorporated robotic arms into its production process, where their movement is classified into three dimensions (X, Y, Z). This is particularly notable in the three-dimensional printing of massive structures and buildings. However, it is important to note that this technology is currently in the developmental stage, undergoing ongoing advancements and improvements.

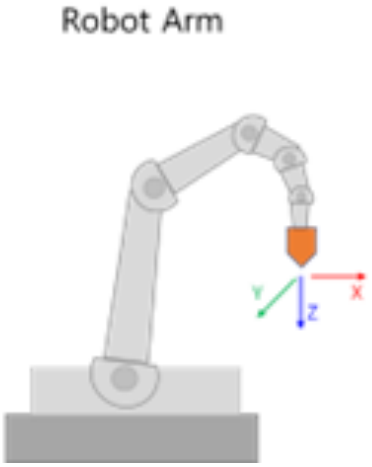


FIG 8: FDM three-dimensional Printing with Robotic Arms

2.2.5 Hybrid three-dimensional printers

Hybrid manufacturing refers to the integration of additive three-dimensional printing and subtractive methods within a single setup. These printers enable the interchange of tools for the creation of models. In the context of Fused Deposition Modeling (FDM) three-dimensional printers that incorporate subtractive heads, many of them are built with a Cartesian structure.

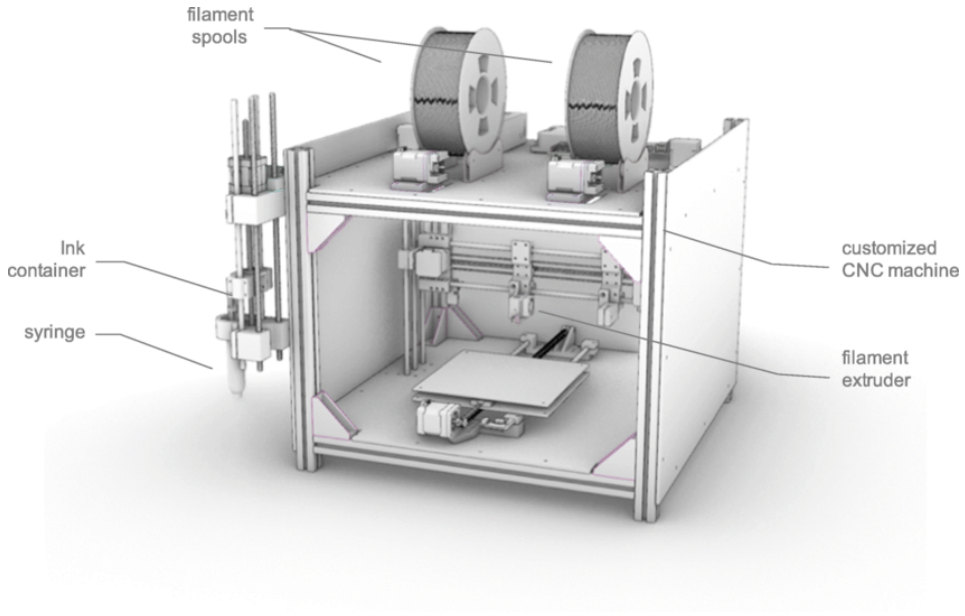


FIG 9: Hybrid three-dimensional printers

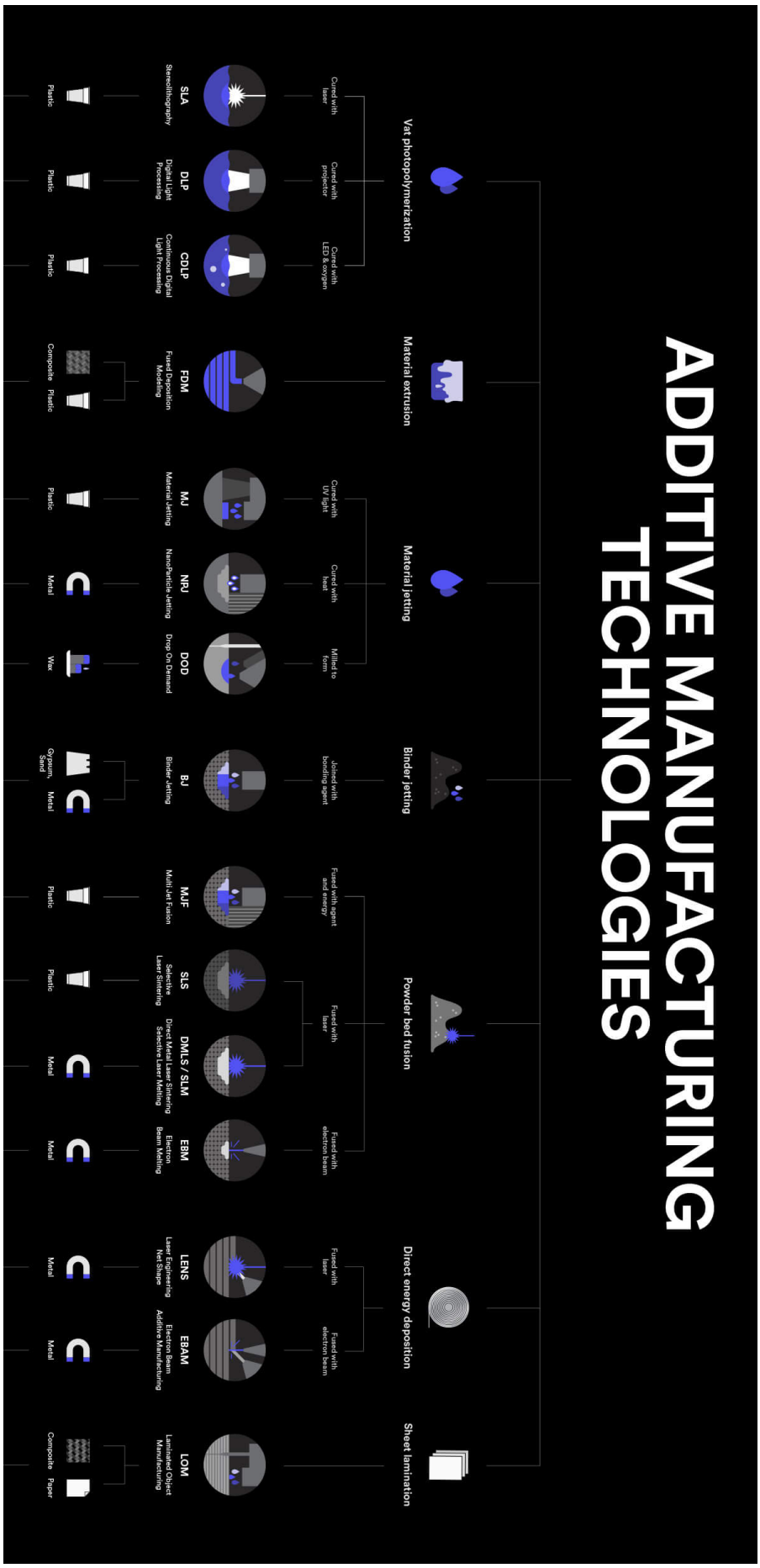


FIG 10 : Types of three-dimensional printer

CHAPTER-3

3. CONSTRUCTION OF DELTA three-dimensional PRINTER

The construction / Design of Delta Three-dimensional printer consist of three components i.e. Mechanical , Electrical and Computational (programming) . These components are described in details in this section .

3.1.1 Mechanical build

To construct the model of Delta Three-dimensional printer materials such as Wood and Steel were selected. Wood is a preferred material due to its ease of manipulation and adaptability, while steel is often chosen for its cost-effectiveness and widespread availability.

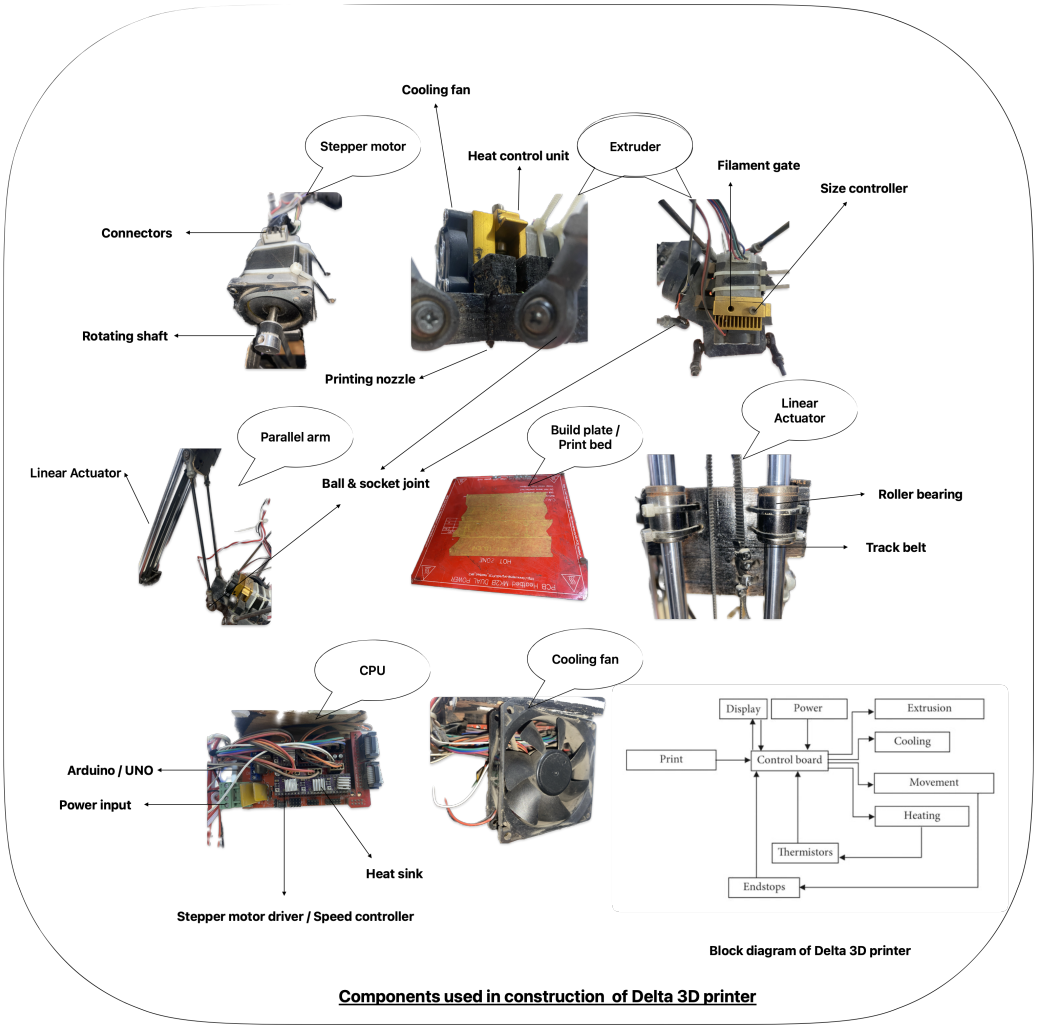


Fig.11. Components used in construction of Delta 3 dimensional printer

To construct Delta Three-dimensional printer devices and components were purchased . includes Frame Parts , Build plate / Print bed , Parallel arms , Cartridge , Screws and bolts , Rotating rims , Ball socket assembly , Medium density fibreboard (MDF).

The base model of Delta Three-dimensional printer is made by wood. The wood panels were cut in accordance with the blueprints to construct the printer's base, roof, hinges, and head, as well as the cavities required to pass the wires and attach the End-stop switch. The three stepper motors are then mounted in the machine's ceiling, the brake's end, and the printing material carrier. Further, all the openings were filled with plastic boards, and the basis axes, X, Y, and Z are created using steel bars. The printer's head is attached to the parallel arms, and then the extruder is screwed to the hinges. Each of the three sides' arms come together in the centre, where the extruder is attached. Finally, the stepper motors and linear actuator are linked to the belts. The final assembly of Delta Three-dimensional printer is shown in Fig.3 [3].

3.1.2 Electrical build

To operate mechanically assembled Delta Three-dimensional printer parts, electronic components are required, which consists of four Stepper Motors, Touch screen, Arduino (UNO), Motor drivers, Extruder, Blow fan, End-stop switches, Heatsink, Temperature sensor.

Further the three-stepper motor were positioned at X, Y and Z axes along with motor driver on the Arduino panel, the End-Stop switches were attached to the Arduino panel along X, Y and Z axes, LCD screen, power supply was connected to Arduino panel. The programming was done on the Arduino to operate Delta Three-dimensional printer.

3.1.3 Programming for printing process

The printing process will be executed by three selected programs.

Firstly, the Marlin firmware were installed which controls the motion of the printer along X, Y and Z axes. Initially, the dimensions and measurements of Delta Three-dimensional printer were entered, including its kinematics, steps per millimetre and extruder temperature. Secondly the CAD

(Computer-aided design) model of structure which is to be printed attached with the Delta Three-dimensional printer via “Repetier-Host”. Finally, the “Repetier-Host” amendment the structure in the form of printed layer through G-Code. Marlin firmware understand G-Code and print Three-dimensional structures [2].

CHAPTER-4

4. Working principle of Delta three-dimensional Printers

Delta three-dimensional printers use the Cartesian coordinate system which consists of three axes X, Y and Z to deposit or extrude the filament. The three arms in this system are interconnected using Ball-and-socket joints, and each arm is constructed as a parallelogram. By adjusting the angles of the parallelograms, these arms have the capability to move from one specific X or Y point to another. [7]. The arms are suspended down from a fixed platform or linear actuator which helps to gain the stability and linearity in system for better precision. Mechanics that drive or moves the motion of arms are fixed in that platform. the print head or the base of the Delta three-dimensional printer is quite lighter. This reduced weight helps to reduce the inertia of Delta three-dimensional printer by reducing inertia, the end movement at the production head or at the point of contact respond quickly, while retaining its accuracy.

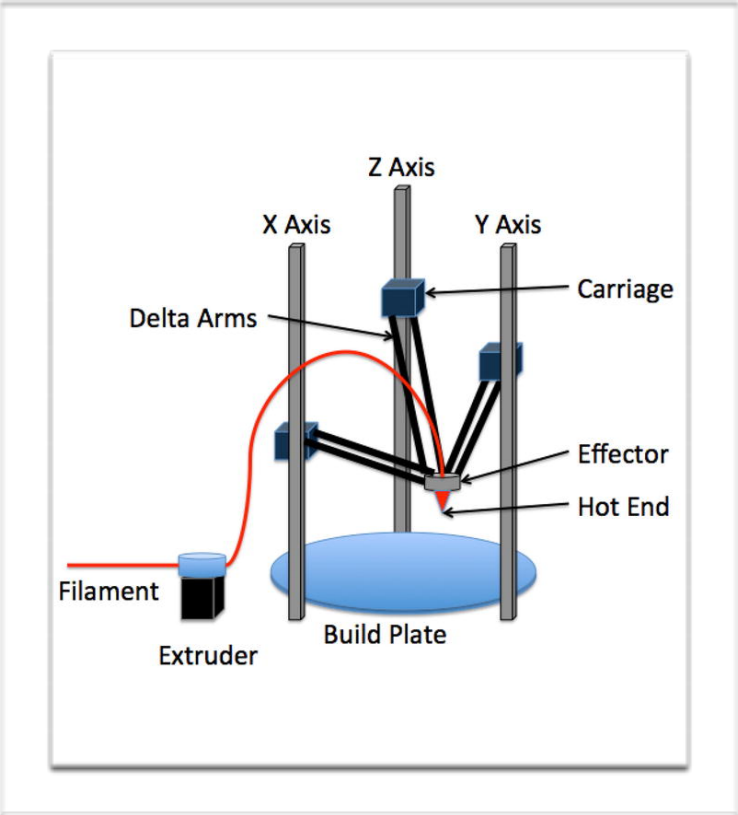


FIG 12: Mechanical structure of Delta Fused Deposition Modeling three-dimensional Printers

4.1.1 Extruder

The extruder is the most important part of a three-dimensional printer where material changes its state from solid to liquid and further solidify and take a shape .The material is deposited or laid in successive layers onto a base pad, following the dimensions of the setup. The setup typically includes components such as a stepper motor, heat sink, fan, hot end, and nuts and bolts that are utilized to secure the assembly together.
You could build a multi-coloured piece or a piece that contains more than one type of plastic without changing the filament

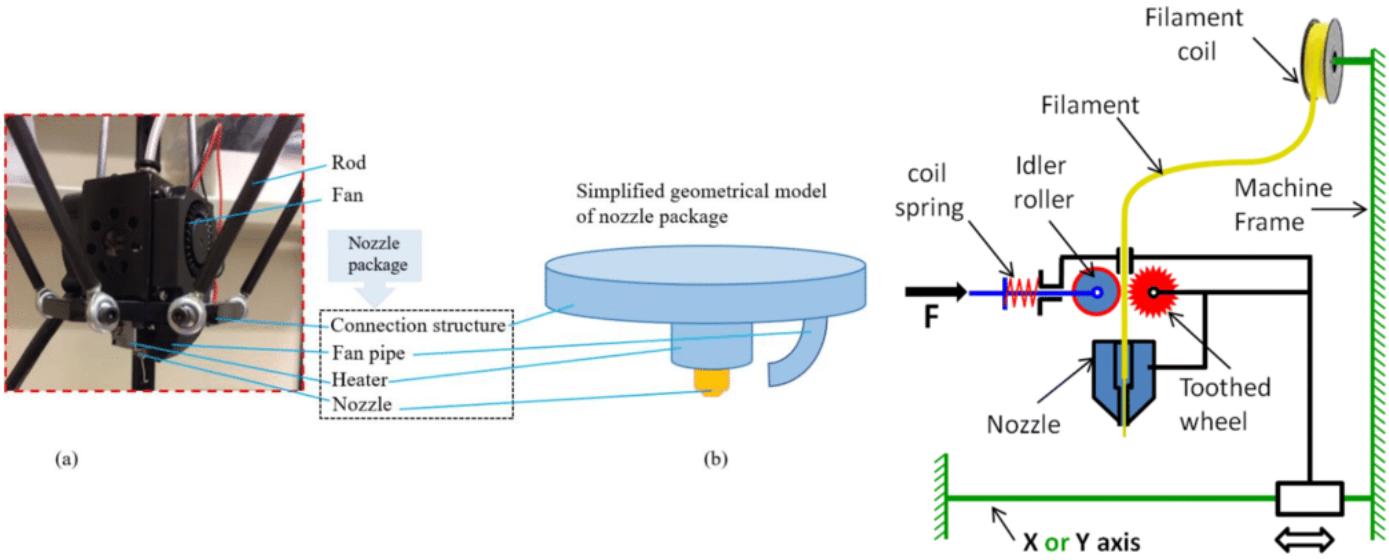


FIG 13: Extruder

4.1.2 Arduino (UNO)

The Arduino UNO is a fundamental board in the Arduino platform, serving as the motherboard for Arduino devices. The name "UNO" signifies 'one' in Italian. It features a microcontroller that acts as the processor and handles all logical and digital functions. To facilitate programming and customization, dedicated configuration software is available for the Arduino UNO. This board is highly powerful and often serves as the central processing unit in various projects.

Arduino UNO is built around a microcontroller and is designed to be user-friendly. Its configuration can be easily adjusted according to specific requirements, similar to other Arduino boards like the Arduino Mega. The board includes digital and analog Input/Output pins, shields, and additional circuits to support various functionalities.

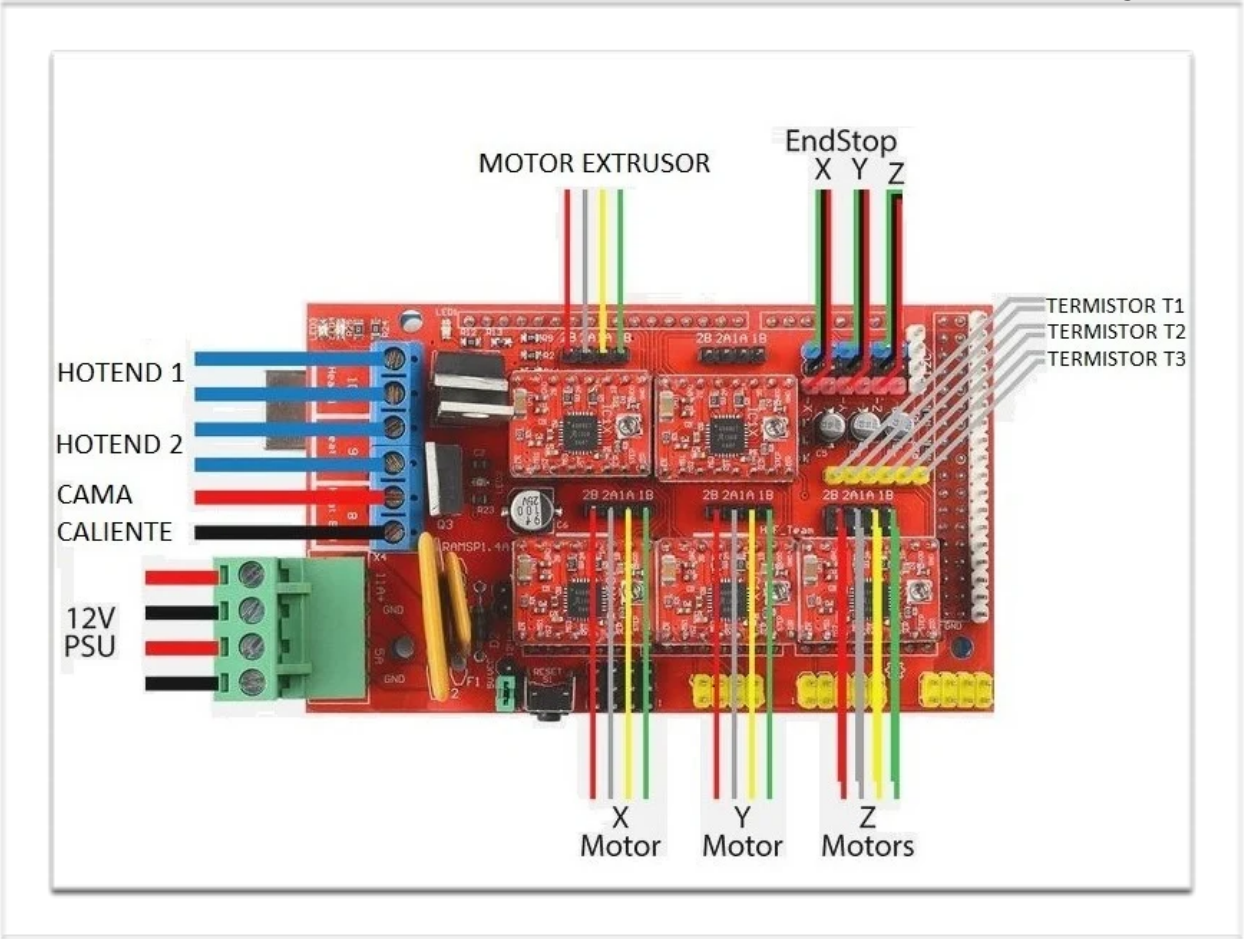


FIG 14: Arduino (UNO)

4.1.3 Software control

The set of several electronic and mechanical hardware are combined together to perform a set of work but here comes the role of control that how our system communicate with digital data to hardware via electrical pathway .

These kind of communications are highly complex and made any system such that it is quite complex to work upon it , as our Vision is to avail three-dimensional printers to give a shape of several innovative ideas which are ready to have a shape .

We comes up with several software which helps to communicate in much simpler way , hare we use

- **Repetier host for the controls of our Delta printer.**

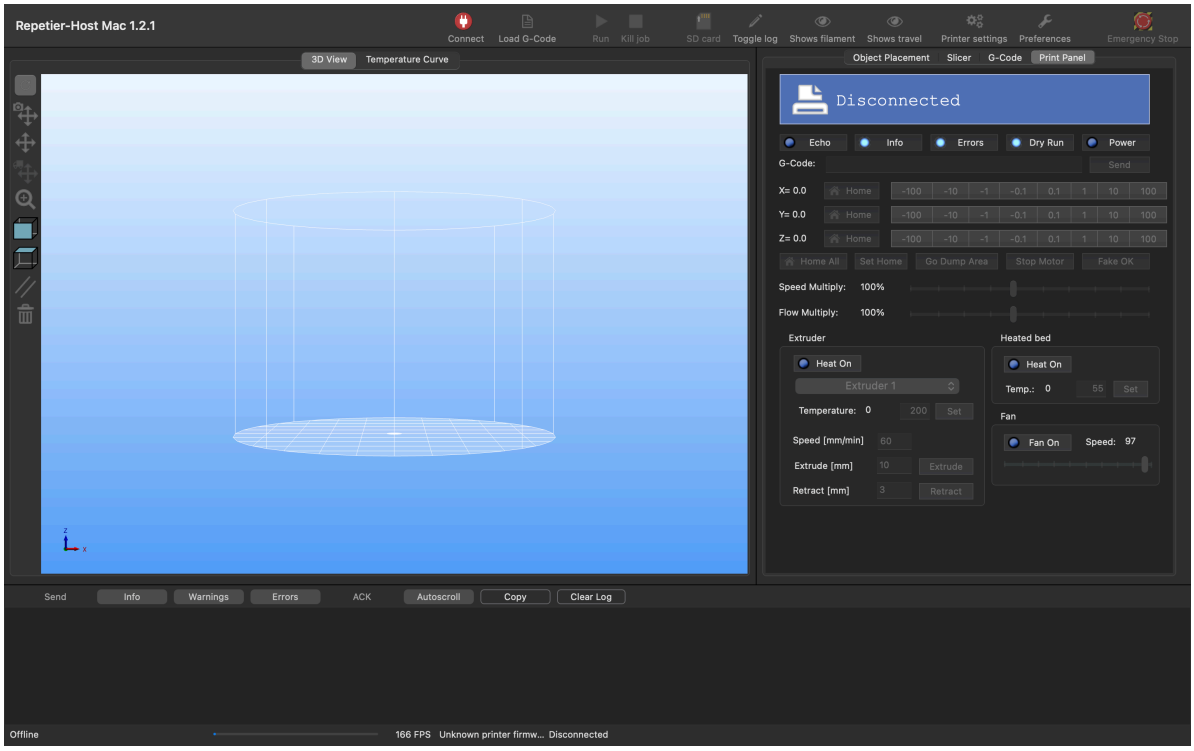


FIG 15: Repetier host (Version 1.2.1 (106))

- **Fusion 360 for give digital shape to our imagination**

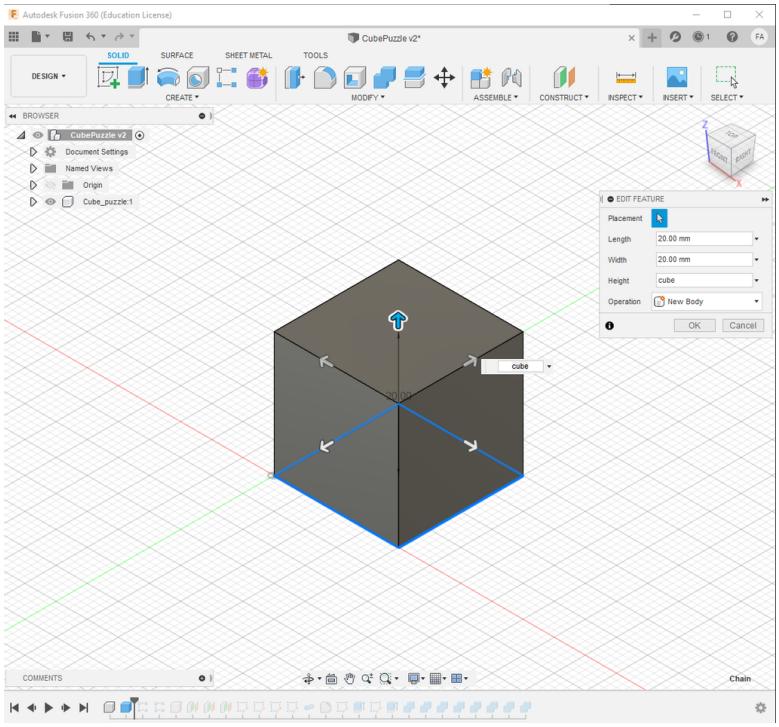


FIG 16: FUSION 360

4.1.4 Print

All commands and data to give a shape to our material , our printer starts by identifying the position of extruder and start forming a base line to the structure as provided after slicing and the repetitive depositing of material over and over takes some time depends on the shape and size of structure , the finalised product is ready after the printing process is done .

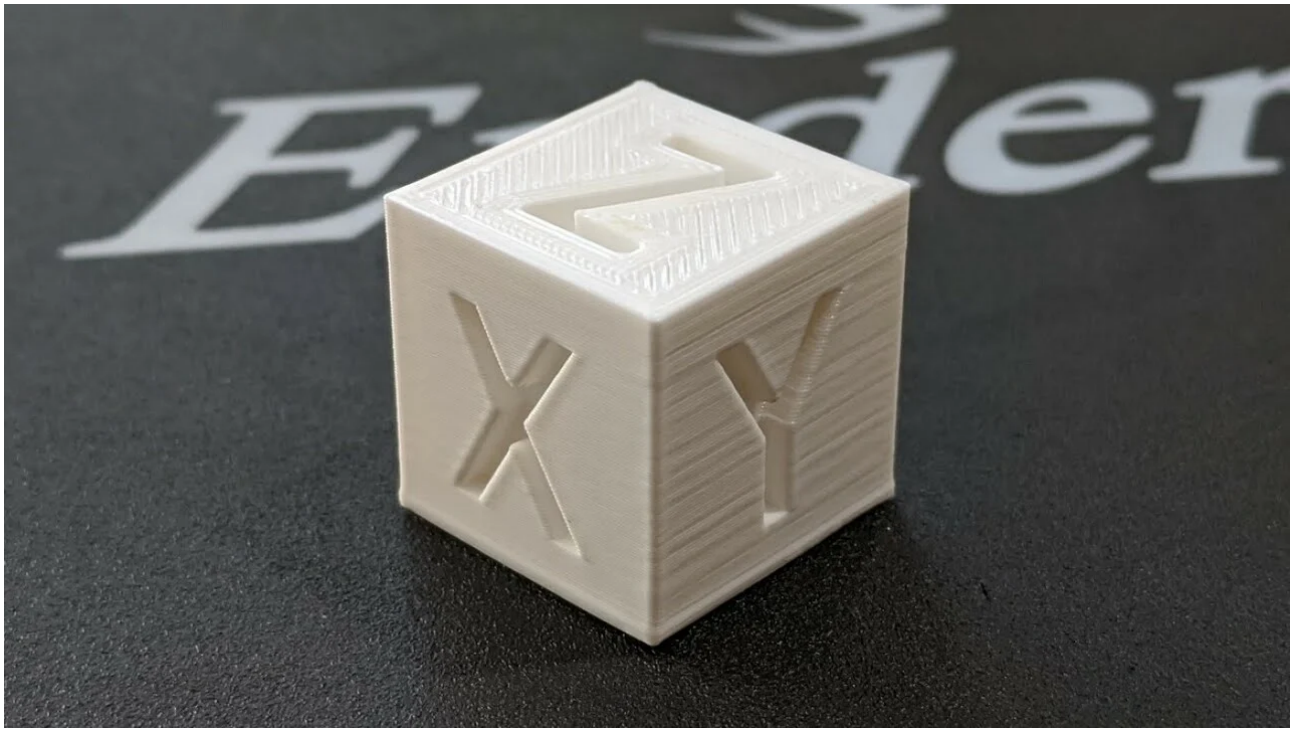


FIG 17: THREE-DIMENSIONAL PRINTED OBJECT

4.1.5 Steps to print a three-dimensional structure using Delta three-dimensional printer

In this section various steps taken to print an object physically from three-dimensional printer are explained .

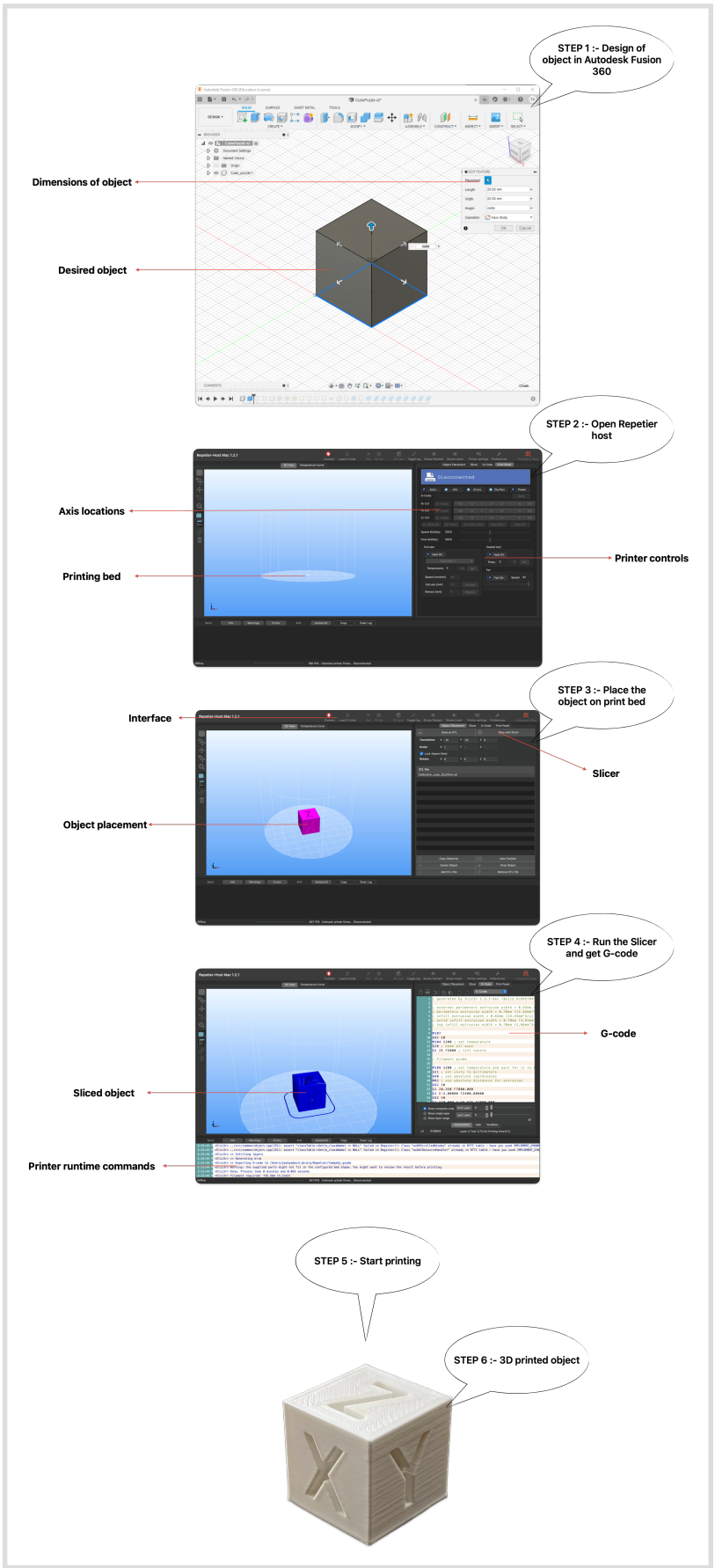
Step 1:- Design the CAD (Computer-aided design) model of desired structure on any finite element based software Fusion 360 , Meshmixer , Powermill , Unity , Adobe Dimension etc. which is to be printed .

Step 2:- Open "Repetier-Host" and configure the Delta three-dimensional printer , set all axis to home setting , turn on heating pad and cooling fan.

Step 3:- Place the CAD (Computer-aided design) on printing area of "Repetier-Host" , calibrate the dimensions of printing area as per structure .

Step 4:- Slice the structure on slicer window and get G-code , start the uninterrupted printing process for required time .

Step 5:- Foil and clean the extra extruded material by sanding to get finished product.



CHAPTER-5

5.1 Why Delta Fused Deposition Modeling three-dimensional Printers ?

three-dimensional printing basic structure stands on the movement of stepper motor which are controlled by Arduino (UNO) , in delta printing we use three set of moving parts which provide more degree of freedom to our extruder as compare to others in delta printing we use all axis movement together to reduce time and cost.

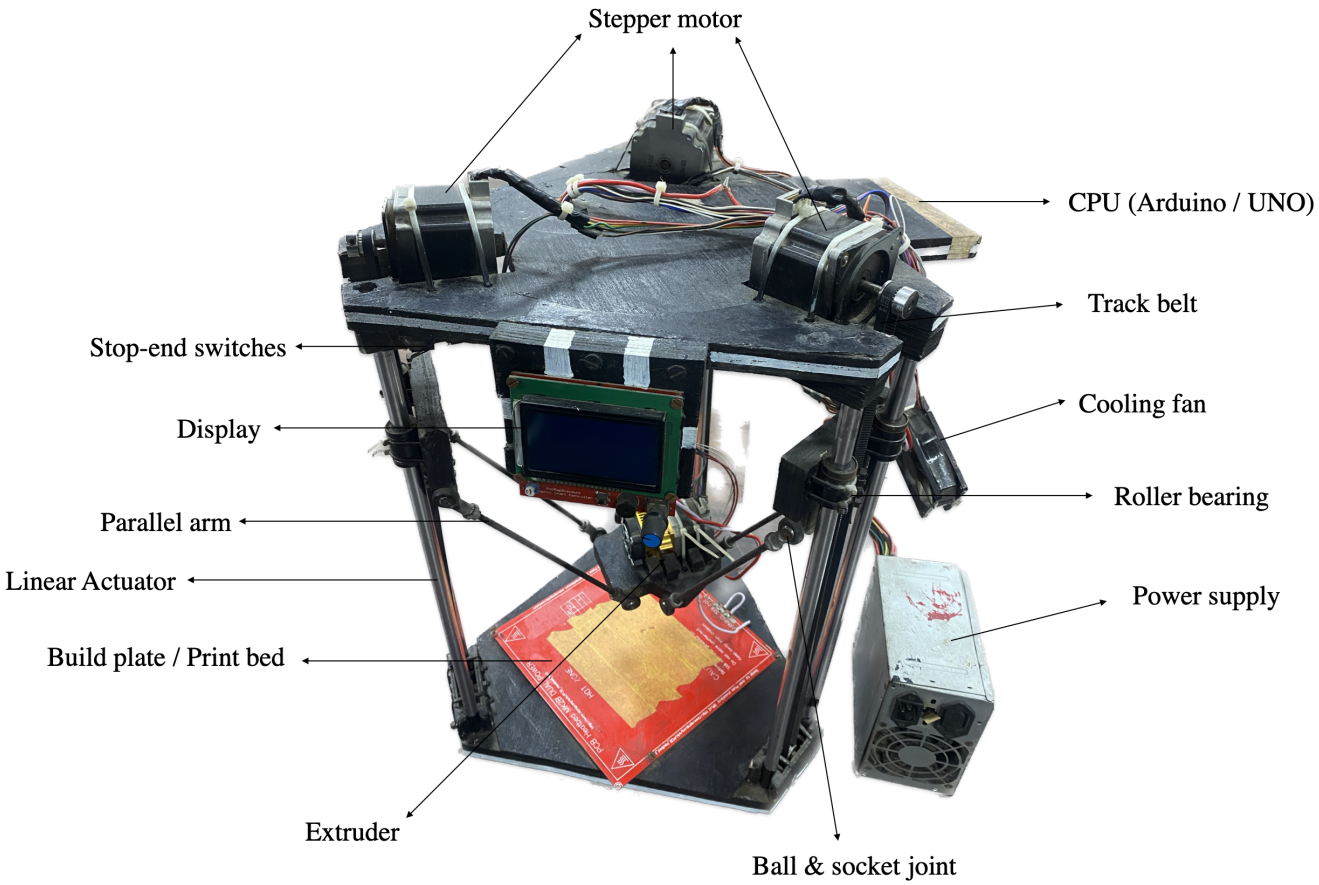


FIG 19: DELTA THREE-DIMENSIONAL PRINTER

5.2 Delta three-dimensional printer advantages

- It provide a range or heights to desired structure as to vary the height is very simple , we just need to increase the length of linear roads.
- As to make three-dimensional printing availability we need a printer which is small and easy to carry and quite simpler to assemble so that the reach of printer can increase and all the qualities are acquired by Delta three-dimensional printer.
- To make complex structure so that our imagination will not be bounder by any limitation there is Ball-and-socket joint in linear actuator which provide range or movement with smooth movement .
- As we move close to the centre of base the movement per strike will become more smaller and the accuracy or least movement will decrease which results in greater accuracy at centre so it is very efficient in nano printing . Or at small scale printing.
- The basic structure of Delta three-dimensional printer is very simple and further we also tries to make it very smilier for future upgrade .

5.3 three-dimensional printing is in developing phase so we has several challenges which we need to overcome some disadvantages we are facing now.

- The foundational structure of Delta three-dimensional printer is based on height so the physical dimension of our printer is quite large in hight , this further cause unsuitability and vibration while operating as we increase heights .
- To make our setup simple to use and make this three-dimensional printing quite generalised we made several complex changes which work together to give such simple interface so to detect error become more and more difficult.
- As our setup is pretty much efficient with change in heights but in case of horizontal expansion we feels limitations that to expand base may cause configuration and also it looses accuracy as we move outer from centre .

5.4 Conclusion

(I) A working model of Delta three-dimensional printer is designed and developed. This developed printer has many advantages such as It can produce more complicated geometries , relatively quick, has low setup cost, and works with a enormous expanding range of materials over traditional methods of printing.

(II) The printing process of structure using Delta three-dimensional printer is discussed in detail.

(III) A physical structure is printed using developed three-dimensional printer. On testing it has found that it is light weight, good finishing surface and small in size with high accuracy.

(IV) Building a Delta three-dimensional model still has a lot of problems that need to be fixed. Increasing the number of headers (Nozzles) in the printer could speed up printing, which is the next action that can be taken. The printing procedure must be finished without the requirement for any additional operations in order to solve the finished product problem.

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We, YASH YADAV (2K21/MSCPHY/54) and GOPAL SAINI (2K21/MSCPHY/14) hereby certify that the work which is presented in the Dissertation-II entitled in fulfilment of the requirement for the award of the Master in Science in **Physics** and submitted to the Department of **Applied Physics**, Delhi Technological University, Delhi is an authentic record of my own, carried out during a period from January 2023 to May 2023 under the supervision of **Dr. Deshraj Meena**(Department of Applied Physics), **Dr. Sushila Rani**(Mechanical Engineering Department)

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Name of Conference/Journal: 2nd International Conference on "Advanced Functional Materials and Devices" (AFMD-2023)

Conference Dates with venue (if applicable): March 13-15, 2023

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Build a Delta Three-dimensional printer using Fused Deposition Modeling Technology and it's efficacy in various aspects

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Abstract

Three-dimensional printing is an additive manufacturing process that produces a physical object from a digital design by interacting mechanical power with digital intelligence. This additive manufacturing process works on the principal to lay down thin layers of material and fuse them to get the desired structure. Three-dimensional printers used nowadays are in developing phase and many challenges are associated with them such as the dimensions of Delta Three-dimensional printer are quite large especially its height, which cause unsuitability and vibration while operation. Error detection of Three-dimensional printers are also very difficult due to their complex structure. In this research work, a Hybrid Delta Three-dimensional printer is developed to overcome challenges / disadvantages of Three-dimensional printers.

The Hybrid Delta 3D printer utilises a process of stacking and fusing layers of various materials to create 3D objects. It can produce more complicated geometries than conventional three-dimensional printing technologies , is relatively quick, has low setup cost, and works with a enormous expanding range of materials . This developed Delta Three-dimensional printer has many advantages and will be used extensively in the engineering industry, its application includes prototyping and execute ideas into reality. In designing of Delta Three-dimensional printer, three stepper motor was used to move various parts of Delta Three-dimensional printer which provide more degree of freedom to our extruder to use all axis movement together to reduce time and cost.