

# **FUSED DEPOSITION MODELLING 3D PRINTER USING ARDUINO**

*A Project report submitted in partial fulfillment of requirements  
for the award of the Degree of*

## **BACHELOR OF TECHNOLOGY IN ELECTRONICS AND COMMUNICATION ENGINEERING**

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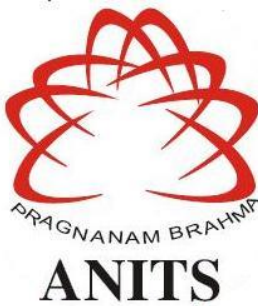
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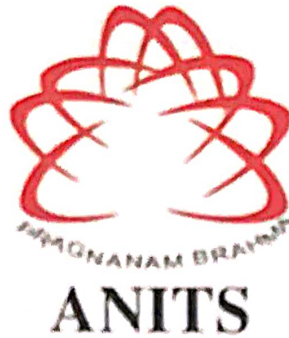
**SANGIVALASA, BHEEMILI, VISAKHAPATNAM-531162, A.P**

**(2018-22)**

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CERTIFICATE

This is to certify that the project report entitled "FUSED DEPOSITION MODELLING 3D PRINTER USING AURDINO" submitted by U. HARSHA VARDHAN (318126512176), K. BHAVANA (318126512146), G.VAMSI (318126512177), D. ASHISH (318126512131) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering of Andhra University, Visakhapatnam is a bonafied work carried out under my guidance and supervision.

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## **ABSTRACT**

3D printing is an Additive Manufacturing Technology for printing 3D objects of any shape from a 3D model or other electronic data sources through additive processes in which successive material are laid down under computer controls. 3D printer uses materials like polymers (PLA and ABS), metals, resin and also ceramics. It is used in a variety of industries including jewellery, footwear, industrial design, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products.

3D printers that run on FDM (Fused Deposition Modelling) Technology build parts layer-by-layer from the bottom up by Heating and Extruding thermoplastic filament. We have used 3D Printing filament as Poly lactic acid or polylactide (PLA, Poly) which is a biodegradable thermoplastic aliphatic polyester derived from renewable resources. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design, print and glue together separate model parts.



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# **CHAPTER 1**

## **INTRODUCTION**

# CHAPTER 1

## 1.1 INTRODUCTION

3D printing or additive manufacturing (AM) is a process for making a 3D object of any shape from a 3D model or other electronic data sources through additive processes in which successive layers of material are laid down under computer controls. Hideo Kodama of Nayoga Municipal Industrial Research Institute is generally regarded to have printed the first solid object from a digital design. However, the credit for the first 3D printer generally goes to Charles Hull, who in 1984 designed it while working for the company he founded, 3D Systems Corp. Charles Hull was a pioneer of the solid imaging process known as stereolithography and the STL (stereo-lithographic) file format which is still the most widely used format used today in 3D printing. He is also regarded to have started commercial rapid prototyping that was concurrent with his development of 3D printing. He initially used photo polymers heated by ultraviolet light to achieve the melting and solidification effect. Since 1984, when the first 3D printer was designed and realized by Charles W. Hull from 3D Systems Corp., the technology has evolved and these machines have become more and more useful, while their price points lowered, thus becoming more affordable.

Nowadays, rapid prototyping has a wide range of applications in various fields of human activity: research, engineering, medical industry, military, construction, architecture, fashion, education, the computer industry and many others. In 1990, the plastic extrusion technology most widely associated with the term "3D printing" was invented by Stratasys by name fused deposition modelling (FDM). After the start of the 21st century, there has been a large growth in the sales of 3D printing machines and their price has been dropped gradually. By the early 2010s, the terms 3D printing and additive manufacturing evolved senses in which they were alternate umbrella terms for AM technologies, one being used in popular vernacular by consumer - maker communities and the media, and the other used officially by industrial AM end use part producers, AM machine manufacturers, and global technical standards organizations. Both terms reflect the simple fact that the

technologies all share the common theme of sequential-layer material addition/joining throughout a 3D work envelope under automated control.

Other terms that had been used as AM synonyms included desktop manufacturing, rapid manufacturing, and agile tooling on-demand manufacturing. The 2010s were the first decade in which metal end use parts such as engine brackets and large nuts would be grown (either before or instead of machining) in job production rather than obligatory being machined from bar stock or plate.

## **1.2 GENERAL PRINCIPLES**

### **1.2.1 Modelling**

3D printable models can be created with the help of CAD design packages or via 3Dscanner. The manual modelling process of preparing geometric data for 3D computer graphics is similar to method sculpting. 3D modelling is a process of Analyzing and collecting data on the shape and appearance of an object. Based on this data, 3D models of the scanned object can be produced. Both manual and automatic creations of 3D printed models are very difficult for average consumers. That is why several market-places have emerged over the last years among the world. The most popular are Shape ways, Thing verse, My Mini Factory, and Threading.

### **1.2.2 Printing**

Before printing a 3D model from .STL file, it must be processed by a piece of software called a "slicer" which converts the 3D model into a series of thin layers and produces a G-code file from .STL file containing instructions to a printer. There are several open source slicer programs exist, including, Slic3r, KISSlicer, and Cura. The 3D printer follows the G-code instructions to put down successive layers of liquid, powder, or sheet material to build a model from a series of cross-sections of a model. These layers, which correspond to the virtual cross sections from the CAD model, are joined or fused to create the final shape of a model. The main advantage of this technique is its ability to create

almost any shape or geometric model. Construction of a model with existing methods can take anywhere from several hours to days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to very few hours; it varies widely depending on the type of machine used and the size and number of models being produced.

### **1.2.3 Finishing**

Although the printer-produced resolution is sufficient for many applications, printing a slightly oversized version of the object in standard resolution and then removing material with a higher-resolution process can achieve greater precision. As with the Accucraft iD-20 and other machines Press Release. International Manufacturing Technology shows some additive manufacturing techniques are capable of using multiple materials in the course of constructing parts.

## **1.3 PROCESSES OF 3D PRINTING**

Many different 3D printing processes and technologies have been invented from late 1970. The printers were originally very large and expensive in what they could produce. A large number of Additive manufacturing processes are now available. Some of the methods melt or soften material to produce the layers, e.g. selective laser melting(SLM), selective laser sintering (SLS), fused deposition modelling (FDM), while others cure liquid materials using different other technologies, e.g. stereolithography (SLA) and With laminated object manufacturing (LOM).

### **1.3.1 Selective Laser Sintering**

Selective laser sintering (SLS) was developed and patented by Dr. Carl Deckard and academic adviser, Dr. Joe Beaman at the University of Texas in the mid-1980, under the sponsorship of DARPA. Deckard was involved in the resulting start-up company DTM, established to design and build the selective laser sintering machines. In the year 2001, 3D Systems the biggest competitor of DTM acquired DTM. The most recent patent regarding Deckard's selective laser sintering technology was issued on January 1997 and expired

on Jan 2014. Selective laser sintering is a 3D-printing technique that uses a laser as the power source to sinter powdered material (mostly metal), aiming the laser at points in space defined by a 3D model, binding the material to create a solid structure. Selective laser melting uses a comparable concept, but in SLM the material is fully melted than sintered, allowing different properties (crystal structure, porosity). Fig 1.1 shows selective laser sintering process(SLS) is a relatively new technology that so far has mainly been used for additive manufacturing and for low-volume production of parts. Production roles are expanding as the commercialization of additive manufacturing technology improves.

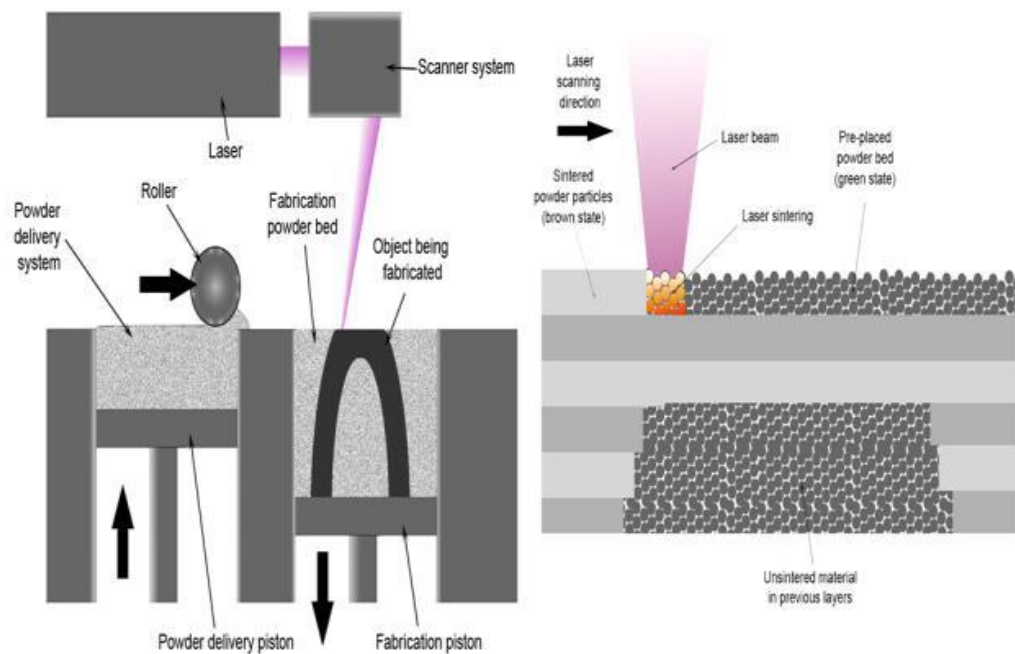


Fig 1.1: Selective Laser Sintering (SLS)

### 1.3.2 Fused Deposition Modelling

Fused deposition modelling (FDM) method was developed by S. Scott Crump in the late 1980s and was designed in 1990 by Stratasys. After the patent on this technology expired, a large open source development community developed and commercial variants utilizing this type of 3D printer appeared. As a result, the price of FDM technology has dropped by two orders of magnitude since its creation. In this technique, the model is

produced by extruding small beads of material which harden to form layers. Fig 1.2 shows Fused Deposition Modelling. A thermoplastic filament or wire that is wound into a coil is unwinding to supply material to an extrusion nozzle head. The nozzle head heats the material up to the certain temperature and turns the flow on and off. Typically, the stepper motors are employed to move the extrusion head in the z-direction and adjust the flow according to the requirements. The head can be moved in both horizontal and vertical directions, and control of the mechanism is done by a computer-aided manufacturing (CAM) software package running on a microcontroller.

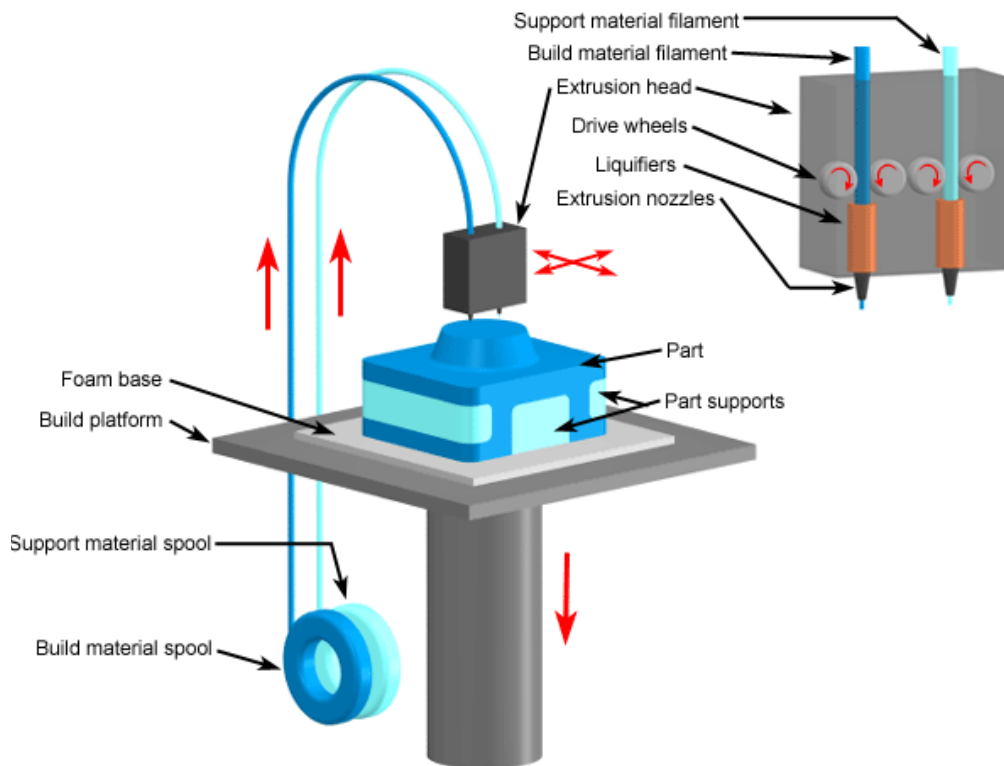


Fig 1.2: Fused Deposition Modelling

### 1.3.3 Stereolithography

Stereolithography is an early and widely used 3D printing technology. 3D printing was invented with the intent of allowing engineers to create prototypes of their own designs in a more time and in an effective manner. The technology first appeared as early as 1970. Dr. Hideo Kodama Japanese researcher first invented the modern layered approach to



stereolithography by using UV light to cure photosensitive polymers. On July 1984, before Chuck Hull filed his own patent and Alain Le Mehaute filed a patent for the stereolithography process. The French inventor's patent application was neglected by the French General Electric Company and by CILAS (The Laser Consortium). Stereolithography is a form of 3-D printing technology used for creating models, prototypes, patterns in a layer-by-layer fashion using photo polymerization, a process by which light causes chains of molecules to link together, forming polymers. Fig 1.3 shows Stereolithography Process. Those polymers then make up the body of a three-dimensional solid. Research in the area had been conducted during the 1970s, but the term was coined by Charles (Chuck) W. Hull in 1986 when he patented the process. He then set up 3D Systems Inc. to commercialize his patent.

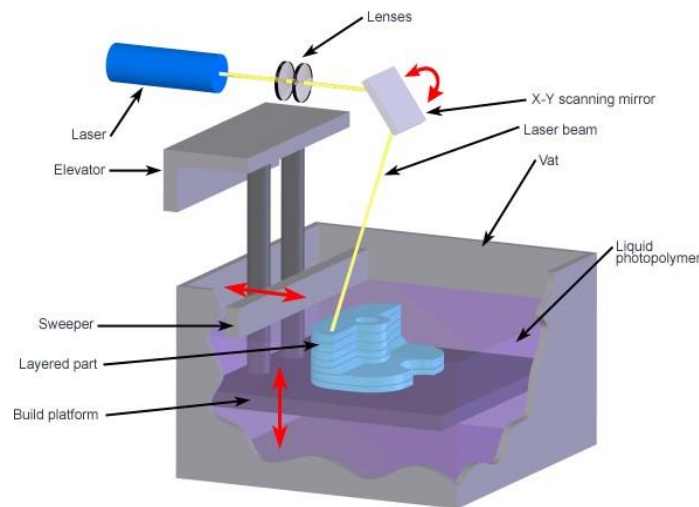


Fig 1.3: Stereolithography

### 1.3.4 Laminated Object Manufacturing

It is a 3D-printing technology developed by Helisys Inc. (now Cubic Technologies). In it, layers of adhesive-coated paper, plastic, or metal laminates are successively joined together and cut to appropriate shape with a laser cutter. Fig 1.4 shows Laminated Object Manufacturing Process. Objects printed with this technique may be additionally modified by machining after the printing process. the typical layer

resolution for this process is defined by material feedstock and usually ranges in thickness from one to many sheets of paper of a copy.

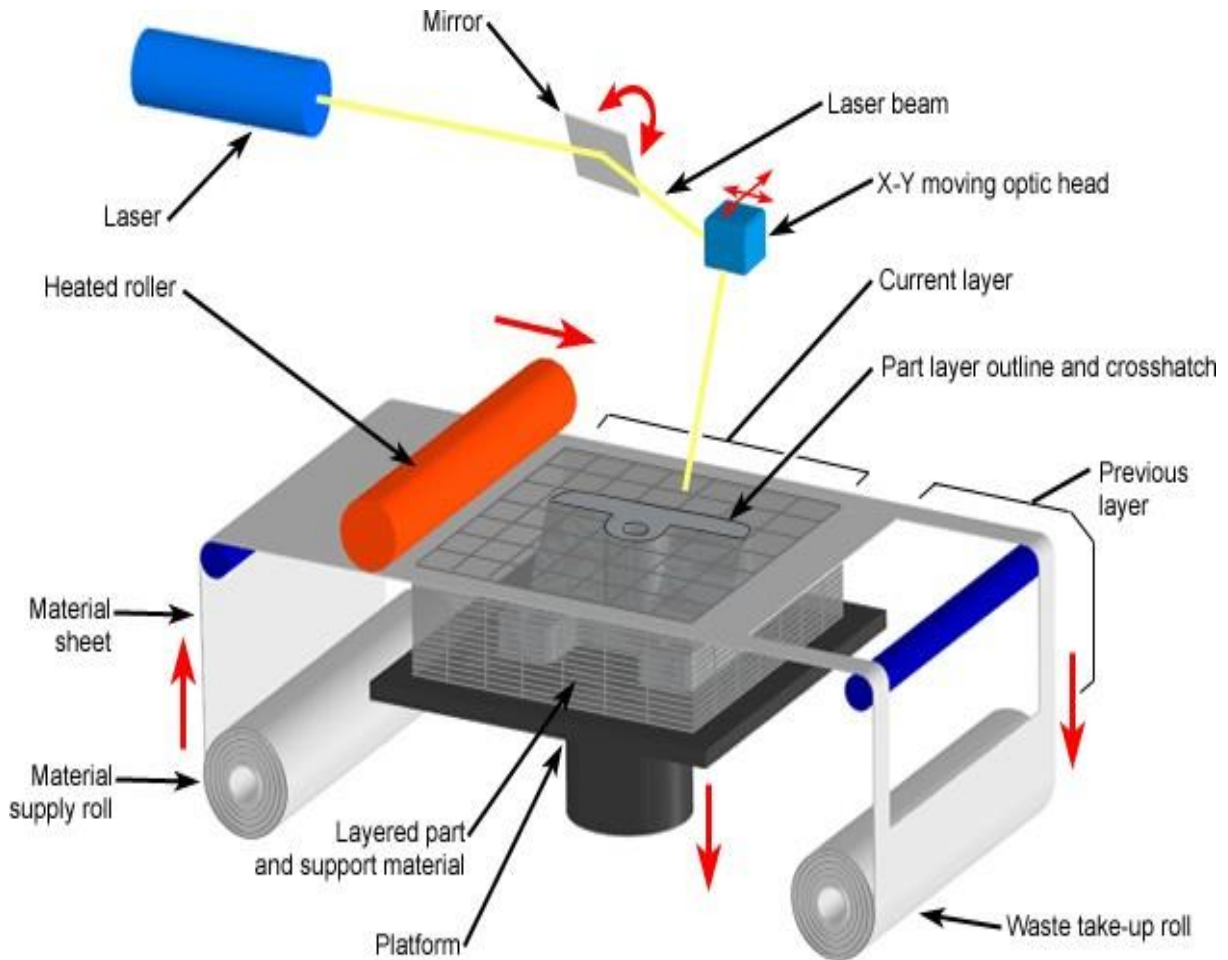


Fig 1.4: Laminated Object Manufacturing

## 1.4 3D PRINTER MATERIAL

The materials used for 3D printing are as diverse as the products that result from the process. As such, 3D printing is flexible enough to allow manufacturers to determine the shape, texture and strength of a product. Best of all, these qualities can be achieved with far fewer steps than what is typically required in traditional means of production. Moreover, these products can be made with various types of 3D printing materials.

Out of all the raw materials for 3D printing in use today, plastic is the most common. With its firmness, flexibility, smoothness and bright range of color options, the appeal of plastic is easy to understand. As a relatively affordable option, plastic is generally light on the pocketbooks of creators and consumers alike. Plastic products are generally made with FDM printers. The types of plastic used in this process are usually made from one of the following materials

### **1.4.1 Acrylonitrile Butadiene Styrene [ABS]**

One of the most widely used material since the inception of 3D printing. This material is very durable, slightly flexible, and lightweight and can be easily extruded, which makes it perfect for 3D printing. It requires less force to extrude than when using PLA, which is another popular 3D filament. This fact makes extrusion easier for small parts. The disadvantage of ABS is that it requires higher temperature. Its glass transition temperature is about 105°C and temperature about 210 - 250°C is usually used for printing with ABS materials. Also another drawback of this material is quite intense fumes during printing that can be dangerous for pets or people with breathing difficulties. So 3D printers need to be placed in well-ventilated area. Also good advice is to avoid breathing in fumes during printing considering the cost of 3D materials ABS is the cheapest, which makes it favorite in printing communities until now.

#### **Technical Specifications:**

- Density- 1-1.4 gm/cm<sup>3</sup>
- Dielectric constant- 3.1 to 3.2
- Dielectric Strength [Breakdown Potential]- 15-16kV/mm [0.59-0.63 V/mil]
- Elastic modulus- 2 to 2.6 GPa
- Elongation at break- 3.5 to 50%
- Flexural modulus- 2.1 to 7.6 GPa
- Flexural strength- 72 to 97 MPa
- Heat deflection temperature at 1.82 MPa -76 to 110°C
- Heat deflection temperature at 455 KPa- 83 to 110°C
- Strength to weight ratio- 37 to 79 kN-m/kg

- Tensile strength: 37 to 110 MPa
- Thermal expansion- 81 to 95  $\mu\text{m/m-K}$

### **Material Properties of Acrylonitrile Butadiene Styrene [ABS]**

- Temperature - 225°C
- Flow Tweak - 0.93
- Bed Temperature - 90°C
- Bed Preparation - apply glue stick 2 layer & then abs glue 1 layer

### **1.4.2 Poly Lactic Acid [PLA]**

Poly lactic acid (PLA) (is derived from corn and is biodegradable) is another well-spread material among 3D printing enthusiasts. It is a biodegradable thermoplastic that is derived from renewable resources. As a result PLA materials are more environmentally friendly among other plastic materials. The other great feature of PLA is its biocompatibility with a human body. The structure of PLA is harder than the one of ABS and material melts at 180 – 220°C which is lower than ABS. PLA glass transition temperature is between 60 – 65 ° C, so PLA together with ABS could be some good options for any of your projects.

#### **Technical Specifications:**

- Density - 1.3 g/cm<sup>3</sup> (81 lb/ft<sup>3</sup>)
- Elastic (Young's, Tensile) Modulus - 2.0 to 2.6 GPa (0.29 to 0.38 x 10<sup>3</sup> psi)
- Elongation at Break - 6.0 %
- Flexural Modulus - 4.0 GPa (0.58 x 10<sup>6</sup> psi)
- Flexural Strength - 80 MPa (12 x 10<sup>3</sup> psi)
- Glass Transition Temperature - 60 °C (140 °F)
- Heat Deflection Temperature At 455 kPa (66 psi) -65 °C (150 °F)
- Melting Onset (Solidus) - 160 °C (320 °F)
- Shear Modulus- 2.4 GPa (0.35 x 10<sup>6</sup> psi)
- Specific Heat Capacity - 1800 J/kg-K

- Strength to Weight Ratio - 38 kN-m/kg
- Tensile Strength: Ultimate (UTS) - 50 MPa ( $7.3 \times 10^3$  psi)
- Thermal Conductivity - 0.13 W/m-K
- Thermal Diffusivity - 0.056

### **Material Properties of Poly Lactic Acid [PLA]**

- Temperature - 180°C
- Flow Tweak - 0.95
- Bed Temperature - 60°C
- Bed Preparation - apply glue stick 2 layer

### **1.4.3 High Impact Polystyrene [HIPS]**

HIPS filament is made from a High Impact Polystyrene material and it is another example of support 3d materials. This material is well spread in food industry for packaging. It is also used to pack CD discs and to produce trays in medicine naturally this filament has bright white color and it is also biodegradable so there is no adverse effect when it is put in tight contact with a human or animal body. HIPS filaments have curling and adhesion problems, which can be reduced by using a heated bed during the printing. HIPS material that can also be used as support structure during the printing and then dissolved in a colorless liquid hydrocarbon Solution.

#### **Tech Specifications:**

- Density - 1.0 g/cm<sup>3</sup> (62 lb/ft<sup>3</sup>)
- Dielectric Strength (Breakdown Potential) - 18 kV/mm (0.7 V/mil)
- Elastic (Young's, Tensile) Modulus -  
1.9 GPa ( $0.28 \times 10^6$  psi)
- Elongation at Break - 40 %
- Flexural Strength - 62 MPa ( $9.0 \times 10^3$  psi)
- Glass Transition Temperature - 100 °C (210 °F)
- Heat of Combustion (HOC) - 43 MJ/kg
- Limiting Oxygen Index (LOI) - 18 %

- Poisson's Ratio - 0.41
- Specific Heat Capacity - 1400 J/kg-K Strength to Weight Ratio - 32 kN-m/kg
- Tensile Strength: Ultimate (UTS) - 32 MPa (4.6 x10<sup>3</sup> psi)
- Thermal Conductivity - 0.22 W/m-K
- Thermal Diffusivity - 0.16
- Thermal Expansion - 80 µm/m-K
- Vicat Softening Temperature - 110 °C (230 °F)
- Water Absorption After 24 Hours - 0.08%

### **Material Properties of High Impact Polystyrene [HIPS]**

- Temperature - 225°C
- Flow Tweak - 0.91
- Bed Temperature - 90°C
- Bed Preparation - apply glue stick 2 layer & then abs glue 1 layer

## **1.5 HARDWARE COMPONENTS**

- Arduino Mega 2560.
- Ramps 1.4
- Steppers Motors
- Stepper Motor Drivers(A4988)
- Extruder
- Filament (PLA)
- Eccentric Nuts
- Hot End
- Aluminium Extrusions.
- Wheels
- Stepper Motor Pulleys
- Support Pulleys
- Timing Belt

- Switch Mode Power Supply(SMPS)
- Sliding nuts

## 1.6 SOFTWARES USED

For development of this printer we used the open source “MARLIN firmware” which is one of the most widely used firmware for 3D printer. Now the entire 3D printing process is divided into three steps as shown below.

- 1) **Modelling Software:** Used for creating 3D CAD models. Ex: Tinkercad
- 2) **Slicing Software:** It is the most important for the operation of 3D printer. In general Slicing Software has 6 steps.
  - a) Setting up Printer Limitations.
  - b) Importing the CAD Model in .STL format.
  - c) Arranging the model on the printer bed.
  - d) Setup Commands where the every detail about the object is set.
  - e) Slice and Preview layers: this is the important step where the Slicing Software Slices(Cuts) the CAD model on basis of its Z-axis and preview how the layers were sliced and the respective G-codes are generated.
  - f) Export: Once the Slicing is finished export that sliced G-Codes into the Interface.
- 3) **Interface for 3D printer:** Pronterface is a simple graphical user interface that allows you to monitor and control your printer from a USB-connected computer. With it you can directly move stepper motors, control bed and nozzle temperatures, send [G-code](#) commands directly via a terminal or console window, and much more.
- 4) **Arduino IDE:** It is an Arduino Integrated Development Environment used for uploading the firmware into the Arduino Mega 2560.

# **CHAPTER 2**

# **3D PRINTER**

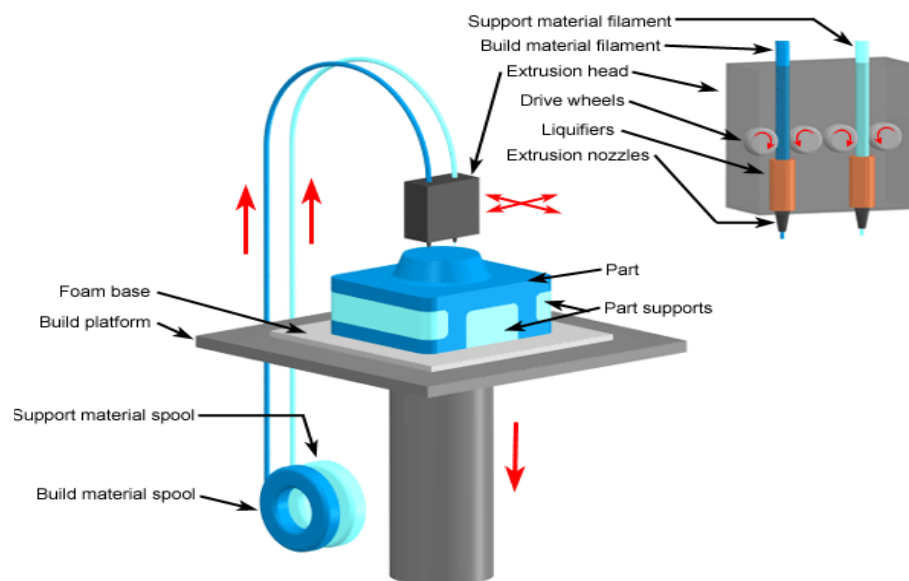


# CHAPTER 2

## 3D Printer

### 2.1 INTRODUCTION

Fused deposition modelling (FDM) method was developed by S. Scott Crump in the late 1980s and was designed in 1990 by Stratasys. After the patent on this technology expired, a large open-source development community developed and commercial variants utilizing this type of 3D printer appeared. As a result, the price of FDM technology has dropped by two orders of magnitude since its creation. In this technique, the model is produced by extruding small beads of material which harden to form layers. **Fig: 2.1 shows the working of fused Deposition Modelling.** A thermoplastic filament or wire that is wound into a coil is unwinding to supply material to an extrusion nozzle head. The nozzle head heats the material up to the certain temperature and turns the flow on and off. Typically, the stepper motors are employed to move the extrusion head in the z-direction and adjust the flow according to the requirements. The head can be moved in both horizontal and vertical directions, and control of the mechanism is done by a computer-aided manufacturing (CAM) software package running on a microcontroller.



**Fig 2.1: Fused Deposition Modelling (FDM)**

Fused deposition modelling, or FDM 3D Printing, is a method of additive manufacturing where layers of materials are fused together in a pattern to create an object. The material is usually melted just past its glass transition temperature, and then extruded in a pattern next to or on top of previous extrusions, creating an object layer by layer. In layman's terms, a typical FDM 3D printer takes a plastic filament and squeezes it through a hot end, melting it and then depositing it in layers on the print bed. These layers are fused together, building up throughout the print, and eventually they will form the finished part.

## 2.2 FLOW CHART

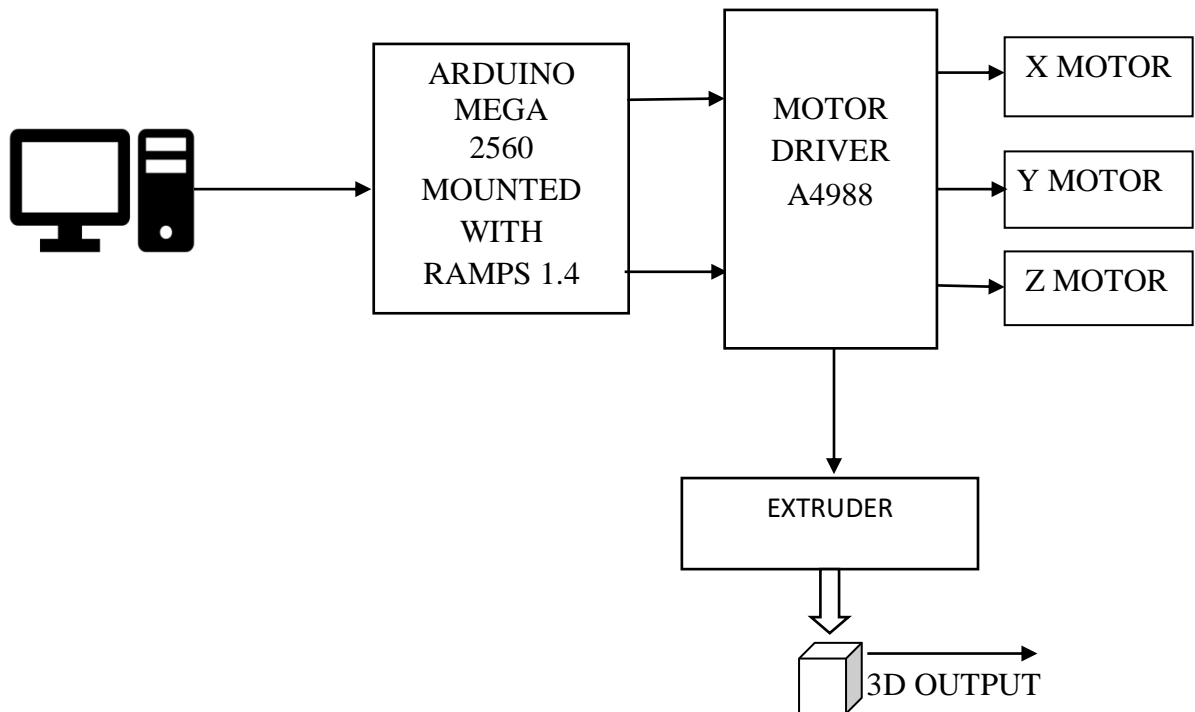


Fig 2.2: Block Diagram of 3D Printer.

The figure 2.2 shows the block diagram of the 3D Printer in which the Arduino mega 2560 connects the computer with the motor drivers which drives the axes controlling stepper motors and the extruder stepper motor .

Initially the 3D CAD model of the object to be printed is converted into STL format file. Further the STL format file is given to slicing software like **CURA** which divides the model

into individual material layers throughout the z-axis called slices to form G-Codes. These G-Codes are given to Arduino mega 2650 with the help of interfaces like **Pronterface** to print a 3D object. The Arduino mega is connected to stepper motors using motor driver A4988 for easy operation of the stepper motor. These stepper motors are responsible for the linear motion along x-axis, y-axis and z-axis according to the G-Codes. The A4988 drivers connected to the Arduino Mega controls the movement of the PLA filament into the extruder through a stepper motor. The extruder ejects the PLA material required for the printing to the Hotend and then the hotend melts that PLA material into semi liquid state on the base platform layer by layer according to the G-Codes to form the required 3D object.

### **2.3 WORKING PRINCIPLE**

All 3D printing techniques are based on the same principle. A 3D printer takes a digital model (as input) and turns it into a physical three-dimensional object by adding material layer by layer.

It is way different than traditional manufacturing processes such as injection molding and CNC machining that uses various cutting tools to construct the desired structure from a solid block. 3D Printing, however, requires no cutting tools: objects are manufactured directly onto the built platform.

The process starts with a digital 3D model (a blueprint of the object). The software (specific to the printer) slices the 3D model into thin, two-dimensional layers. It then converts them into a set of instructions in machine language for the printer to execute.

Depending on the type of printer and size of the object, a print takes several hours to complete. The printed object often requires post-processing (like sanding, lacquer, paint, or other types of conventional finishing touches) to achieve the optimal surface finish, which takes additional time and manual effort.

Different types of 3D printers employ different technologies that process different materials in different ways. Perhaps the most basic limitation of 3D Printing, in terms of materials and applications, is that there is no one-size-fits-all solution.

**CHAPTER 3**  
**HARDWARE**  
**COMPONENTS**

## CHAPTER 3

### HARDWARE COMPONENTS

#### 3.1 INTRODUCTION

In this section of hardware components we have discussed various hardware components used to build the 3D printer with uses and specifications.

##### 3.1.1 Frame

Frame is made of Aluminium Extrusions. We generally use Aluminium Extrusions because they are cost effective and are Resistant to Corrosion. Here we are using an 20×40 V Slot Aluminium Extrusion Profile.



Fig 3.1: Aluminium Extrusions

The figure 3.1 shows the aluminium extrusion which is used to build the frame of the 3D printer.

### 3.1.2 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Fig 3.2 Shows Arduino Mega

#### Features:

1. ATmega16U2 instead 8U2 as USB to serial converter
2. 1.0 pinout
3. Stronger RESET circuit
4. 5V operating voltage
5. Input voltage (recommended) range from 7V to 12V
6. Input voltage (limit) range from 6V to 20V
7. 40mA DC current per I/O pin
8. 256KB flash memory of which 8KB used by the bootloader
9. 8KB SRAM
10. 4KB EEPROM



Fig 3.2: Aurdino Mega 2650.

The figure 3.2 shows the image of Arduino Mega 2650 which is used as the interface between the hardware and software used in 3D printer.

### 3.1.3 Ramps 1.4

RepRap Arduino Mega Polulu Shield, or RAMPS, is a board that serves as the interface between the Arduino Mega — the controller computer — and the electronic devices on a RepRap 3D printer. The computer extracts information from files containing data about the object you want to print and translates it into digital events, like supplying a voltage to a specific pin.

It takes many, many such pins turning on and off to tell a printer what to do. Unfortunately, the Mega doesn't have enough power to actually operate the printer's hardware.

That's where the RAMPS board comes in. It organizes and amplifies the information coming from the Mega so that they're properly directed down the correct channels.

For example, if the hot end carriage needs to move one step to the left, the RAMPs board routes the signals from the Mega to the X-axis stepper motor via the appropriate pins and wires.

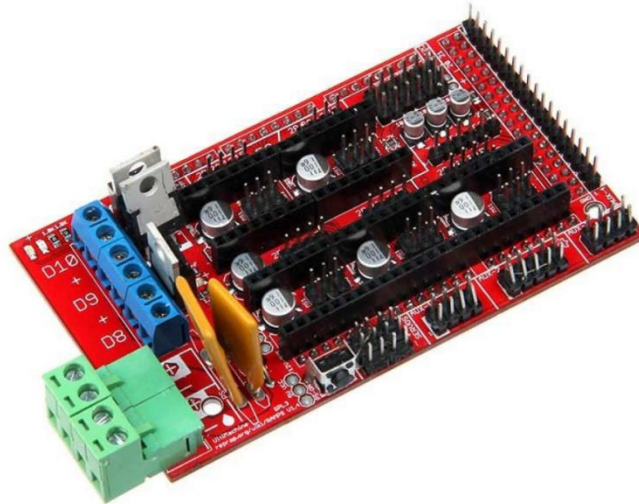


Fig 3.3: Ramps1.4

The figure 3.3 shows the image of Ramps 1.4 motherboard which is mounted on the Arduino Mega 2560 and acts as the interface.

### 3.1.4 Stepper Motors

A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can be commanded to move and hold at one of these steps without any position sensor for feedback

(an open-loop controller), as long as the motor is correctly sized to the application in respect to torque and speed.

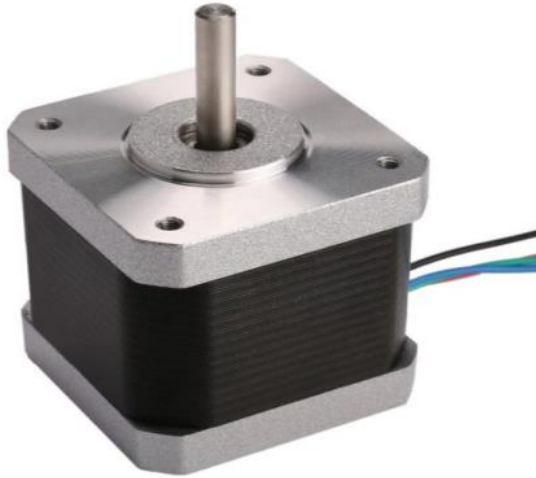


Fig 3.4: Stepper Motor

The above figure 3.4 shows a brushless dc stepper motor which is responsible for linear motion along different axes.

### **3.1.5 A4988 Drivers**

The A4988 driver Stepper Motor Driver is a complete micro-stepping motor driver with built-in converter, easy to operate. It operates from 8 V to 35 V and can deliver up to approximately 1 A per phase without a heat sink or forced air flow (it is rated for 2 A per coil with sufficient additional cooling).

A4988 driver Stepper Motor Driver includes a fixed off-time current regulator, the regulator can be in slow or mixed decay mode. The converter is the key to the easy implementation of the A4988.

The application of A4988 interface is very suitable for a complex microprocessor is not available or overload. In the stepping operation, the chopping control in the A4988 automatically selects the current decay mode (slow or mixed). The mix decay current control scheme can reduce the audible motor noise, increased step accuracy, and reduced power consumption.



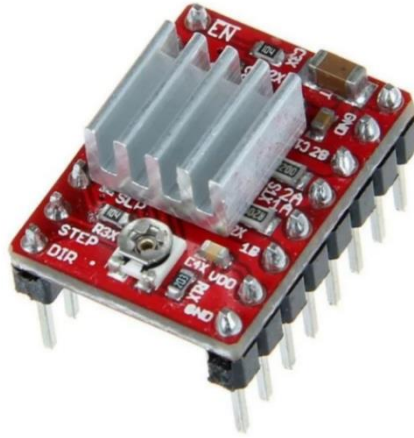


Fig 3.5 : A4988 Drivers

The figure 3.5 shows a A4988 stepper motor which is used to drive the axis stepper motors and the extruder stepper motor in a 3D printer.

### 3.1.6 Extruder

The extruder, also known as print head extrudes the filament and deposit it on the print bed. The extruder can be categorized in two sections. One is called the cold end while the other is known as the hot end. The job of the cold end is to lock the filament while pushing it gradually downwards to the hot end.

The hot end that has a nozzle attached to it at the end, maintains a high temperature greater than the melting point of the filament. The hot end melts the filament which is further deposited on the print bed.

The extruder itself is made of different parts.

- **The Filament Drive Gear:** Also known as extruder drive gear is responsible for pushing the filament into the hot end.
- **The Heat Sink:** The heat sink along with the heat Sink Fan ensures that the material is still in solid state until it reaches the nozzle.
- **The Heater Cartridge:** This is the component that works to heat up the filament.
- **The Thermocouple:** To maintain the right temperature, the extruder uses a temperature sensor. This is used for the hot end.
- **The Cooling Fan:** Once the melted filament is deposited, it must be cooled down for setting before the next layer gets deposited. The job of the cooling fan is to ensure the same.

- Nozzle:** This forms the tip of the extruder. The filament is melted and it comes out of the nozzle for deposition. There are different sizes of nozzles that the printers use. 0.4 mm is the most common one. By keeping the smaller diameter of nozzle, one can achieve finer details with greater accuracy. And, larger nozzle helps in printing at a higher speed. Figure 3.6 shows the Bowden Extruder



Fig: 3.6 Extruder

The above figure 3.6 shows the extruder which extrudes the PLA material into the hot end using stepper motors.

The layout and position of 3D printer's cold end are generally determined by whether it is a direct extruder or Bowden extruder. The cold end consists of an extruder motor and gearing mounted either to the printer's frame or the print head itself, depending on the style of extruder. Additionally, there may be PTFE tubing present to guide the filament into the hot end – a necessity in Bowden extruders.

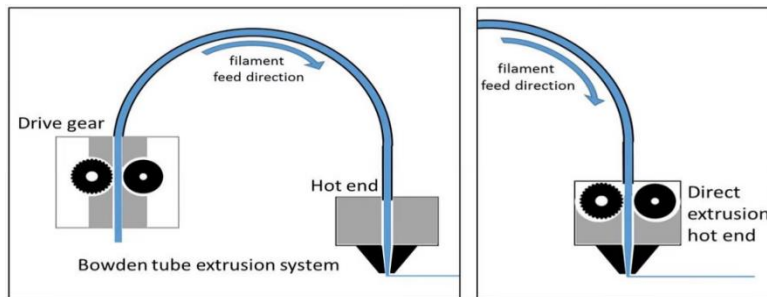


Fig 3.7: Bowden and Direct Extrusion Systems.

The figure 3.7 shows different type of extrusion systems. They are Bowden and Direct extrusion systems.

### 3.1.7 Hot End

The hotend can be described as the component of an FDM 3D printer that heats, melts and extrudes the material layer by layer through a nozzle. The whole structure of the hotend helps to maintain a consistent and accurate temperature as well as providing an optimized thermal dissipation. The main important issue with 3D printer is temperature maintenance, in this 3D printer we used PID algorithm to maintain Temperature of the Hotend.



Fig 3.8: Hot-End

Figure 3.8 shows the hot end and its different parts, used to heat, melt and extrude the PLA.

### 3.1.8 End Stops

End stops or limit switches are used on every moving axes of a 3D printer. End stops fulfill two important functions in a 3D printer: Reference system for the axes system and safety.

The other important aspect of an endstop is protecting the hardware from damage. Should any movement try to exceed the physical limits of the machine, the endstop will cut the movement.

Hardware endstops are electrically connected to the endstop ports of the printer control board and will provide a signal when the endstop condition is met.

Regardless of the type the basic way of working is the same:

- A typically 5 Volt signal (HIGH) drops to 0 Volt (LOW): Normally closed (NC) switch

- A 0 Volt signal (LOW) rises to 5 Volts (HIGH): Normally open (NO) switch.

Probes can act like an endstop for the minimum Z-axis. While the typical endstop has a fixed position, the probe is mounted on the print-head and can freely move around the bed.



Fig 3.9: End Stops

The Figure 3.9 shows the image of an end stop which is used to tell the printer when the axes end point is reached.

### 3.1.9 Filament

Polylactic Acid, commonly known as PLA, is one of the most popular materials used in desktop 3D printing. It is the default filament of choice for most extrusion-based 3D printers because it can be printed at a low temperature and does not require a heated bed. Figure 3.10 shows the PLA Filament. PLA is a great first material to use as you are learning about 3D printing because it is easy to print, very inexpensive, and creates parts that can be used for a wide variety of applications. It is also one of the most environmentally friendly filaments on the market today. Derived from crops such as corn and sugarcane, PLA is renewable and most importantly biodegradable.



Fig 3.10 :Poly Lactic Acid Filament

### 3.1.10 Eccentric Nuts

The eccentric nuts are used to adjust the tension of the wheels. The hole of the eccentric is not at the centre instead it is moved to one side to change the eccentricity and makes the wheels to fit correctly.



Fig 3.11: Eccentric Nut

The figure 3.11 shows the image of an eccentric nut which is used in this 3D printer to hold the wheels tight towards the frame that is responsible for the good movement of parts.

### 3.1.11 Sliding Nuts

Here we are using T nuts of size M5. This flat M5 T nut is a kind of simple economy T slot nut, pre-assembly slide in nut. This simple sliding nut can only be inserted into the t slot from the end of aluminum profile. It is usually used with hexagon socket bolts for fastening connections on aluminum profiles (Aluminum Extrusions).



Fig 3.12: Sliding Nuts

The figure 3.12 shows the image of sliding nuts which are used in our 3D printer to fix the screws to aluminium extrusions to built the frame.

### 3.1.12 Pulley and Timing Belt

The Pulley and The Timing Belt combo forms an integral part of the 3-D printer. These are used for the precision motion to print even the most intricate designs. GT2 Timing Belt Pulley is widely used in the 3d printer. GT2 Timing\_Belt pulley Specially design for NEMA 17 stepper motor used in 3d Printer.

The Aluminium GT2 Timing Pulley 20 Tooth 5mm Bore For 6mm Belt is for precise motion control, GT2 belts, and pulleys offer excellent precision at a great price. This pulley has 20 teeth and a 5mm inner bore. Two set screws can be used to attach it firmly to any 5mm diameter shaft. Full aluminium construction means these are very light and very durable.



Fig 3.13 :GT2 Pulley and Timing Belt

The figure 3.13 shows the GT2 Pulley and Timing Belt which are connected with stepper motors for the movement in 3D Printer.

### 3.1.13 Switched Mode Power Supply

A switched-mode power supply is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. In 3D printers we generally use 12V 20A switched mode power supply so, we cannot use transistorized power supply this is the main reason we go for SMPS. Fig 3.13 shows Switched Mode Power Supply.



Fig: 3.14 Switched Mode Power Supply

The figure 3.14 shows an image of the Switched Mode Power Supply used to supply the power for the 3D Printer.

### **3.1.14 Threaded Rods**

These are used in controlling the Z-Axis of the 3d printer. With the help of Threaded Rods connected to the stepper motor and the nut connected to the Z-axis extrusion we can control Z-Axis movement in 3d printer. Fig 3.14 shows the Threaded rod mounted with nut.



Fig: 3.15 Threaded rod with nut

The figure 3.15 shows the image of a threaded rod which is responsible for the movement in Z- axis of the 3D Printer.

# **CHAPTER 4**

# **SOFTWARE**



## **Chapter 4**

### **SOFTWARE**

#### **4.1 INTRODUCTION**

In this section we have discussed about the softwares required for the 3D Printer. In our 3D printer we uses 4 types of softwares. They are modelling software called Tinkercad for 3D modelling, slicing software to obtain g-codes, a graphical user interface like ProInterface and Arduino IDE for interfacing arduino mega 2650.

#### **4.2 TINKERCAD - 3D MODELLING SOFTWARE**

This is a browser-based 3D design app geared towards beginners. The software features an intuitive block-building concept, allowing you to develop models from a set of basic shapes. Tinkercad is full of tutorials and guides to aid any aspiring novices get the designs they're looking for. It even allows you to share and export files with ease.

With a library of literally millions of files, users can find shapes that suit them best and manipulate them as they wish. It also has a direct integration with 3rd party printing services, allowing you to print and have your print at your door-step at the press of a button. Even though it can be a bit too simple to the point of limitation, it serves as a great way to learn about 3D modelling.

#### **4.3 SLICING SOFTWARE**

The slicing software, also called slicer, is computer software used in the majority of 3D printing processes for the conversion of a 3D object model to specific instructions for the printer. In particular, the conversion from a model in STL format to printer commands in g-code format in fused filament fabrication and other similar processes.

The slicer first divides the object as a stack of flat layers, followed by describing these layers as linear movements of the 3D printer extruder, fixation laser or equivalent. All these movements, together with some specific printer commands like the ones to control the

extruder temperature or bed temperature, are finally written in the g-code file, that can afterwards be transferred to the printer.

A slicer tells the printer everything it needs to know to print an object in the best possible way. We call it a “Slicer” because of its main function: dividing the model into individual material layers throughout the z-axis or “slices”. The 3D Printer does not receive a geometric file (Commonly STL), but a G-Code. A G-Code is a detailed command list readable by a printer to optimize everything it needs during the process.

### 4.3.1 Slicing Process

Any process must have an input and end with an output. For a slicer, the 3D model and the manufacturing requirements are the input and the G-Code file is the output. The following are the typical steps for slicing a model.

**Setup printer settings:** The slicer needs all the information regarding the printer’s limitations. If this isn’t correctly set from the beginning, the G-Code will send commands impossible for the printer to handle. Additionally, there are more settings regarding the extruder type and the material specifications.

**Import model:** Once the printer data is set, you need to import the model you’ll work with. All slicers read STL, but other files like OBJ, 3DF and AMF are becoming more accepted every year.

**Arrange model:** A slicer interface allows control over the position of the part and its contact with the printer bed. There are also scaling and alignment options.

**Setup commands:** Here’s the most important step for slicers. Every printing parameter is set. Further down in this post we’ll get deeper into it.

**Slice and preview layers:** With everything set, the slicer is ready to calculate and cut the part into layers. Here you can preview the resulting elements and how they will be applied in real life. Most slicers calculate an estimation for printing time and material quantity to use.

**Export:** After checking and making sure everything is ok, you can create and save your file. Every slicer has the option to generate a G-Code. Depending on which software you use, there are alternative file options.

Here we will be using one of the most trusted open source Slicing Software **CURA** developed by company **ULTIMAKER**. Cura is compatible with all file types like STL, OBJ, X3D. It has custom control which gives over 400 settings for granular control for hassle free and smooth printing.

#### 4.4 PRONTERFACE

Pronterface is a simple graphical user interface that allows you to monitor and control your printer from a USB-connected computer. With it you can directly move stepper motors, control bed and nozzle temperatures, send G-code commands directly via a terminal or console window, and much more.

Created by the influential RepRap initiative, Pronterface has been around for a long time, and it's part of the Printron suite of simple tools for managing and controlling both 3D printers. Below figure 4.1 shows the interface of Pronterface.

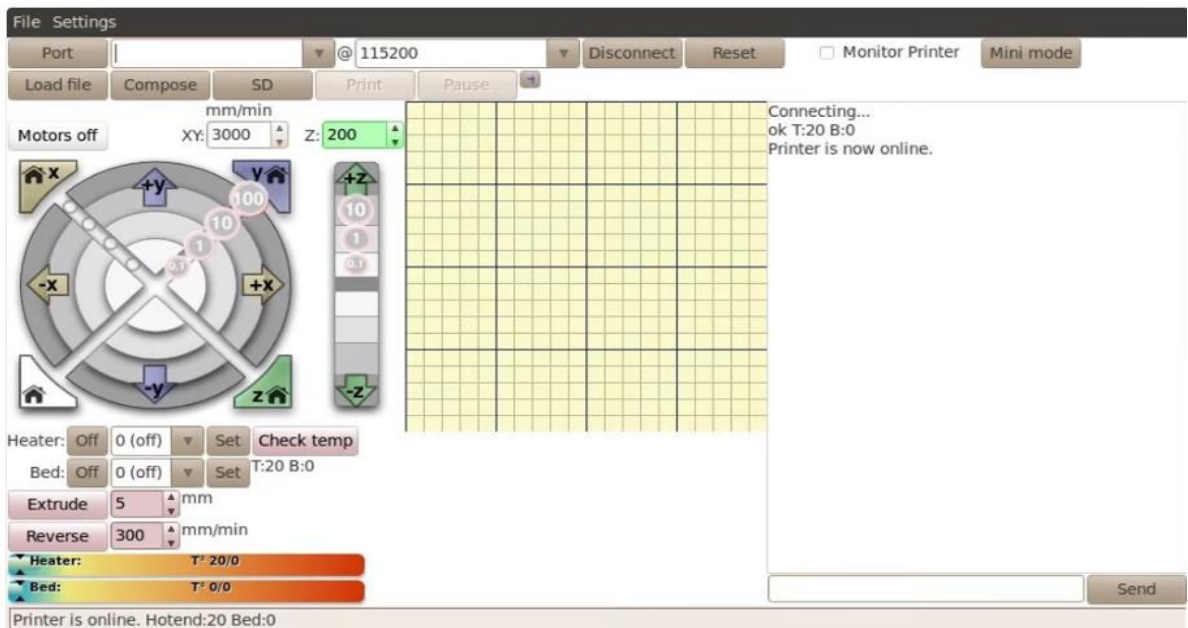


Fig: 4.1 Pronterface

## 4.5 ARDUINO MEGA IDE

Arduino Mega 2560 can be programmed using Arduino IDE software which is an official Arduino software used to program all Arduino boards. This software is used for writing, compiling, and uploading the code into the Arduino board.

This unit comes with a USB interface so a USB cable can be used to connect the device with the computer through which you can transfer sketch (Arduino program is called a sketch) to the board. Moreover, this software is open source which means it is free to use and anyone can use this software to allow the board to work as per the number of instructions you send from this software to the Arduino board. Fig 4.2 shows the flowchart of the entire 3D printing process from designing to printing.

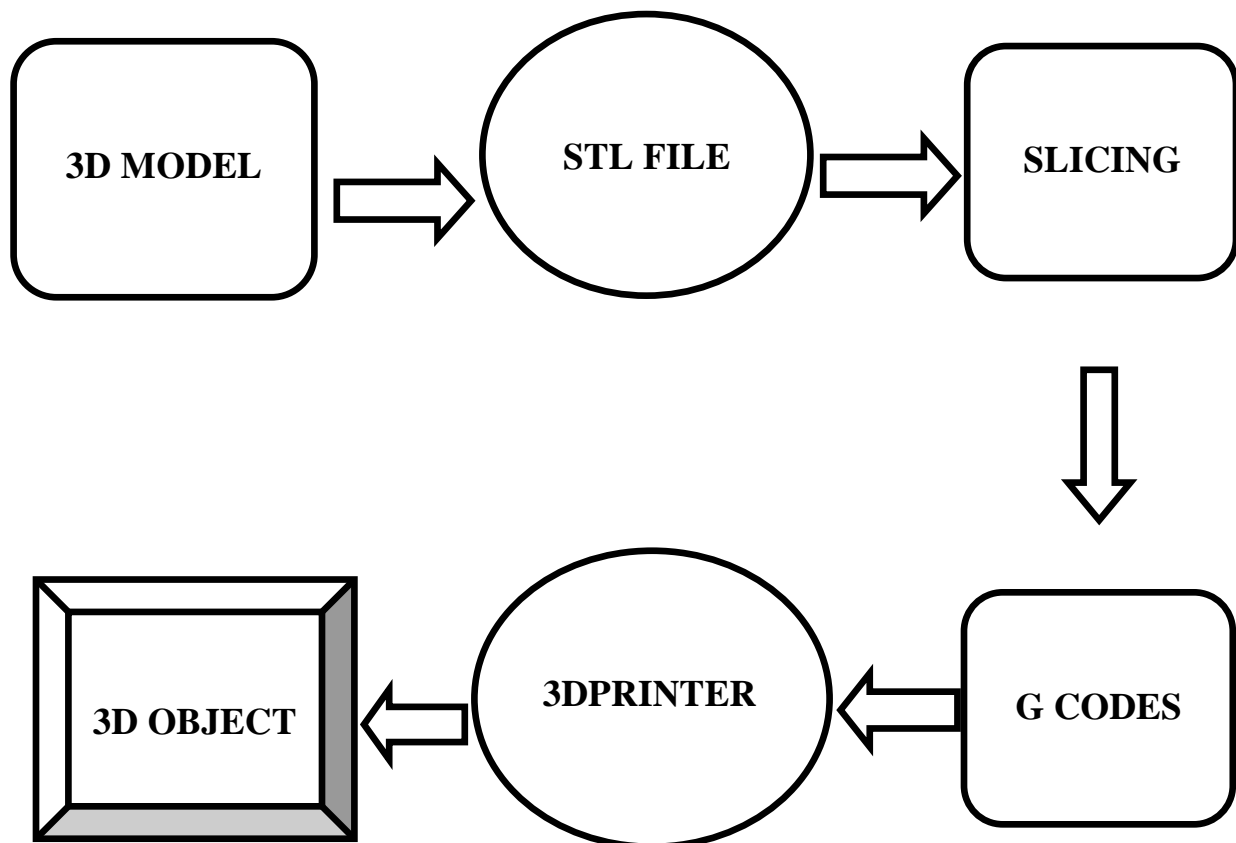


Fig: 4.2: Flowchart for 3D printing process.

# **CHAPTER 5**

## **DESIGN OF 3D PRINTER**

# Chapter 5

## DESIGN OF 3D PRINTER

### 5.1 INTRODUCTION

The design concepts of the 3D Printer deals with the circuit diagram of Ramps 1.4 mother board in which the connection of Ramps 1.4 with end stops, extruder stepper motors and axes stepper motors are shown. In this section we provide information regarding the linear motion along x,y and z axes, stepper motor rated current and also different calibrations which have to be done to increase the efficiency of the machine to get good quality print

### 5.2 CIRCUIT DIAGRAM

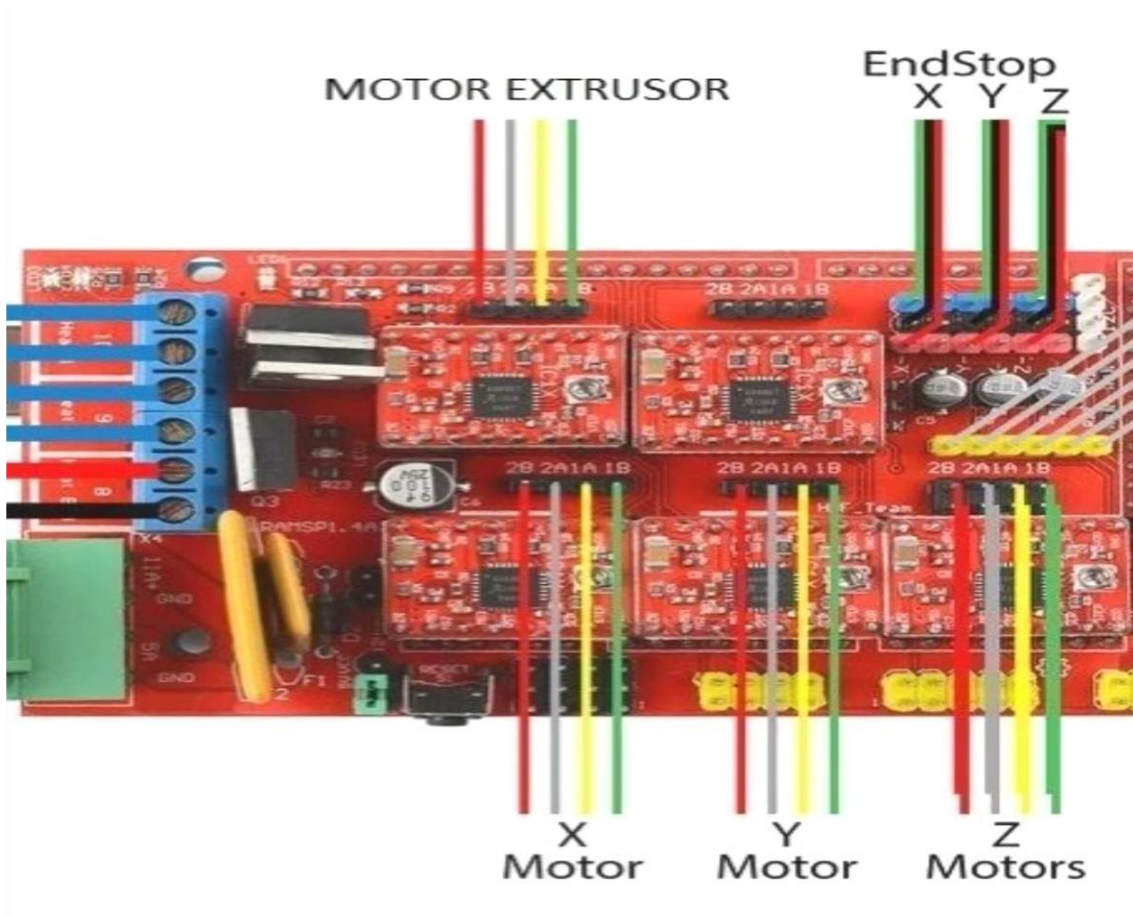


Fig 5.1: Circuit diagram of Ramps 1.4

Figure 5.1 shows the Ramps 1.4 board and its connections for the x, y, z, E0 and E1 stepper motors. The Z connector is actually doubled, so we can plug 2 separate stepper motors into

this one stepper driver. E0 and E1 are for extruder stepper motor connections and we have one extruder stepper motor and it is connected to E1 pin. From left to right of Ramps 1.4, each column corresponds to x-min, x-max, y-min, y-man, z-min, z-max. The three end stops for the three axes x, y and z are connected to this pins on Ramps 1.4

### 5.3 LINEAR MOTION ALONG DIFFERENT AXES

3D printer's linear motion system is one of the most important of the many mechanisms that make up a 3D printer. The linear motion system on a 3D printer is used to move the hot end and/or built platform along the x-axis, y-axis, and z-axis.

A 3D printer's linear motion systems consist of two main parts: the motor that turns electrical energy into rotational motion, and some kind of mechanism to turn the rotational motion of the motor into linear motion.

Stepper motors are used in 3d printers to to drive their linear motion systems. A stepper motor is a specialized type of motor that allows a controller to tell the motor exactly how much to spin. In other words, the 3D printer electronics can control the position of the stepper motor very precisely. This is important for 3D printing because the ability to set the exact position of the stepper motors translates to setting the exact position of the extruder.



Fig: 5.2 Stepper Motor with Belt Drivers

Belt drives are used in 3D printers for linear motion of the axes. Above Figure 5.2 shows the Stepper motor with Belt Drivers. A belt drive consists of a timing belt with teeth, a toothed pulley which is attached to the motor, and a carriage attached to the belt. When the

motor turns, it turns the pulley. The teeth on the pulley interface with the teeth on the timing belt so that when the motor rotates the pulley, the timing belt is pulled in the direction it needs to go. A carriage is typically attached to the belt such that it moves back and forth with the belt.

**Stepper motor rated current tuning:** Setting the stepper driver current is an important step in calibrating a 3D printer, although typically the value does not need to be exact. There is a window within which the printer will operate without issue.

If the stepper motor is missing steps or you are experiencing layer shifts, the stepper current needs to be increased. This will supply more torque to the motor but also make it (and the driver) run hotter. If the stepper motor is too hot to touch, the stepper current needs to be decreased. This will remove torque and make the motor (and the driver) run cooler.

The general steps for setting current via  $V_{REF}$  are the same between drivers, only the  $V_{REF}$  formula changes:

1. Power up motherboard (Ramps 1.4) via 12V normal power supply.
2. Set multimeter to DC voltage, max 2V range.
3. Connect black/negative multimeter probe to ground. This can be a negative terminal or the top of the USB connector.
4. Connect the red/positive probe to the trim pot on top of the driver to measure  $V_{REF}$ .
5. Turn the trim pot SLOWLY with a screwdriver, then remeasure.

For A4988 Stepper motor driver

The typical sense resistor value is 0.1.

$$V_{REF} = 8 \times \text{max current} \times \text{sense resistor value.}$$

max current for stepper motor from its data sheet is 1.5A .

so finally, we get **Vref=1.2v**



### 5.3.1 The X-axis linear motion

The x axis linear motion carries the hot end and extruder the x axis consists of one stepper motor connected to the hot end using belt drivers and pulleys to cause the motion of hot end in positive and negative x directions.

### 5.3.2 The Y-axis linear motion

The y axis linear motion carries the print surface with or without the heat bed platform. The y axis consists of one stepper motor connected to the platform using belt drives and pulleys to cause the motion of platform in positive and negative y directions.

### 5.3.3 The Z-axis linear motion

The z axis linear motion carries through the threaded rod connected to the Stepper Motor. The z axis consists of one stepper motors to lift the entire z axis using belt drives and pulleys to cause the motion of platform in positive and negative z directions. Figure 5.3 shows the Hardware implementation of the 3D printer along with the Respective axis.



Fig: 5.3: Representing X, Y and Z axes in 3D Printer.

## **5.4 CALIBRATIONS**

As with any mechanical product with moving parts, calibration plays an important role in ensuring consistent accuracy. 3D printers is also one such machine which needs calibration. They are exceptionally accurate pieces of equipment, but only if they are calibrated after the initial setup and whenever they are moved or transported.

This process of adjustment and fine-tuning is used to correlate the readings of an instrument (or piece of equipment) with a standard, in order to check the instrument's accuracy. Some of the parameters to be calibrated in a 3D printer are temperature, acceleration, distance ...etc.

### **5.4.1 Bed Leveling**

One of the most important things to check before starting a print is that the bed is level. An unlevel bed means that the distance between the nozzle and the build plate changes at different points and can result in problems with print adhesion and the quality of the first layer. The biggest problem when manually leveling a 3D printer bed is finding the correct distance between the nozzle and the print surface. Too far and your prints won't stick. Too close and you'll damage the print surface. So the nozzle should be in paper thickness difference with the base platform where the printer prints the 3D object.

### **5.4.2 Temperature Calibration**

The temperature plays a crucial role in getting quality products using 3D Printer. The temperature up to which the filament should be heated to get a good print depends on the type of filament. The temperature of the PLA filament which is used to print a 3D object ranges from 180°- 220°C. The optimum temperature for a quality print should be identified from the range of temperatures. The best method to find the optimum temperature is by building a temperature tower as shown in the figure 5.4 with different temperatures and finding the best temperature for the filament.



Fig 5.4: Temperature tower

In the figure 5.4 the temperature tower is built with different temperatures ranging from 180°C-210°C. The quality of the print increases as the temperature increases. The good print is obtained at the temperature 210°C. So the optimum temperature for good quality print for this 3D printer is 210°C.

### 5.4.3 Retraction Distance and Retraction Speed Calibration

FDM works by melting plastic filament and extruding it accurately one layer at a time to build up 3D geometry. By its nature, the plastic will continue to ooze and drip out of the nozzle even when not pushed by the extruder. To combat this, our slicers use retraction, where the filament is withdrawn from the hot end, alleviating pressure and minimizing ooze. When properly tuned, this has the effect of removing stringing, the unwanted oozing of plastic between two points of the model.

**Retraction distance:** The length the filament is pulled away from the nozzle in mm.

**Retraction speed:** The speed at which this filament is withdrawn in mm/sec.

By varying retraction distance & retraction speed, the section of print where the ooze and drip from the nozzle gets minimized, that retraction values are taken into consideration.

Figure 5.5 shows the Retraction Distance Testing Tower, the print retraction distance is varied from 5mm up to 7.5 with a difference of 0.5mm per section of the print. From the Figure 5.5 we can clearly see that at retraction distance of 7mm print is clear.

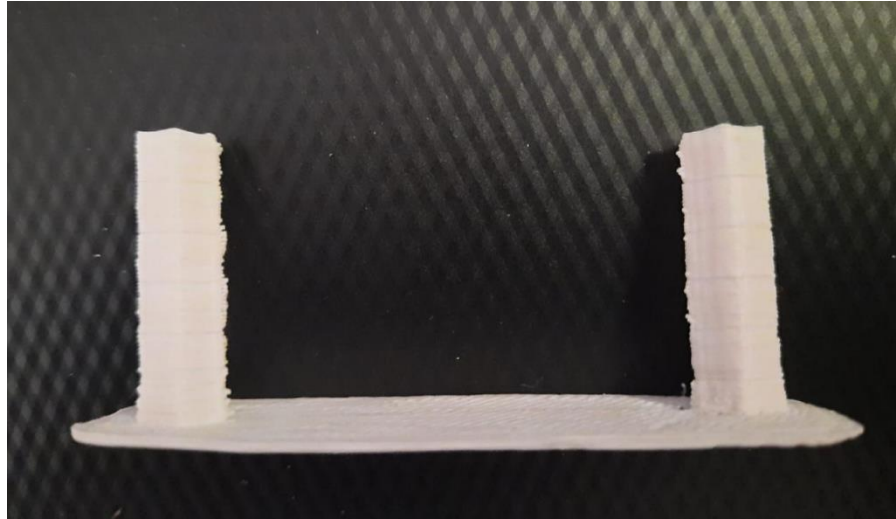


Fig 5.5: Retraction distance testing tower

Figure 5.6 shows the Retraction speed Testing Tower where the print retraction speed is varied from 25mm/sec to 50mm/sec with a difference of 5mm/sec per section of the print and from the figure 5.6 we can clearly see that at retraction speed of 50mm/sec the print is clear.

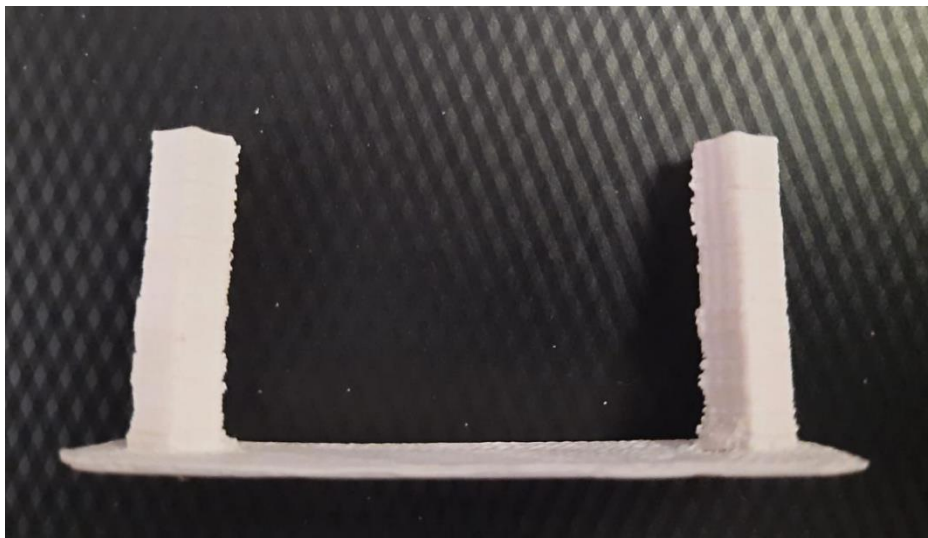


Fig 5.6: Retraction speed testing tower

#### 5.4.4 X,Y,Z Axis Calibrations

For 1.8° stepper motor, in micro stepping mode(1/16 of full step) makes 3200 steps to complete 1 full revolution(i.e. 360°). For X &Y axes we had used timing belt(2mm pitch) and pulley(20 teeth) for linear movement along the axes, for one full 360° rotation of stepper motor the axis would move 40mm,

$$\text{steps per mm along X \& Y axes} = \frac{\text{motor steps per revolution}}{\text{no. of pulley teeth} * \text{Belt Pitch}}$$

which results in 80 steps for a stepper motor to make a linear movement of 1mm along the X & Y axes.

Along Z axis we had used a 4 start lead screw of 2mm pitch , for linear movement along the axes,for one full 360° rotation of stepper motor the axis would move 8mm,

$$\text{steps per mm along Z axis} = \frac{\text{motor steps per revolution}}{\text{no. of start} * \text{pitch of rod}}$$

which results in 400 steps for a stepper motor to make a linear movement of 1mm along the Z axis.

# **CHAPTER 6**

## **RESULTS**

# CHAPTER 6

## RESULTS

### 6.1 INTRODUCTION

In this section we kept the image of Fused Deposition Modelling (FDM) 3D printer which we built using Arduino. We also provided some 3D print models before and after calibration to show the necessity of calibrations to get a good quality print and also some of the 3D print models of objects like pulleys, gear rods..etc which are useful to build other hardware projects.

However these 3D Printers are generally used in various applications like

- Education.
- Industrial design.
- Engineering and Construction.
- Automotive.
- Aerospace.
- Dental and medical industries.
- Consumer products.
- Art.
- Jewellery.
- Food Processing.
- Prosthetics.
- Prototyping.
- Defense.

These are just a few of the countless ways, from education to medicine to industry to the arts, that 3D printing technologies impact our world today.



## 6.2 RESULT

a) FDM 3D Printer using Arduino: Figure 6.1 shows the hardware implementation of 3D printer connected with the Arduino and Ramps 1.4 board.

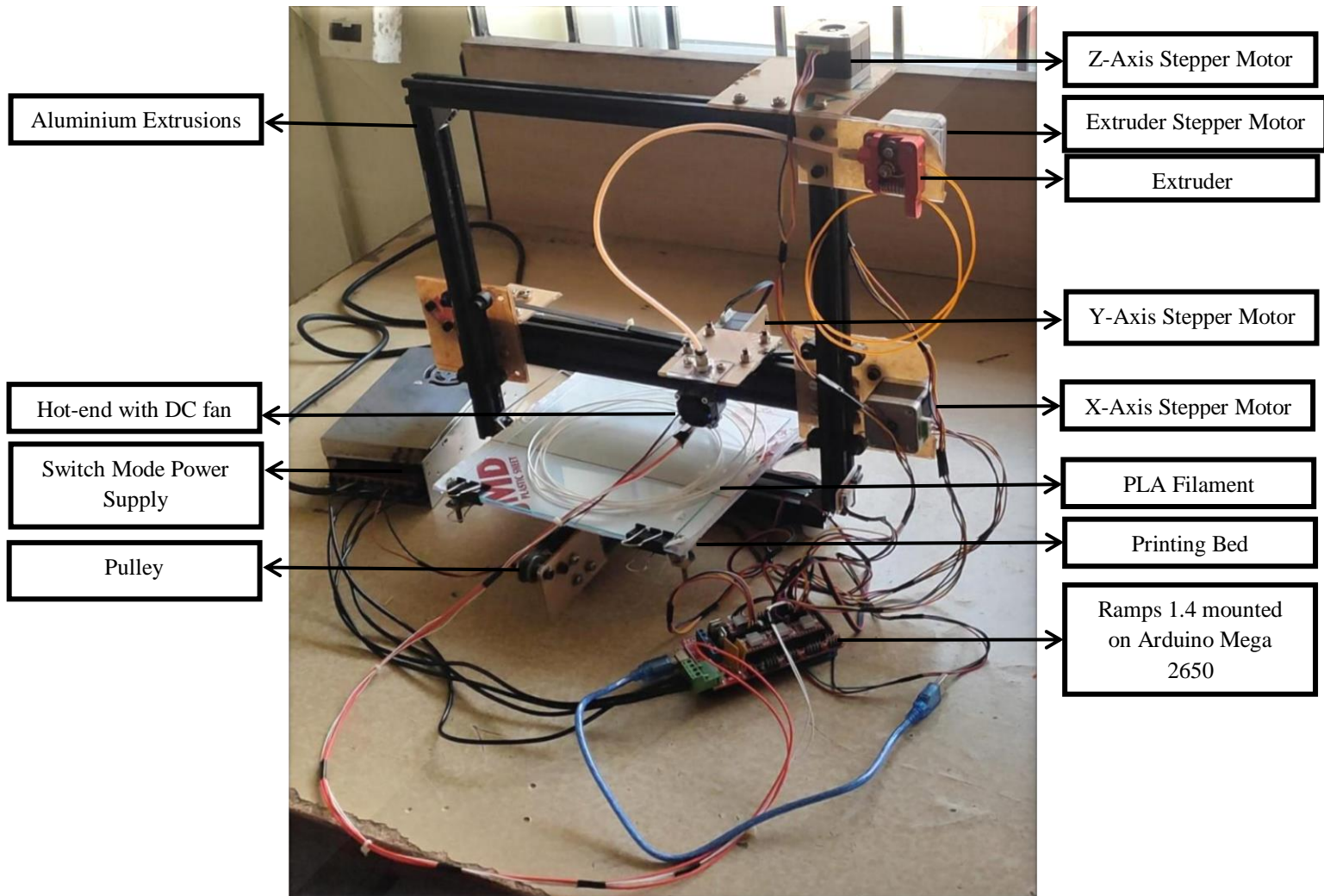


Fig 6.1: FDM 3D Printer using Arduino

b) Cube model before and after calibration: Calibrations is one the must for every 3D printer. A good Calibrated 3D printer gives the better shapes with less errors. Below figure 6.2 which is before calibrations have errors and the figure 6.3 shows us the cube after



calibrations and the errors are reduced. From figure 6.2 i.e. without calibrations we can clearly see the unwanted layers and in figure 6.3 i.e. after calibrations there were less unwanted layers.



Fig 6.2: 3D Cube Model Before Calibrations

Fig 6.3: 3D Cube Model After Calibrations

c) 3D models useful for projects: We can print many items useful for our project, some of which are shown in the below figures 6.4 and 6.5. Figure 6.4 shows the Pulley which can be used in our project as an replacement for the pulley used in timing belt and Figure 6.5 shows the sample Gear which can be 3D printed.



Fig 6.4: Pulley



Fig 6.5: Gear

## **CONCLUSION:**

This project emphasizes on Fused Deposition Modelling (FDM) 3D Printing Technology which is rapidly evolving. This project focuses on making a economically feasible FDM 3D Printer using Arduino. This 3D printer enables a person to print a 3D object layer by layer using Poly Lactic Acid (PLA) material. The PLA material is chosen because of its printing ability at low temperatures and it doesn't require a heat bed .

The 3D printer is built using a Arduino IDE software for programming the Arduino Mega 2650 for its high processing power and user friendly nature. It also uses Slicer software for converting STL format files into G-Codes. The print area (150mm x 130mm x 90mm) and movement of base platform allows manufacturing complex parts. Now a 3D printer which is capable of manufacturing both educational as well as commercial prototypes was built and tested by printing 3D objects using PLA.

## **FUTURE SCOPE:**

The limitations of this project point towards the advancements to be done in the future. The cooling mechanism of the 3D Printer is responsible for good print should be regulated according to temperature. This can be done by regulating the speed of the fan near the hot end. Also in future we can include another extruder to print objects with two colors.

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