A Project Report

ON

DESIGN AND DEVELOPMENT OF A LOW COST 3-DIMENSIONAL PRINTER

Submitted in partial fulfillment of the requirements for award the

Degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS ENGINEERING

BY

SHIMRAN BHATIA – 16444

SHUBHAM MISHRA – 16449

SHUBHAM PANDEY – 16450

SONI GANGWAR – 178411

Under the Supervision of

Prof. Rakesh Kumar Singh

Department of Electronics Engineering,
Kamla Nehru Institute of Technology, Sultanpur
Affiliated to

Dr A.P.J. Abdul Kalam Technical University, Lucknow (UP) – India

2019-20

Electronics Engineering Department

Kamla Nehru Institute of Technology

Sultanpur (UP) – 228118

CERTIFICATE

This is to certify that **Ms. Shimran Bhatia (16444), Mr. Shubham Mishra (16449), Mr. Shubham Pandey (16450)** and **Ms. Soni Gangwar (178411)** have carried out the project work entitled **"DESIGN AND DEVELOPMENT OF A LOW COST 3-DIMENSIONAL PRINTER"** Submitted in partial fulfillment of the requirements for award the Degree of Bachelor of Technology in Electronics Engineering from Kamla Nehru Institute of Technology, Sultanpur affiliated to Dr. A.P.J. Abdul Kalam Technical University, Lucknow.

This report is the record of the candidates' own work carried out by them under our supervision and guidance. This project work is the part of their Bachelor of Technology in Electronics Engineering curriculum. Their performance was excellent and we wish them good luck for their future endeavors.

HEAD OF DEPARTMENT — **PROF. R K SINGH**

(ELECTRONICS ENGINEERING) — **(PROJECT GUIDE)**

DECLARATION

I hereby declare that this submission is our own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree of the university or other institute of higher learning, except where due acknowledgement has been made in text.

SHIMRAN BHATIA – 16444

SHUBHAM MISHRA – 16449

SHUBHAM PANDEY – 16450

SONI GANGWAR – 178411

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SHIMRAN BHATIA – 16444

SHUBHAM MISHRA – 16449

SHUBHAM PANDEY – 16450

SONI GANGWAR – 178411

ABSTRACT

Additive manufacturing, often referred to as 3D printing, is a new way of making products and components from a digital model. Like an office printer that puts 2D digital files on a piece of paper, a 3D printer creates components by depositing thin layers of material one after another, only where required , using a digital blue print until the exact component has been created.

Interest in additive techniques is growing swiftly as applications have progressed from rapid prototyping to the production of end-use products. Additive equipment can now use metals, polymers, composites, or other powders to “print” a range of functional components, layer by layer, including complex structures that cannot be manufactured by other means. By eliminating production steps and using substantially less material, ‘additive’ processes could be able to reduce waste and save more than 50% of energy compared to today’s ‘subtractive’ manufacturing processes, and reduce material costs by up to 90%. The use of additive manufacturing can potentially benefit a wide range of industries including defense, aerospace, automotive, biomedical, consumer products, and metals manufacturing.

This project aims to develop a 3D printer that not only counts for a cost effective output but a product that can be used by each and every one. After this project gets a final touch it will benefit the common people where the cost effectiveness is very crucial. Many 3D printing technologies are available to build a 3D object but this project aims to use that 3D manufacturing process that gives a cost effectiveness solution at a low wastage of printing material.3D printers capable of outputting in color and multiple materials already exist and will continue to improve to a point where functional products will be able to be output.

INDEX

CHAPTER 1 - INTRODUCTION

1.1. INTRODUCTION

History of printing starts from the duplication of images by means of stamps followed by the flat bed printing process in 18th century. In mid of the 19th century, color printing called as **Chromolithography** became very popular. A revolution occurred when the print workings, specifically a 2D printer was used as a peripheral device, which made a persistent human readable representation of the graphics a text in paper. After some years the concept of 3D printer starts evolving, a new way to look at the past printing technologies.Our report emphasizes on the design and development of a low cost 3D printer. 3D printer basically is concept to make or print the objects layer by layer and thus making it so called “Three dimensional”.

3D printing or additive manufacturing (AM) is any of various processes for making a three-dimensional object of almost any shape from a 3D model or other electronic data source primarily through additive processes in which successive layers of material are laid down under computer control. A 3D printer is a type of industrial robot.

The main aim of this project is to make the 3D printer available to a common man making this equipment easy to operate and automate working once the command and specific design is given to this device. So operating time will automatically decrease as it can handle the task without any human intervention .This also makes this device reasonable and approachable to everyone this project. This project deals or in other words targets the people who has cost as a main constrain and thus making a 3D printer useful in school laboratories, making imitation jewellery for women, automobile industries, making a prototype material in industries etc. This project aims to produce a plastic 3D output and make it accurate as close as possible compared to the present 3D printer requirements. This technology is a newly expanding find in terms of increasing the efficiency, increase in accuracy of product, reducing the cost of the printer.

3D printing technology is all about developing the self-replicating machine and bringsversatility due to which medical implants are possible through these printers’ end products. This technology has a drastic impact and can bring a radical change in our world as more and more people are getting accesses to these amazing machines.

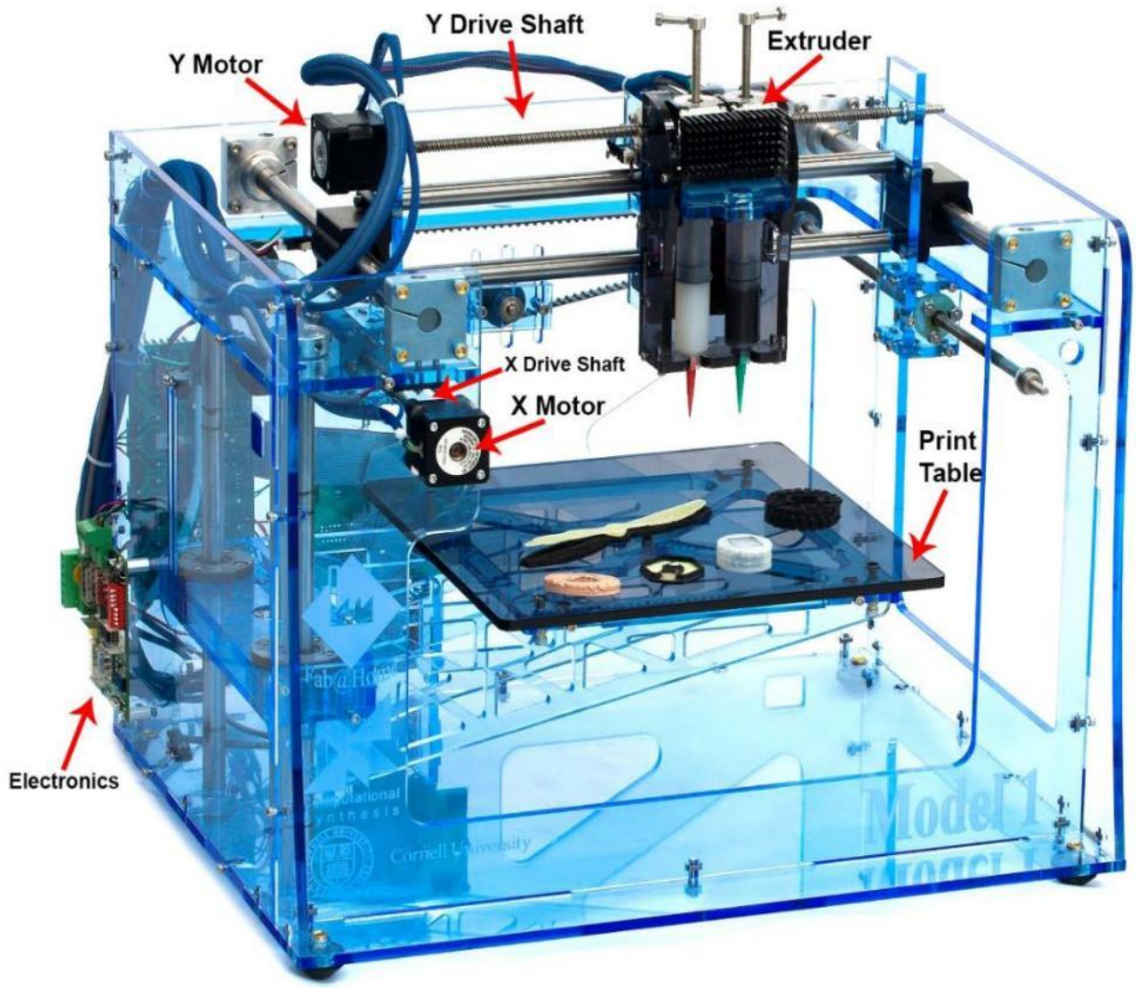

fig 1.1. A 3-D printer

3D-Printer is a machine reminiscent of the Star Trek Replicator, something magical that can create objects out of thin air. It can “print” in plastic, metal, nylon, and over a hundred other materials. It can be used for making nonsensical little models like the over-printed Yoda, yet it can also print manufacturing prototypes, end user products, quasi-legal guns, aircraft engine parts and even human organs using a person’s own cells.

Each of these printed layers is a thinly-sliced, horizontal cross-section of the eventual object. Imagine a multi-layer cake, with the baker laying down each layer one at a time until the entire cake is formed. 3D printing is somewhat similar, but just a bit more precise than 3D baking. In the 2D world, a sheet of printed paper output from a printer was “designed” on the computer in a program such as Microsoft Word. The file - the Word document which contains the instructions that tell the printer what to do.

In the 3D world, a 3D printer also needs to have instructions for what to print. It needs a file as well. The file, a Computer Aided Design (CAD) file is created with the use of a 3D modeling program, either from scratch or beginning with a 3D model created by a 3D scanner. Either way, the program creates a file that is sent to the 3D printer. Along the way, software slices the design into hundreds, or more likely thousands, of horizontal layers. These layers will be printed one atop the other until the 3D object is done.

The picture shows the structure of a typical 3D printer. The print table is the platform where the object for printing has been situated. It provides the basic support for manufacturing objects layer by layer.

The extruder is the most important part of a 3D-Printer. As the extruders in the normal paper printers, this extruder is also used to pour ink for printing. The movement of extruder in various dimensions creates the 3D print. For printing a 3d object, the extruder has to access X, Y and Z coordinates. For achieving this, many techniques are used according to the printer specification required for various applications.If the 3D-Printer is a desktop printer, the Z axis movement of the extruder can be avoided and that function can be transferred to the print table. This will avoid complexity in 3D printing as well as time consumption.

When the STL file is input to the printer, the microcontroller extracts each layer from it and also extracts each line segment from each layer. Then it gives controls to the movement of the extruder at required rate. The X-direction movement of extruder is made possible by the X-motor. When the X motor rotates, the shaft also rotates and the extruder moves in X direction. The Y-direction movement of extruder is made possible by the Y-motor. When the Y motor rotates, the shaft also rotates and the extruder moves in Y direction. The X direction movement is made by the print table.

In the case of desktop printers, the printing ink is usually plastic wire that has been melted by the extruder at the time of printing. While printing, the plastic wire will melt and when it fall down to the printing table. Consider printing larger objects like house using 3D printer. There will not be any X motor or Y motor in that case. An extruder which can pour concrete mix is fixed on the tip of a crane. The crane is programmed for the movement of extruder in X, Y and Z axis. Generalizing the facts, the extruder need to access all the 3 coordinates in space to print and object. The method used for that doesn’t matters much.

CHAPTER 2 – LITERATURE REVIEW

2.1. ADDITIVE MANUFACTURING

Additive manufacturing is a truly disruptive technology exploding on the manufacturing scene as leading companies are transitioning from “analog” to “digital” manufacturing. Additive manufacturing uses three dimensional printing to transform engineering design files into fully functional and durable objects created from sand, metal and glass. The technology creates products layer by layer – after a layer’s particles are bound by heat or chemicals the next layer is added and the binding process is repeated. It enables geometries not previously possible to be manufactured. Full-form parts are made directly from computer-aided design (CAD) data for a variety of industrial, commercial and art applications.

Manufacturers across several industries are using this digital manufacturing process to produce a range of products, including: engine components for automotive applications, impellers and blades for aerospace use, pattern less sand moulds for pumps used in the oil and energy industry, and medical prosthetics which require easily adaptable design modifications.

This advanced manufacturing process starts with a CAD file that conveys information about how the finished product is supposed to look. The CAD file is then sent to a specialized printer where the product is created by the repeated laying of finely powdered material (including sand, metal and glass) and binder to gradually build the finished product. Since it works in a similar fashion to an office printer laying ink on paper, this process is often referred to as 3D printing. The 3D printers can create a vast range of products, including parts for use in airplanes and automobiles, to replacing aging or broken industrial equipment, or for precise components for medical needs.

There are tremendous cost advantages to using additive manufacturing. There is little to no waste creating objects through additive manufacturing, as they are precisely built by adding material layer by layer. In traditional manufacturing, objects are created in a subtractive manner as metals are trimmed and shaped to fit together properly. This process creates substantial waste that can be harmful to the environment. Additive manufacturing is a very energy efficient and environmentally friendly manufacturing option.

Additive manufacturing swiftly creates product prototypes – an increasingly critical function that significantly reduces the traditional trial-and-error process – so new products can enter the market more quickly. Likewise, it can promptly create unique or specialized metal products that can replace worn or broken industrial parts. That means companies can avoid costly shut downs and drastically compress the time it takes to machine a replacement part.

With additive manufacturing, once a CAD drawing is created the replacement part can be printed. Storage of bulky patterns and tooling is virtually eliminated.

Major global companies, including Ford, Sikorsky and Caterpillar, have recognized that additive manufacturing can significantly reduce costs while offering design freedoms not previously possible. They have begun to implement the technology into their manufacturing processes. Additive manufacturing has robust market capabilities ranging from aerospace to automotive to energy, and it is not uncommon to find 3D printers in use at metal-working factories and in foundries alongside milling machines, presses and plastic injection molding equipment.

fig. 2.1. Additive manufacturing technique

2.2 PRESENT 3-D PRINTING TECHNOLOGIES

The aim of all the 3D printing technologies is to develop an additive manufacturing process that creates an object layer by layer. Some common features for all the additive manufacturing processes is the usage of computer with special 3D modeling software. The first part of this process is to create a CAD diagram. The AM device reads the output from the CAD file and builds a structure layer by layer with the printing material which can be plastic, powder filaments or may be a sheet of paper. This chapter deals with all the famous 3D Printing Technologies that are used commonly.

2.2.1. Stereo lithography (SLA) - This method is the oldest method and is still been used nowadays. This method was patented in year 1986. This process involves a stereo lithography apparatus (SLA) which converts liquid plastic into solid 3D objects. In this method the CAD file generated creates an output in such a way that can be understood by the electronics. The Standard Tessellation Language (STL) is commonly used for this process. This process first produces STL file such that the printing machine should have the information of each layer. The SLA machine uses laser to cut the layer when a required dimension is completed and this process is repeated again and again till the whole structure is printed on the printed plate.

After plastic hardens a platform of the printer drops down in the tank a fraction of a millimeter and laser forms the next layer until printing is completed. Once all layers are printed the object needs to be rinsed with a solvent and then placed in an ultraviolet oven to finish processing.

Stereo lithography is widely used in prototyping as it does not require too much time to produce an object and cost is relatively cheap comparing to other means of prototyping.

fig. 2.2. Stereo lithography technique

2.2.2. Fused Deposition Modeling (FDM) – Fused Deposition Modeling (FDM) technology was developed and implemented in 1980's. By using this method not only functional prototypes can be printed but also concept models and final end-use product is implemented. What is good about this technology is that all parts printed with FDM can go high-performance which is highly beneficial for mechanic engineers and manufactures. FDM is the only 3D printing technology that builds parts with production grade thermoplastics, so things printed are of excellent mechanical, thermal and chemical qualities. This method does not waste plastics so this method is widely uses more over this method does not uses lasers.

3D printing machines that use FDM Technology build objects layer by layer from the very bottom up by heating and extruding thermoplastic filament. The whole process is bit similar to stereo lithography .Firstly a special software "cuts" CAD model into layers and calculates the way printer's extruder would build each layer then the printer heats thermoplastic till its melting point and extrudes it throughout nozzle onto base, that can also be called a build platform or a table along the calculates path.

Once the layer is finished, the base is lowered to start building of next layer .compared to the previous process this method is bit slower. When printing is completed support materials can easily be removed either by placing an object into water and a detergent solution or snapping the support material off by hand.

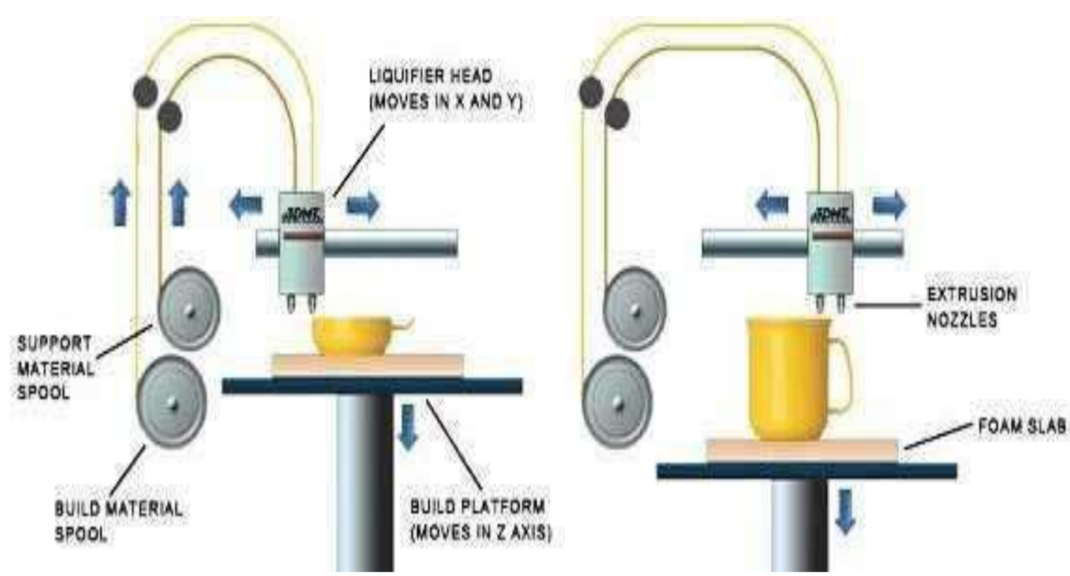

fig. 2.3. Fused deposition modeling technique

2.2.3. Selective Laser Sintering (SLS) – Selective laser sintering is a technique that uses laser as power source to form solid 3D objects. This technique was also developed in 1980's .the main difference between the SLS and SLA is that it uses powdered material in the vat instead of liquid resin as stereo lithography does. Unlike some other additive manufacturing processes such SLA and FDM, SLS doesn't need to use any support structures as the object being printed is constantly surrounded by unfiltered powder. Like all other methods listed above the process starts with creation of computer aided design (CAD) file, which then needs to be converted to .stl format by special software the material to print with might be anything from nylon ceramics and glass. To some metals like aluminum, steel or silver. Due to wide variety of material that can be used with this type of 3D printer this technology is very popular for 3D printing customized product.

2.2.4. Selective Laser Melting (SLM) – Selective laser melting (SLM) is a technique that also used 3D CAD data as a source and forms a 3D object by means so a high-power laser beam that fuses and melts metallic powders together. This method fully melts the metal material into solid 3D- dimensional part unlike selective lasers interring. The fine metal powder is evenly distributed onto a plate, and then each slice of 2D layer image is intensively fused by applying high laser energy that is directed to the powdered plate. The energy of laser is so intense that the metal powder melts fully and forms a solid object. After the layer is completed the process starts over again for the next layer. Metals that can be used for SLM include stainless steel, titanium, cobalt chrome and aluminum.

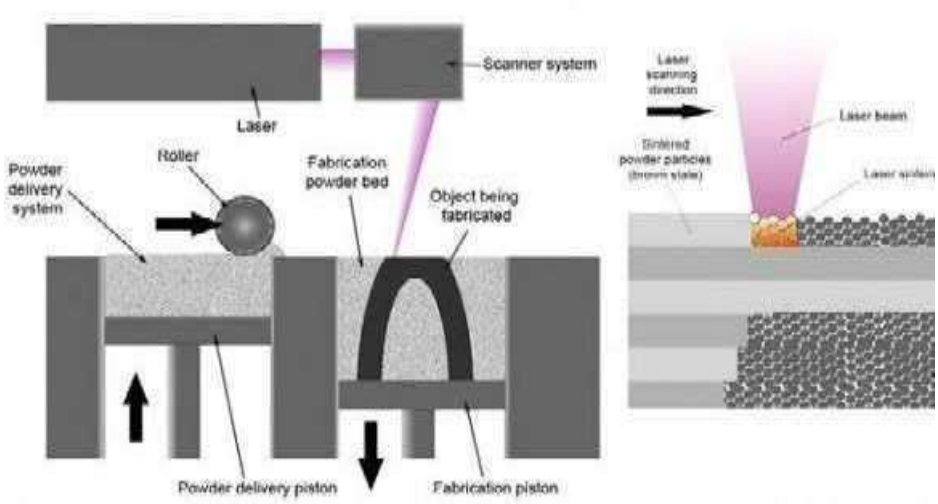

fig. 2.4. Selective laser melting technique

2.3. PROJECT AT A GLANCE

This chapter deals with the introduction, design and goal and the basic working principle of how the project works with a simplified block diagram and its brief explanation. Thus with this chapter the main motive of the project would be clear with the basic understanding of the project.

2.3.1. Definition

3D Printing technology is an additive manufacturing technology where a three dimensional object is created. This technology is a rapid prototyping technology.

2.3.2. Design

The design structure that this project aims is a Cartesian model. Another type of printer is Delta Model.

2.3.3. Problem Statement

The present 3D printing technology is very time consuming with a high manufacturing cost. This project aims not only to reduce the cost of the 3D Printer but also working upon its accuracy and time constraints.

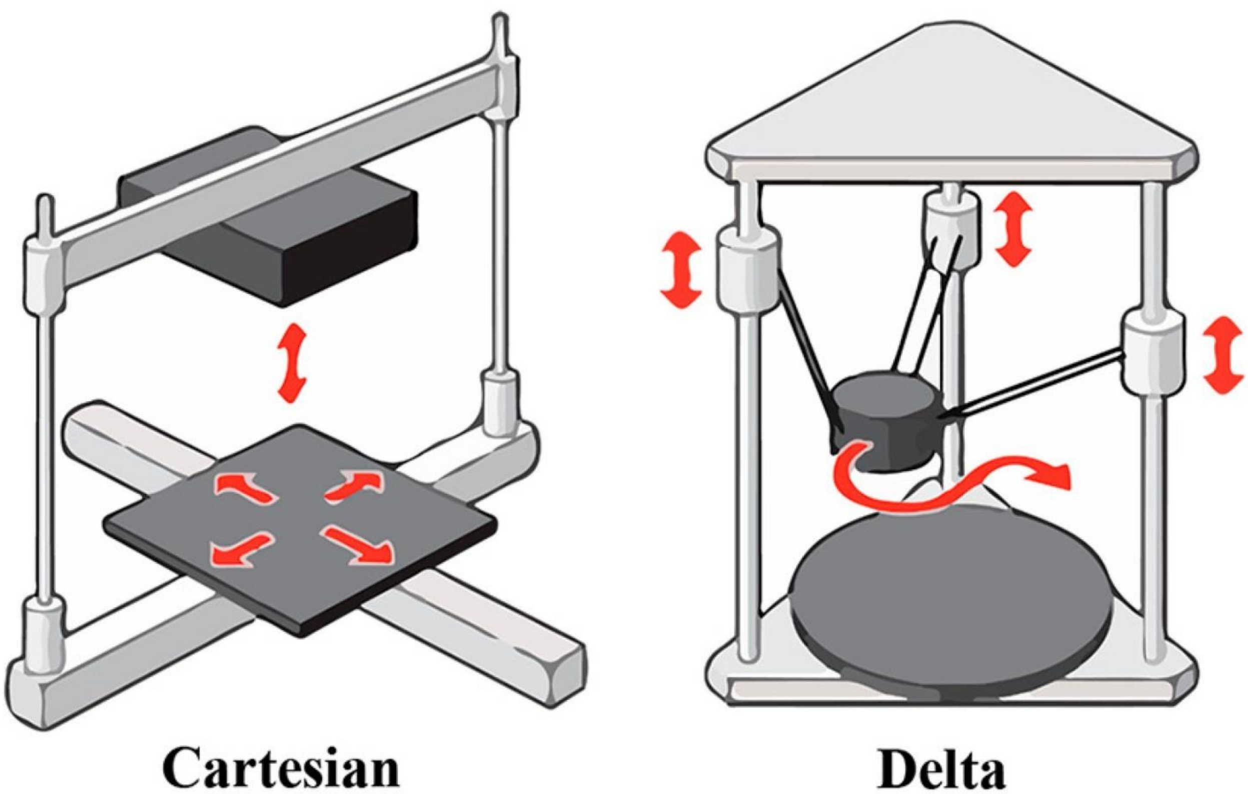

fig. 2.5. Cartesian and delta model

2.3.4. Possible Solution

The possible solution is designing a frame and using only the most important materials and using the printing technology that minimizes the wastage of plastic to give maximum efficiency to the product output.

2.3.5. Simplified Block Diagram

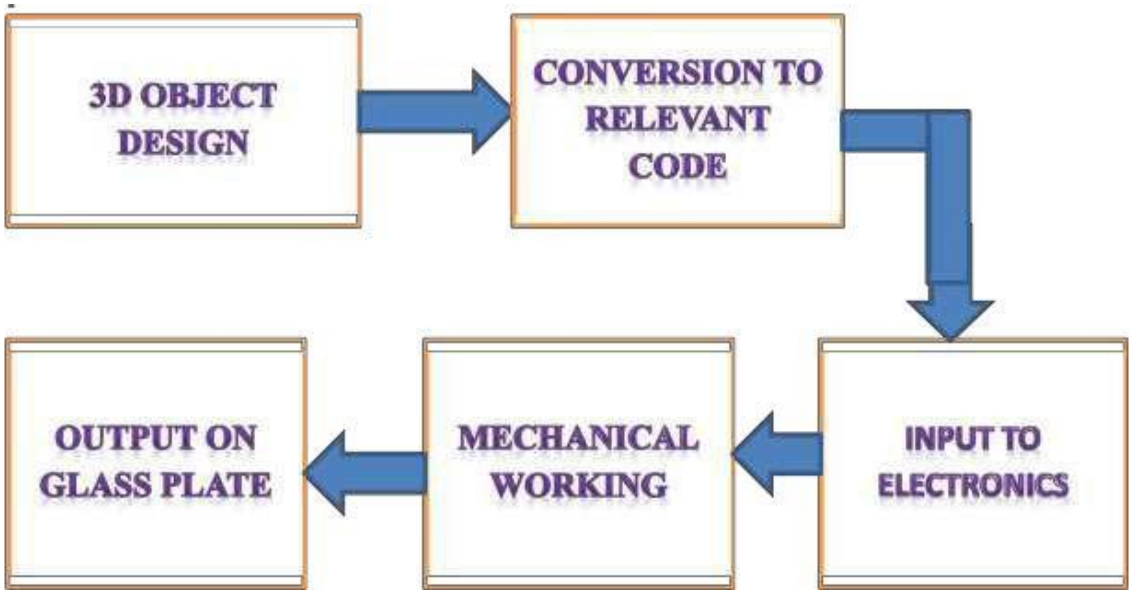

Fig. 2.6. Simplified block diagram of the 3-D printer

This above block diagram describes the basic working of the product. As shown in above block diagram:

Firstly a 3D object is designed using a CAD Tool and then is converted in such a file format specifically a G-Code using software's like Cura or Repetier that is understandable by the electronics that mainly includes the Microcontroller.

Input is given to the electronics that give commands to the motors according to the design in the CAD Tool.

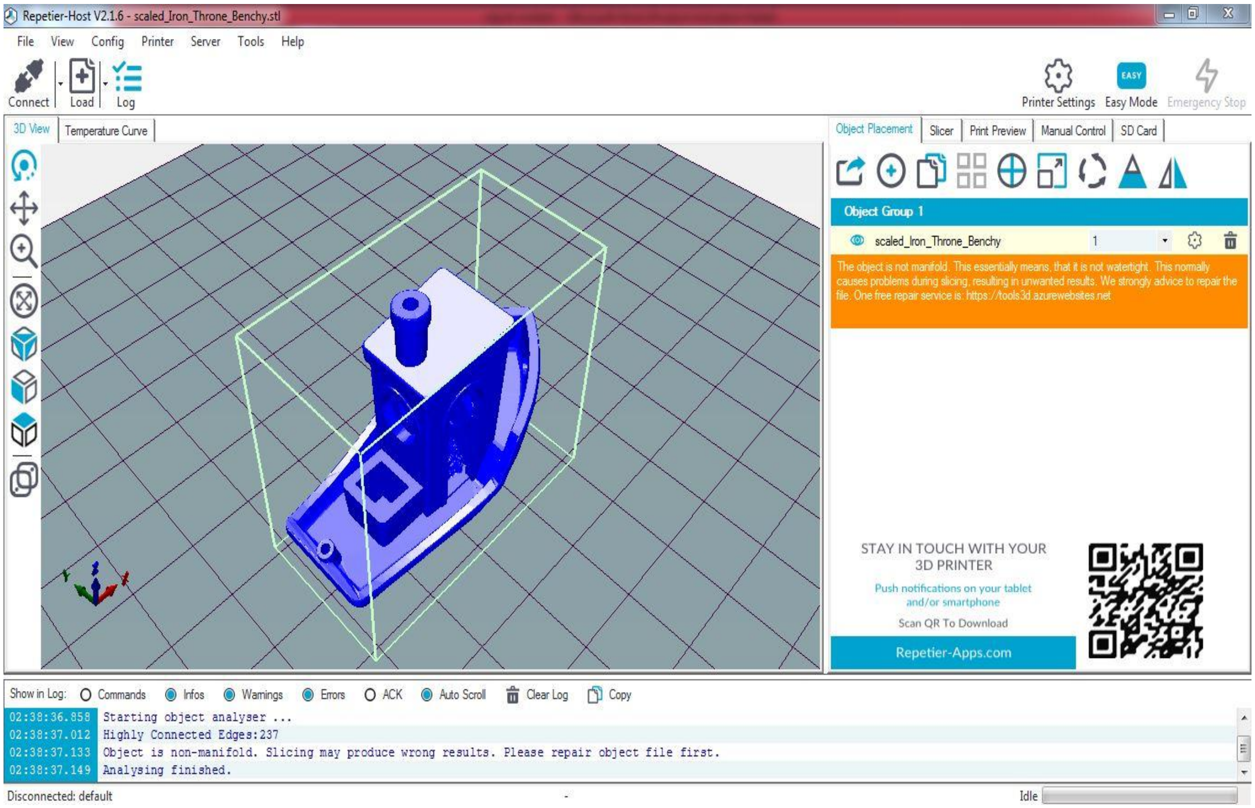

Fig. 2.7. Inputs given to the CAD Tool

The mechanical components including motors, extruder works accordingly and thus a layer by layer object is printed (in layman language plastic is glued) on the print plate or glass plate. After the 3D object gets cooled to a certain temperature the final end product can be taken out.

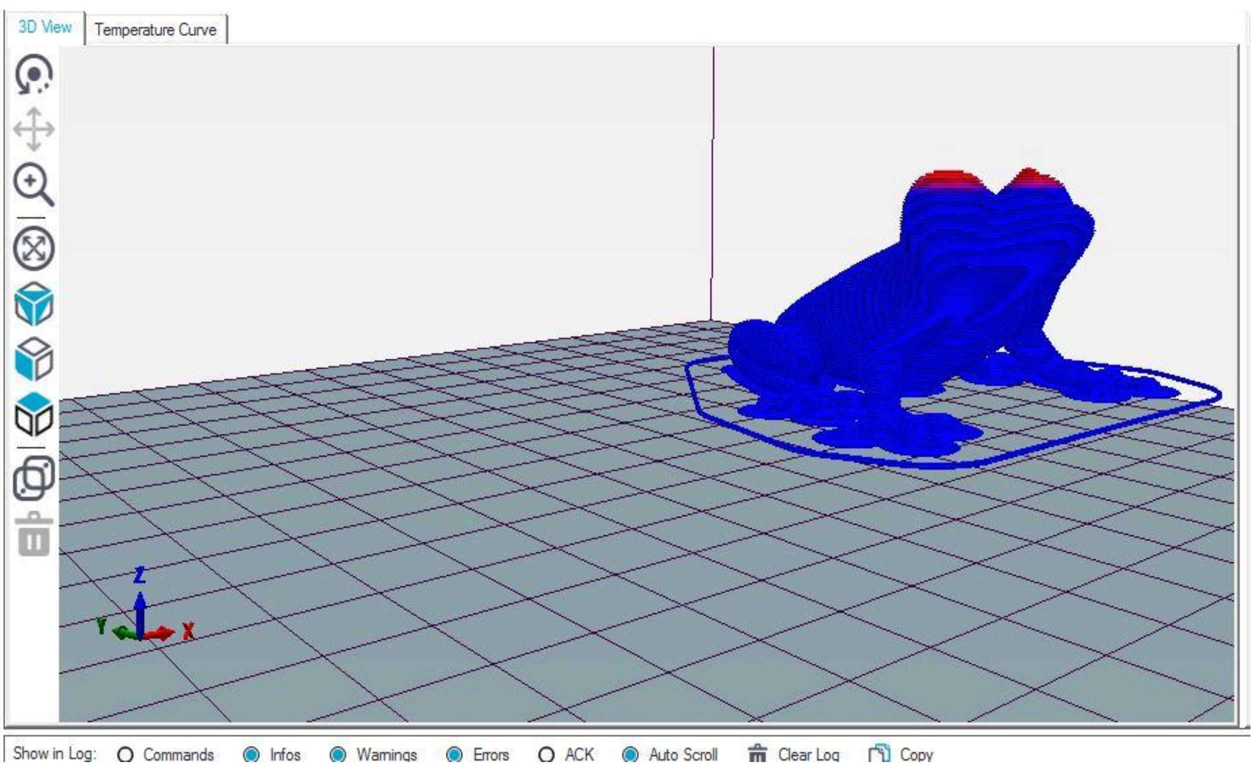

Fig. 2.8. Designing the object to be made

In this way the simple process works to build a 3D object. Thus a prototyping of the project also becomes easier as the specified or the required designed on an initial stage is formatted on a CAD Tool and your printer starts to print! To get a change in the final product structure the design in the CAD Tool only needs the change, rest all the working remains unchanged.

2.3.6. Working with Files

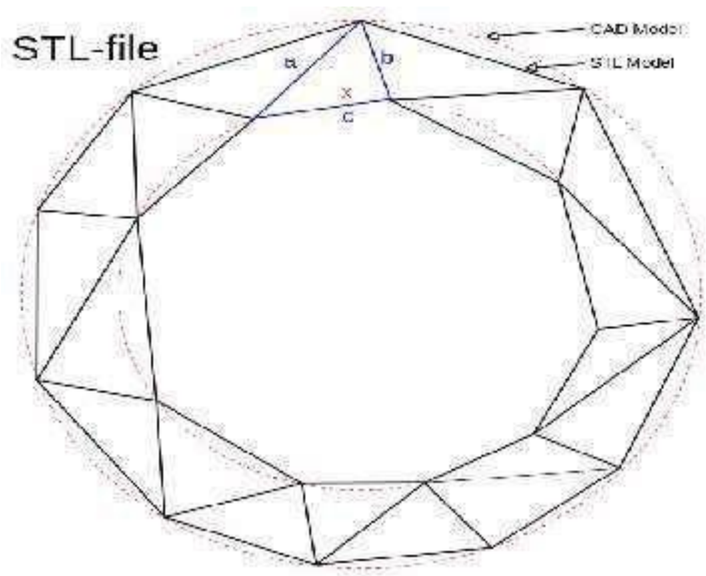

Fig. 2.9. The .stl file

There are several different file types used in 3D Printing file extensions that includes .stl, .fff, .gcode, .factory. STL and OBJ files are the output from the CAD Software's. After the STL and OBJ files are imported the next work is to add the process. This process adds all the information that how the object is sliced and printed on the print plate including the settings of the extruder, infill, temperature, supports etc. After this process is saved and exported a FFF file is created. If we want to again change the process settings for example changing the printing speed, infill percentage etc. There comes option of "Edit Process Settings". After making such modification the OK option is clicked to save the changes.

2.3.7. How 3D Printer Works?

The basic working principle of 3D printer is to print the object layer by layer fill the targeted object design and to finish the printer has a frame structure and three axis x y and z axis that moves left to right front to back and up and down .

The component called extruder which is responsible for feeding the plastic to print and melt the plastic. To print the plastic layer the movement of the extruder and stepper motor need to be controlled for that PWM generated by the Arduino is used, the g-code generated is used to drive the axis accordingly with help of CAD tools targeted objects are designed and converted into g codes with the help of software like Repetier and being given to electronics that includes motor which is placed on the frame according to the frame design. According to the commands given tothe electronics motor works and through the help of extruder which is also running through the motor melts the plastic accordingly on the print plate.

The plastic material used in this project is bio degradable plastic materials. After the object is finished the final object is taken out. In this way the process started with the designing object specifically a 3D object and ended with the generating the same 3D object same object in front our eyes!

2.4. COMPONENT DESCRIPTION

This chapter includes the description of various different components used in the development of the system project. It is really very necessary to describe the features of the components that are used in the designing of the system. This chapter includes the brief description of the components along with their pin configuration and different features.

2.4.1. Frame

Selection of frame is an essential part for system designing. This frame gives the support to the printer. All the axes of the motor added to this frame. The threaded rods are mounted on this frame and rubber strips controlled by motor action.

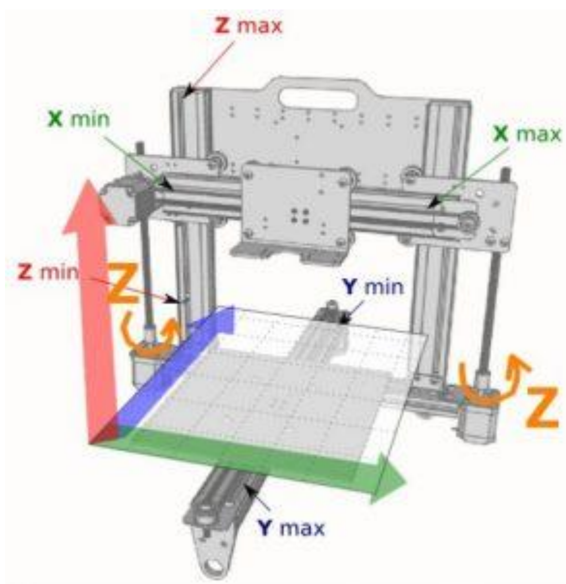

fig. 2.10. Frame of the 3-D printer

2.4.2. Extruder

Extruder consists of two parts, a cold top part that feeds the plastic filament, hot part at bottom that melts and extrudes the plastic. The speed of the extruder head may also be controlled, to stop and start deposition and form and interrupted plane without stringing or dribbing between sections.
The extruder used here is MK3 extruder.

fig. 2.11. The extruder

Specifications:

Filament Diameter (mm)

1.75

Nozzle Diameter

0.2mm

Cable Length

0.3 m (30 cm)

Length (mm)

75

Width (mm)

28

Height (mm)

37

The v6 HotEnd allows you to print a wide variety of materials, from soft and flexible to sturdy and strong. This is possible due to the PTFE (Polytetrafluoroethylene) liner tube through the hotend that you can extend into your extruder – this gives the ability to add the confinement and constraint needed to make excellent quality prints with flexible filaments. This technology opens new doors for your 3D printing aspirations. The maximum temperature that the extruder can reach is 250 degree C.

2.4.3. Stepper Motor

The stepper motor is an electromagnetic device that converts digital pulses into mechanical shaft rotation. Many advantages are achieved using this kind of motors, such as higher Simplicity, since no brushes or contacts are present, low cost, high reliability, high torque at low speeds, and high accuracy of motion.

This project involves the usage of at least five motors specifically five stepper motors .one motor to control the Y-axis, the other to control the X-axis, two to control Z-axis and one to control the extruder. The configuration of all the five motors is same and the driver is used to drive the motor.

fig. 2.12. The stepper motor

The two types of stepper motors that are the bipolar motor and unipolar motor. The bipolar and unipolar motors are similar, except that the Unipolar has a center tap on each winding.

Don’t forget to name the motors when completing the electronics part so that the wiring won’t get very confusing and untidy.

2.4.4. Driver A4988

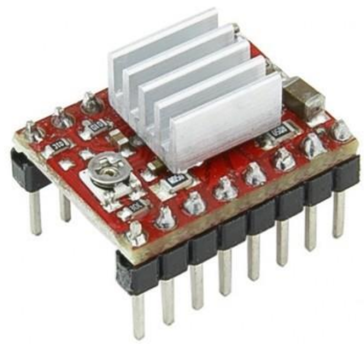

fig. 2.13. Driver A4988

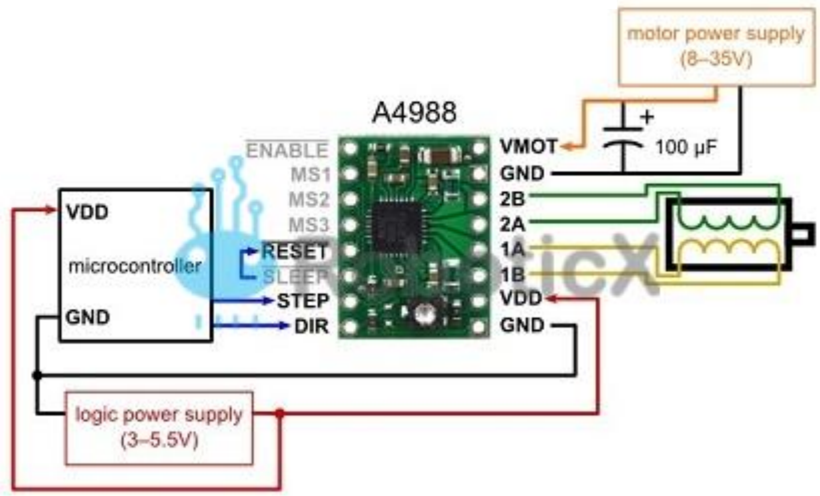

fig. 2.14. Pin diagram of driver A4988

The driver features adjustable current limiting, over current protection, and five different micro step resolutions. It operates from 8 – 35 V and can deliver up to 2 A per coil. Four drivers are used for running 5 motors, one for X, one for Y axis, one for extruder and one for driving 2 motors on Z axis. Heat Sink is pasted on the ramp so that IC should not be burned out.

2.4.5. Plastics

Plastics are one of the most important materials that are required because it is the material of which the end product is made. This project uses two types of plastics.

- *Acrylonitrile Butadiene Styrene (ABS) Plastics*-

It is a common thermoplastic polymer and is amorphous in nature .The most important prospect of this material is its resistance power subjective to force and toughness.ABS polymers are resistant to aqueous acids, alkalis, concentrated hydrochloric and phosphoric acids, alcohols and animal, vegetable and mineral oils, but they are swollen by glacial acetic acid, carbon tetrachloride and aromatic hydrocarbons and are attacked by concentrated sulfuric and nitric acids. They are soluble in esters, ketones, and ethylene dichloride.

Even though ABS plastics are used largely for mechanical purposes, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperatures. ABS is flammable when it is exposed to high temperatures, such as those of a wood fire. It will melt and then boil, at which point the vapors burst into intense, hot flames.

- *Polylactic Acid or Polyactide (PLA) Plastics*-

It is a biodegradable plastic material which is made from renewable resources such as corn starch and sugarcane. The main difference between the two plastics is that the ABS plastic type is known for its toughness whereas the other is known for its soft type of material. Thus for different purpose different plastic materials are used.

PLA has a minimum melting point of 170 degree C.

fig. 2.15. PLA Plastics

2.4.6. Software required-

Arduino Software:

This application allows installing the printer firmware on the ATMEGA 2560 microprocessor. To update the firmware each time this installation is required.

The firmware used here is called Marlin firmware that is used in most of the 3D printers around the world. The marlin firmware is edited according to the hardware available and baud rate of the communication.

Repetier Software:

The application to slice STL files into the G-Code. Each time the part that needs to be printed needs this type of software.

Before the print job this application is responsible for the communication with the electronics. In simple words it makes the printing output to be ready before the actual printing job.

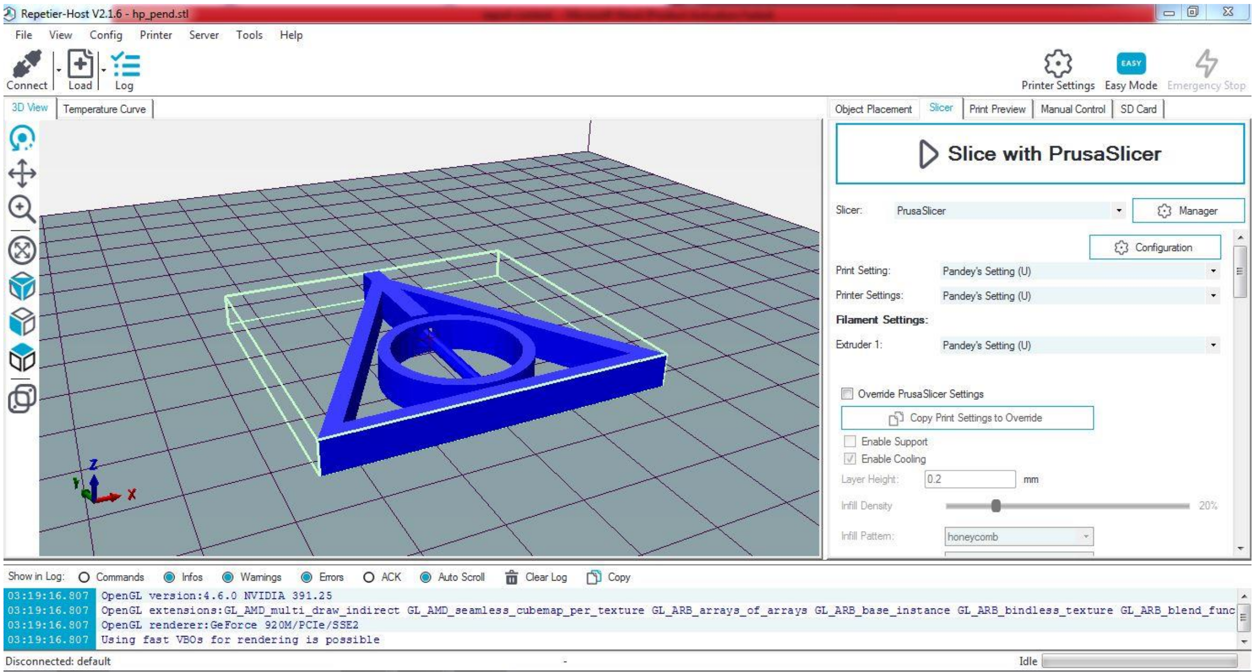

Fig. 2.16. Slicing with Prusa software

When we slice the 3D model, of specific layer width, we get to know the number of layers and time required to print the structure.

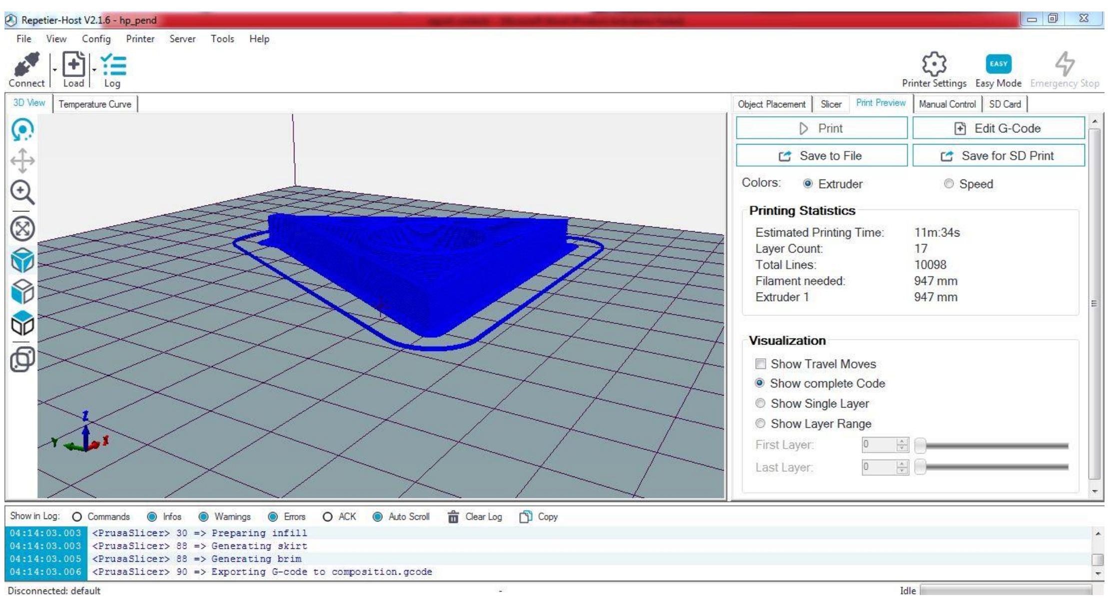

Fig. 2.17. Layers and timing estimation

2.4.7. GT2 timing belt and pulley-

fig. 2.18. GT2 timing pulley

This is Aluminum GT2 Timing Pulley 20 Tooth 8mm Bore For 6mm Belt. For precise motion control, GT2 belts and pulleys offer excellent precision at a great price. This pulley is meant for use with GT2 6mm wide belts only – MXL belts will slip due to the different tooth profile.

This pulley has 20 teeth and an 8mm inner bore. Two set screws can be used to attach it firmly to any 8mm diameter shaft. Full aluminum construction means these are very light and very durable.

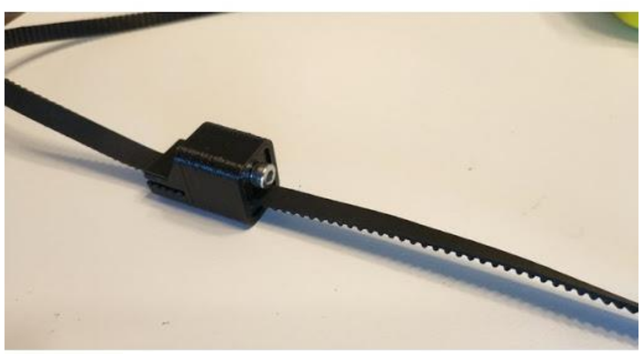

Fig. 2.19. GT2 timing belt

GT2 timing belts and compatible pulleys are popular choices for RepRaps and RepStraps.
The GT2 timing belt is a possible replacement for T2.5 and T5 timing belts that some believe may cause backlash. The GT2 series of belts are designed specifically for linear motion. They use a rounded tooth profile, with 2mm pitch, that guarantees that the belt tooth fits smoothly and accurately in the pulley groove, so when you reverse the pulley direction, there is no room for the belt to move in the groove.

2.4.8. Arduino Mega:

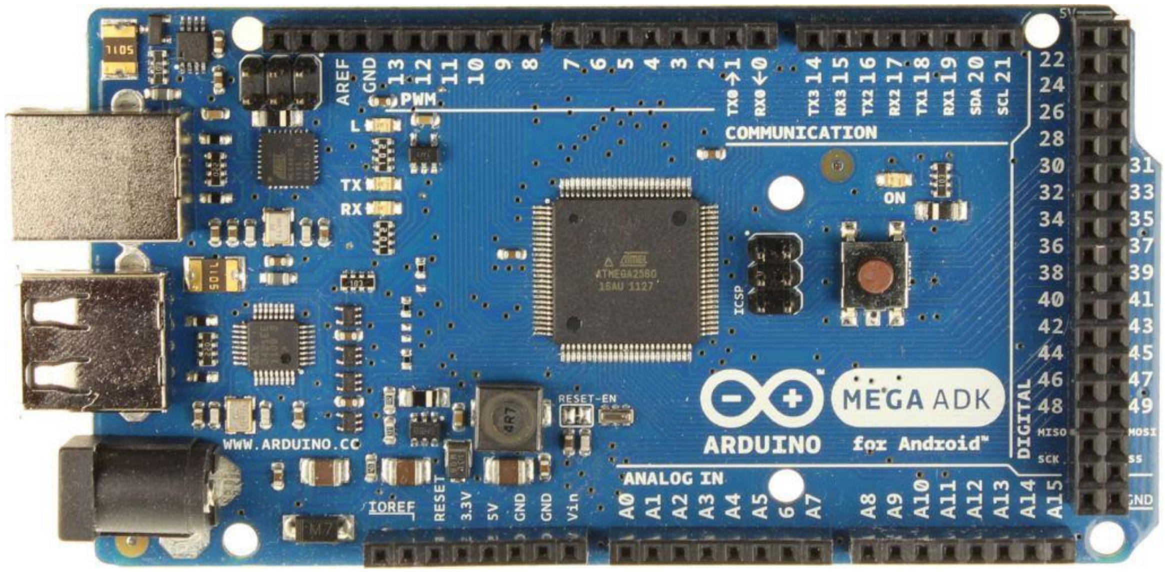

fig. 2.20. Arduino mega

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. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.

2.4.9. Ramps 1.4 Stepper Shield:

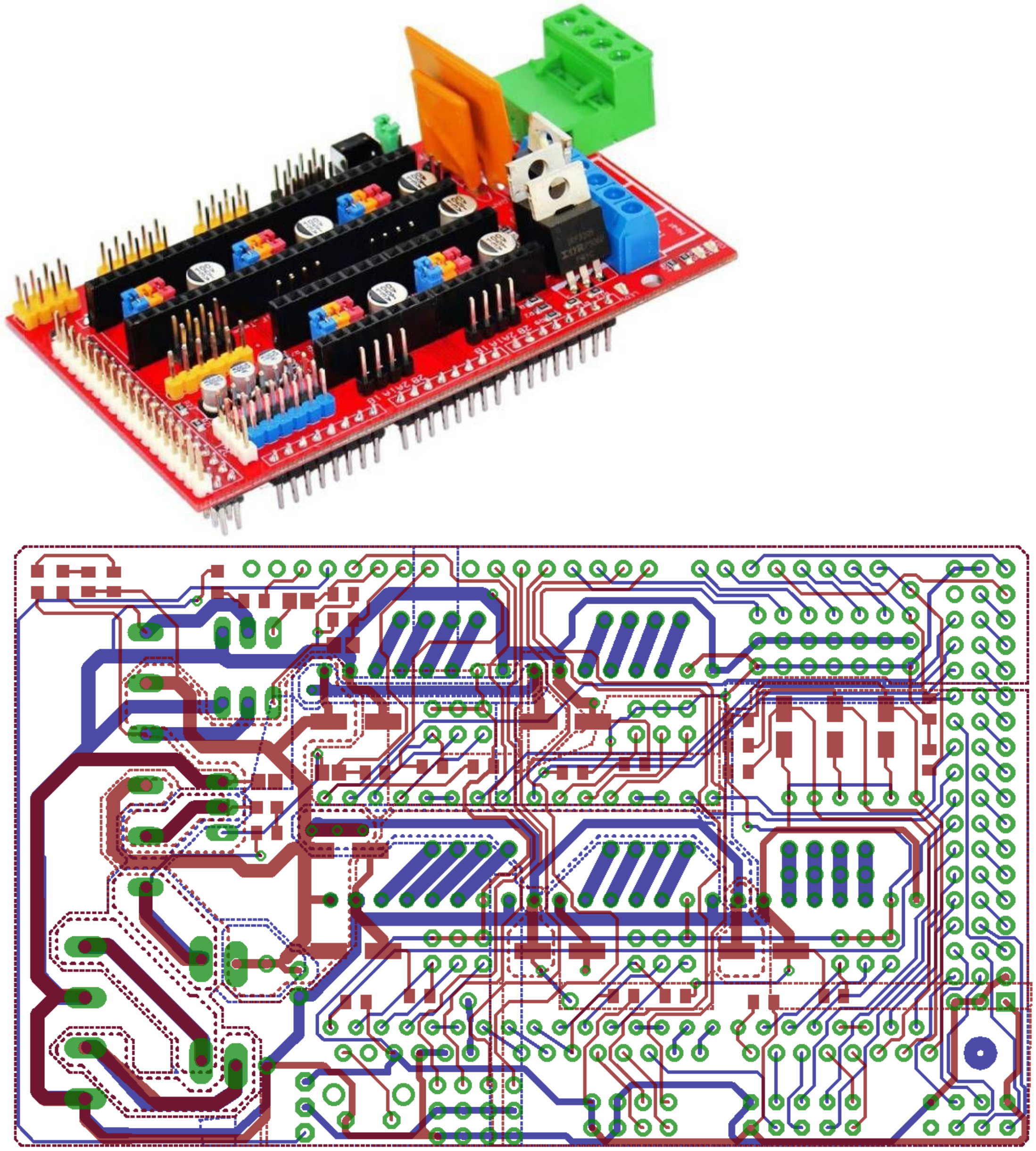

fig. 2.21. Ramps 1.4 Stepper Shield

RepRapArduino 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.

2.4.10. Switched Mode Power Supply

fig. 2.22. switched-mode power supply

A switched-mode power supply (SMPS) is an electronic circuit that converts power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state.

Switching power supplies have high efficiency and are widely used in a variety of electronic equipment, including computers and other sensitive equipment requiring stable and efficient power supply. A switched-mode power supply is also known as a switch-mode power supply or switching-mode power supply.

Switched-mode power supplies are classified according to the type of input and output voltages.

2.4.11. Endstops:

These EndStop Switches are used to sense the endpoints on all the axis in a 3D Printer. This is designed to be used with RepRapMakerbotPrusa Mendel 3D Printers can directly plugin into the RAMPS Boards. The switch comes with mounting holes to mount it firmly on the 3D Printer.

fig. 2.23. Endstops

The mechanical endstop uses a lever switch to detect when it is activated. The switch is wired up so that when activated, it pulls the signal to LOW. There is also an LED on the board that will light up when the switch is activated.It uses a standard 4 pin .100" pitch header and accepts a standard, old-style CD-ROM audio connector cable.

Endstops ensure that a machine, through one of various methods, keeps on object on an axis. (In the case of a 3D printer, the object could be the print head, for example.) This stops the object from derailing or jamming at the end of that axis. Endstop switches are the most common type, used especially by lower-budget machines.

However, there are other types of endstops that you can use, including optical and magnetic endstops. Different types of endstops have different strengths and weaknesses, depending on your necessary level of precision and your budget.

2.4.12. Extruder Feeder motor assembly:

fig. 2.24. Extruder Feeder motor assembly

This assembled motor is used to feed PLA or ABS filament to the hotend of extruder.
The tension in the spring can be adjusted to push the filament between copper pinion on the shaft of motor and pulley.

CHAPTER 3 – 3D PRINTER DESIGN

3.1. Procedure for 3D Printing

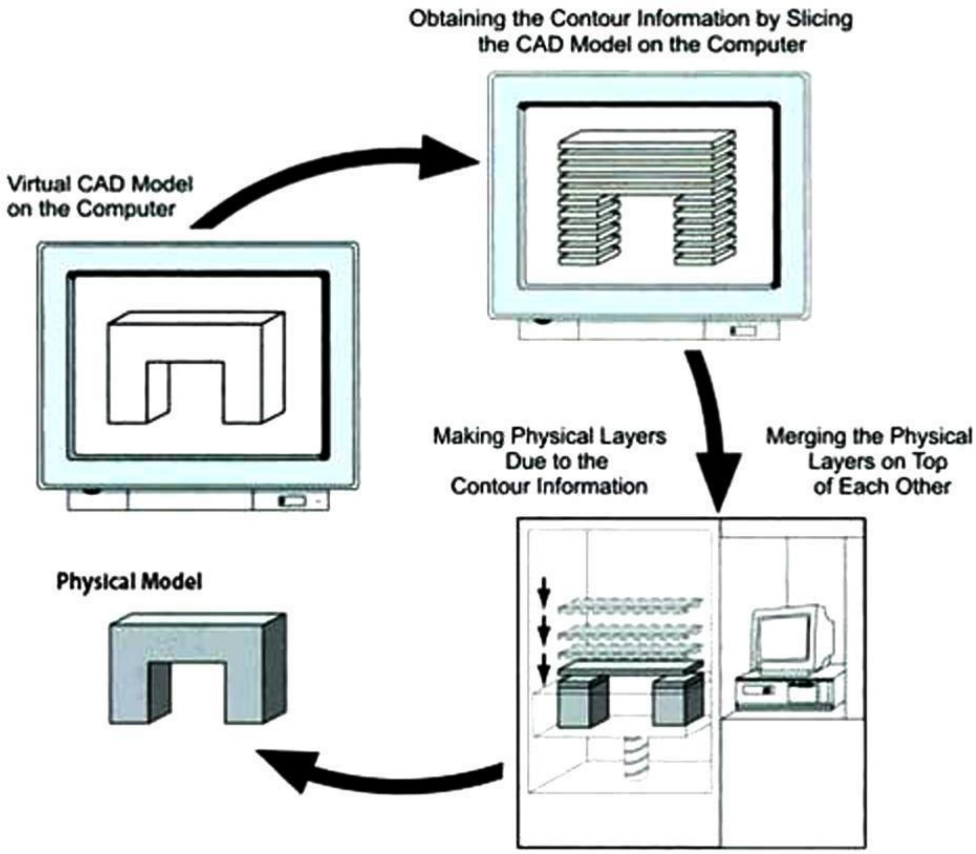

fig. 3.1. Procedure for 3-D PRINTING

Following are the steps to go through for 3D printing any solid model using 3D printer.

3.1.1. First you must create a computer model for printing the object. For creating that, you can use Computer Aided Design Software like AutoCAD, 3DS Max etc. After the object file is created, the file need to be modified. The object file contains numerous amount of curves. Curves cannot be printed by the printer directly. The curves has to be converted to STL (Stereo lithography) file format. The STL file format conversion removes all the curves and it is replaced with linear shapes. If you are unable to draw objects in CAD software, there are many websites available which are hosted by the 3D printing companies to ease the creation of 3D object.

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space. CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

An STL file is a triangular representation of a 3D surface geometry. The surface is tessellated logically into a set of oriented triangles (facets). Each facet is described by the unit outward normal and three points listed in counterclockwise order representing the vertices of the triangle. While the aspect ratio and orientation of individual facets is governed by the surface curvature, the size of the facets is driven by the tolerance controlling the quality of the surface representation in terms of the distance of the facets from the surface. The choice of the tolerance is strongly dependent on the target application of the produced STL file. In industrial processing, where stereolithography machines perform a computer controlled layer by layer laser curing of a photo-sensitive resin, the tolerance may be in order of 0.1 mm to make the produced 3D part precise with highly worked out details. However much larger values are typically used in pre-production STL prototypes, for example for visualization purposes.

The native STL format has to fulfill the following specifications:

(i) The normal and each vertex of every facet are specified by three coordinates each, so there is a total of 12 numbers stored for each facet.

(ii) Each facet is part of the boundary between the interior and the exterior of the object. The orientation of the facets (which way is ``out" and which way is ``in") is specified redundantly in two ways which must be consistent. First, the direction of the normal is outward. Second, the vertices are listed in counterclockwise order when looking at the object from the outside (right-hand rule).

(iii) Each triangle must share two vertices with each of its adjacent triangles. This is known as vertex-to-vertex rule.

(iv) The object represented must be located in the all-positive octant (all vertex coordinates must be positive).

However, for non-native STL applications, the STL format can be generalized. The normal, if not specified (three zeroes might be used instead), can be easily computed from the coordinates of the vertices using the right-hand rule. Moreover, the vertices can be located in any octant. And finally, the facet can even be on the interface between two objects (or two parts of the same object). This makes the generalized STL format suitable for modelling of 3D non-manifolds objects.

3.1.2. Once the CAD file is done and .stl file is created, it is loaded on a Host software like Repetier Host that can slice the loaded STL file into different layers of equal width adjusted according to resolution of the extruder used, here being 0.2mm. Along with this there are many parameters like:

- Infilling: This determines the packing of any solid part of the loaded STL file
- Layer Height: Adjusted according to the resolution of the extruder, here 0.2mm.
- Solid layers: These are the minimum number of solid layers at the base of the whole structure to give it support.
- Fill density: It is the density of packing of PLA or ABS in the printed object.

- Skirt and Brim: it is the outer layer made at a distance from the perimeter of the object around it to give an idea of sticking and removal of melted PLA from the bed.
- Z offset: It is the difference of the height between the bedlevel and z homing position.
- Speed: federate or the speed of the axes is the speed at which they move the carriage along them.

Since controlling such large amount of parameters can be very hectic, various slicers are available to slice the STL file in layers keeping in mind various orientation and hardware that varies with every printer.

This project uses Prusa's slicer for slicing.

3.1.3. Once this Slicer is calibrated according to the printer's hardware, stl file can be loaded. Now the object placement is necessary to determine where will the object be printed on the whole bed. It is adjusted by hit and try of X and Y coordinates.

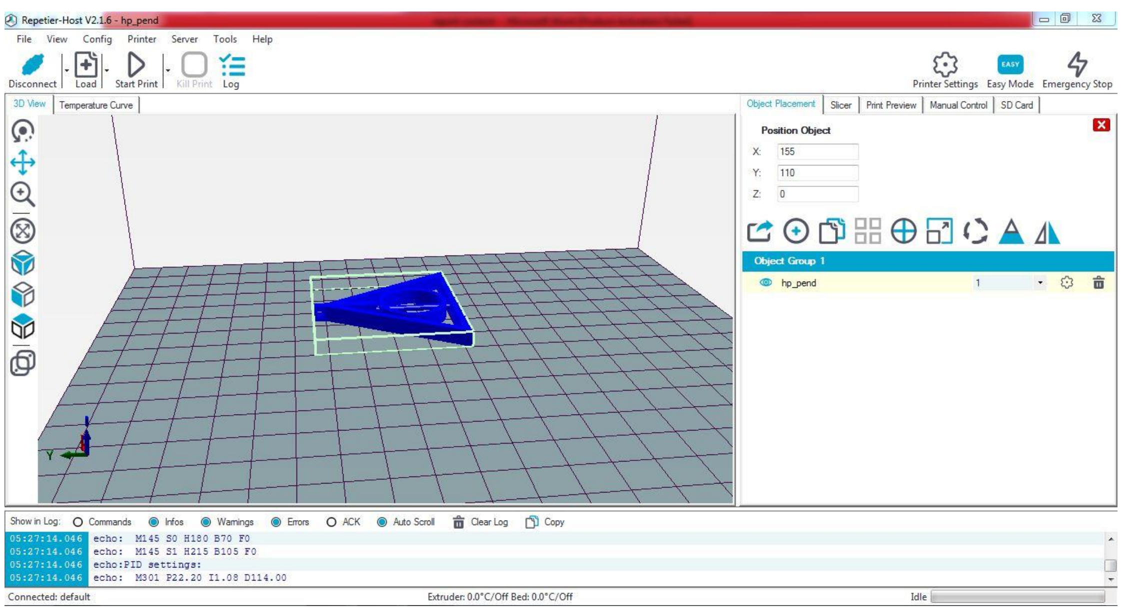

Fig. 3.2. Loading the .stl file

3.1.4. Once the placement is done one can look for the actual dimensions that are going to be printed and look for the extruder filament needed. Now go on slicer and load your settings to slice the STL file.

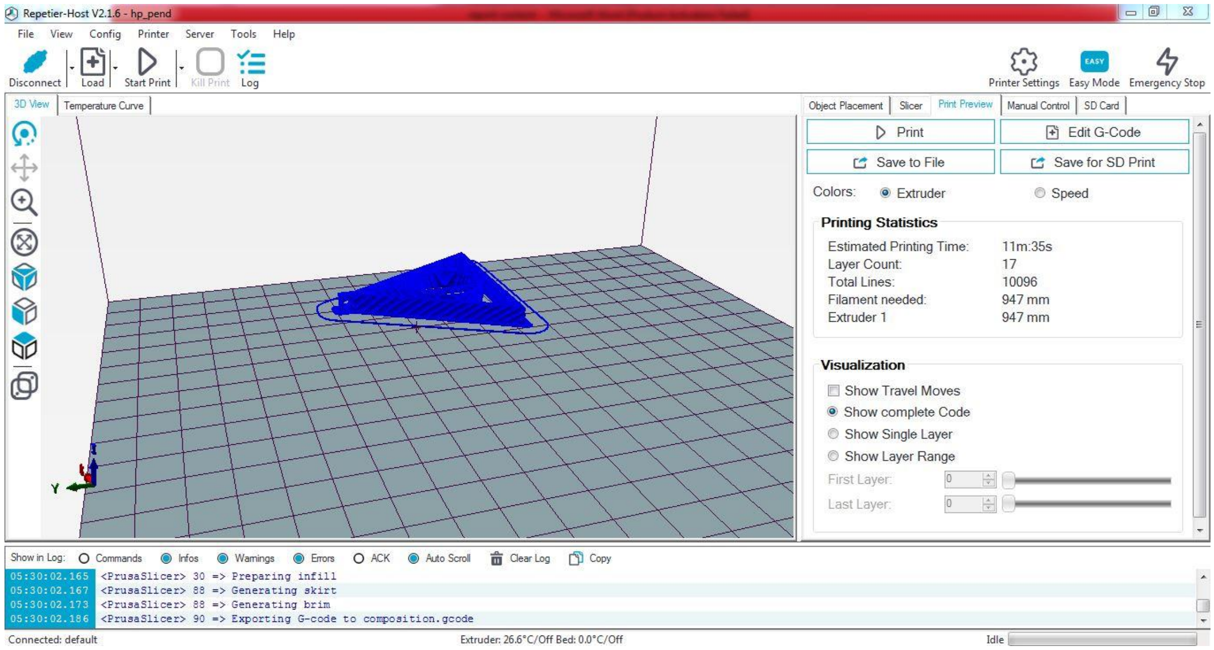

Fig. 3.3. Loading the slicer to the .stl file

3.1.5. Before actually giving the print command, one can first test motors for locomotion of each axis manually, at the manual control tab. Test the homing of each axis, at which they should actually move to endstop of their respective axis.

Home each axis using the home all button at the side of manual control tab.

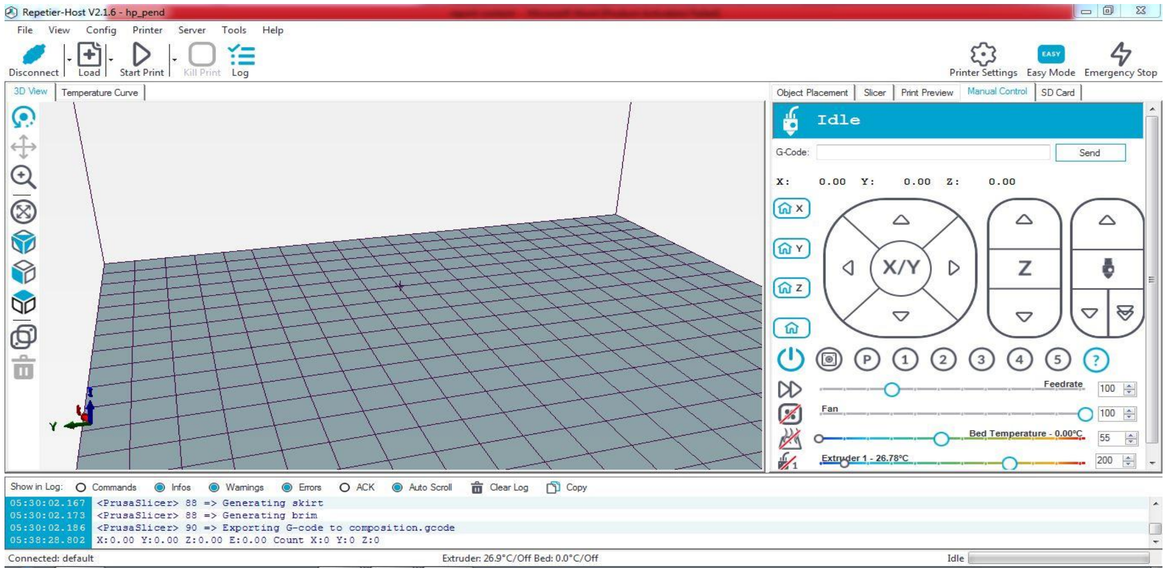

Fig. 3.4. Manual tab control

3.1.6. Give the print command and see it actually print the model. First of all, all the axes will go on homing position and extruder will heat to the set temperature, set to 210 here in the firmware.

3.1.7. Once heating is done, printer will start printing.

3.2. Calibration, Boundary conditions and Failures:

There are tons of Calibration to be done before actually printing anything using printer. The calibrations are:

- Bed-leveling: The printer uses 3 point Bed-leveling. The word "leveling" applied to printer beds is a misnomer. When you "level" the print bed you're not trying to level it to the earth the way you level a picture that you hang on the wall. You're really "tramming" the bed, which means adjusting it so that it is parallel to the printer's XY plane, which is defined by the positions of the X and Y axis guide rails. In case you missed it, let me state specifically: the bed surface is NOT the printer's XY plane. When the bed is properly leveled, it is parallel to the printer's XY plane. The guide rails, which in a properly built machine don't move, are the reference, not the bed plate.

With 3 point leveling, there are three screws, reference, pitch adjust, and roll adjust. The screws are normally arranged so that two of them, reference and pitch adjust, are along the printer's X or Y axes. The roll adjust screw is usually located along an edge of the bed, opposite the other two screws. The reference screw is used to set the overall height of the bed above the carriage plate and not normally used for bed leveling. After initial set-up, only the pitch and roll adjust screws are used to level the bed.

Look at the image, below. Notice that when you turn any screw, the bed is free to pivot at the other two screws, so nothing is forced to bend. The bearings mounted on the carriage plate are not affected.

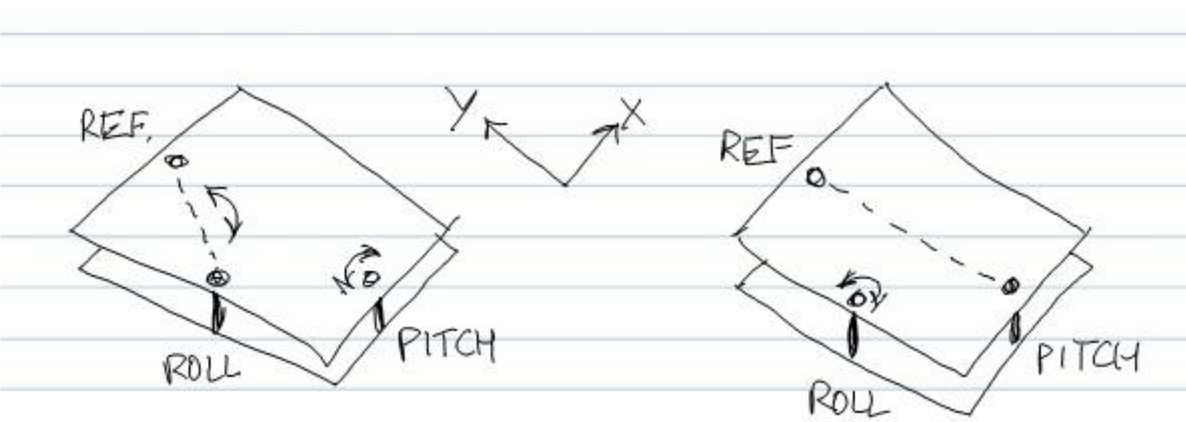

Fig. 3.5. Turning of the screw

To level a bed on 3 points for the first time, you move the nozzle to the reference adjuster and adjust the screw to grab a piece of paper, then move to the pitch adjuster and adjust the screw to just catch a piece of paper. Finally, move the nozzle to the roll adjuster and adjust the screw to just catch the paper. The roll adjustment does not affect the pitch setting because when you adjust the roll, the bed pivots on the reference and pitch screws. After the first time, if ever, you adjust the level by simply tweaking the pitch and roll adjusters. Always adjust pitch first, then roll.

- Current limiting for A4988 drivers: Current limiting to be done for each driver using following formula:

Max current for Nema17 (Imax) = 1.68amp

Vref (voltage between potentiometer and gnd

According to theory, for A4988:

Imax=2.5 * Vref

Vref=0.67 V

Adjust the Vref to be 0.67V for Nema17 motors

- Z-offset measurement: Using a piece of paper measure the z axis coordinate at any point of bed at which the tip of extruder just touches the bed.
- Object Placement: This is done using hit and try method to determine the X and Y coordinates of the object on bed to see that the extruder doesn't collide with any object on its way printing, and that the entire object is printed on the bed.

There are various precautions that the user should take and points which can be considered as the Boundary condition of the printer:

- PLA damage: The PLA filament being used for printing should be kept away from humidity all the time using silica gel kept in a box. Once the humidity is absorbed by the filament, it begins to break in parts. The filament breaks at different points and is disintegrated at different points. The filament loses its flexibility once it absorbs humidity and can break with even a slight twist.
- Cooling for drivers: The A4988 drivers become too much heated up when working, hence it uses heat sinks for proper heat dissipation. For further precautions, a big fan is used on the face of control box for proper ventilation.
- Level Shifting: Layer Shifting refers to sliding of one layer over the other making it difficult for further deposition and distorting the printed object. The printer made begins level shifting in the direction, once the stepper motor of a particular axis gets heated up while long term printing. While printing an object, 76.89mm X 67.65mm X 90.00mm in dimensions.

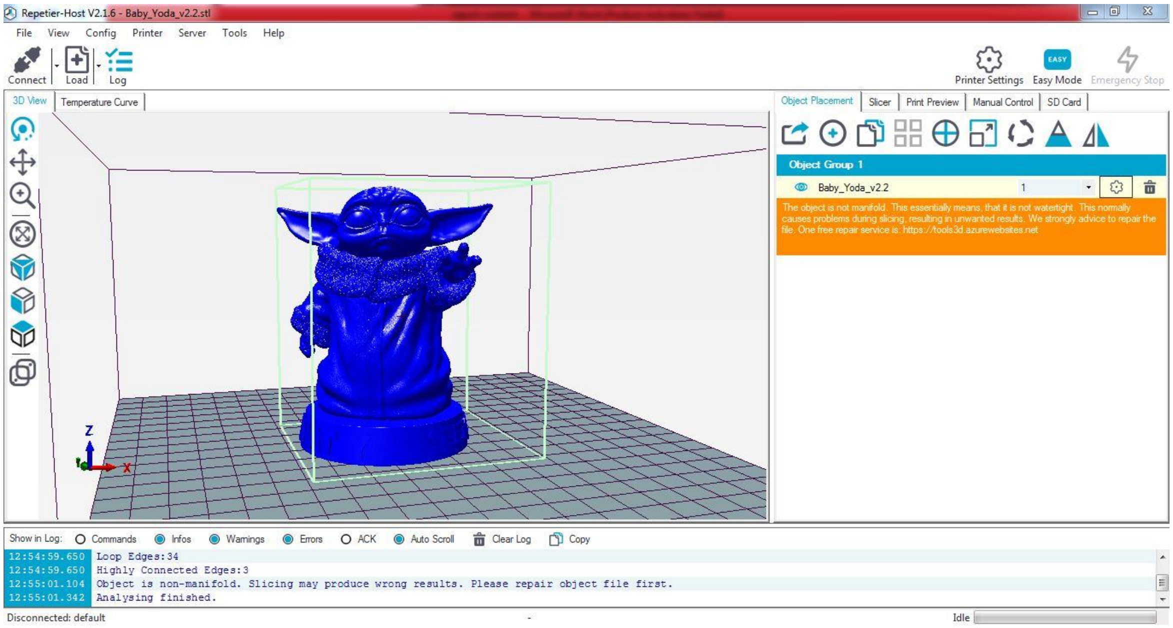

Fig. 3.6. the .stl file of the object to be printed

The object printed well till a height of 60.56mm, after which the layer shifting began, as the x axis motor began too heated up, resulting in an object shown below:

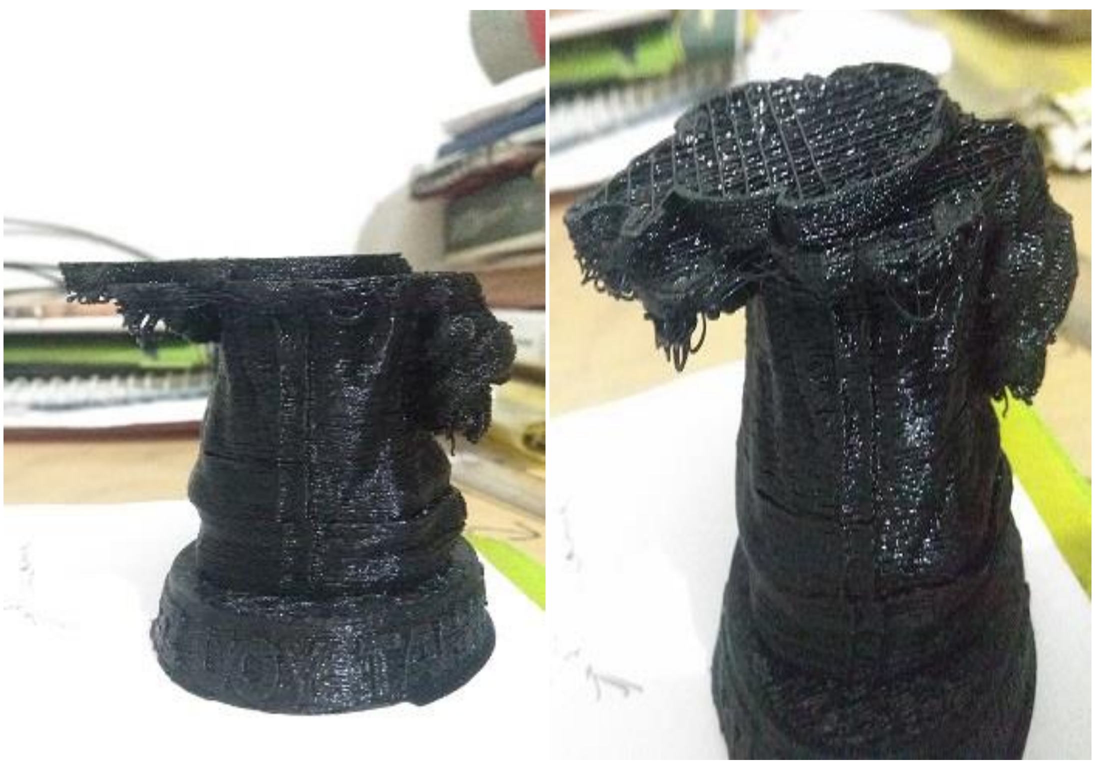

Fig. 3.7. The resulting object

CHAPTER 4 – RESULTS AND DISCUSSION

4.1. RESULTS

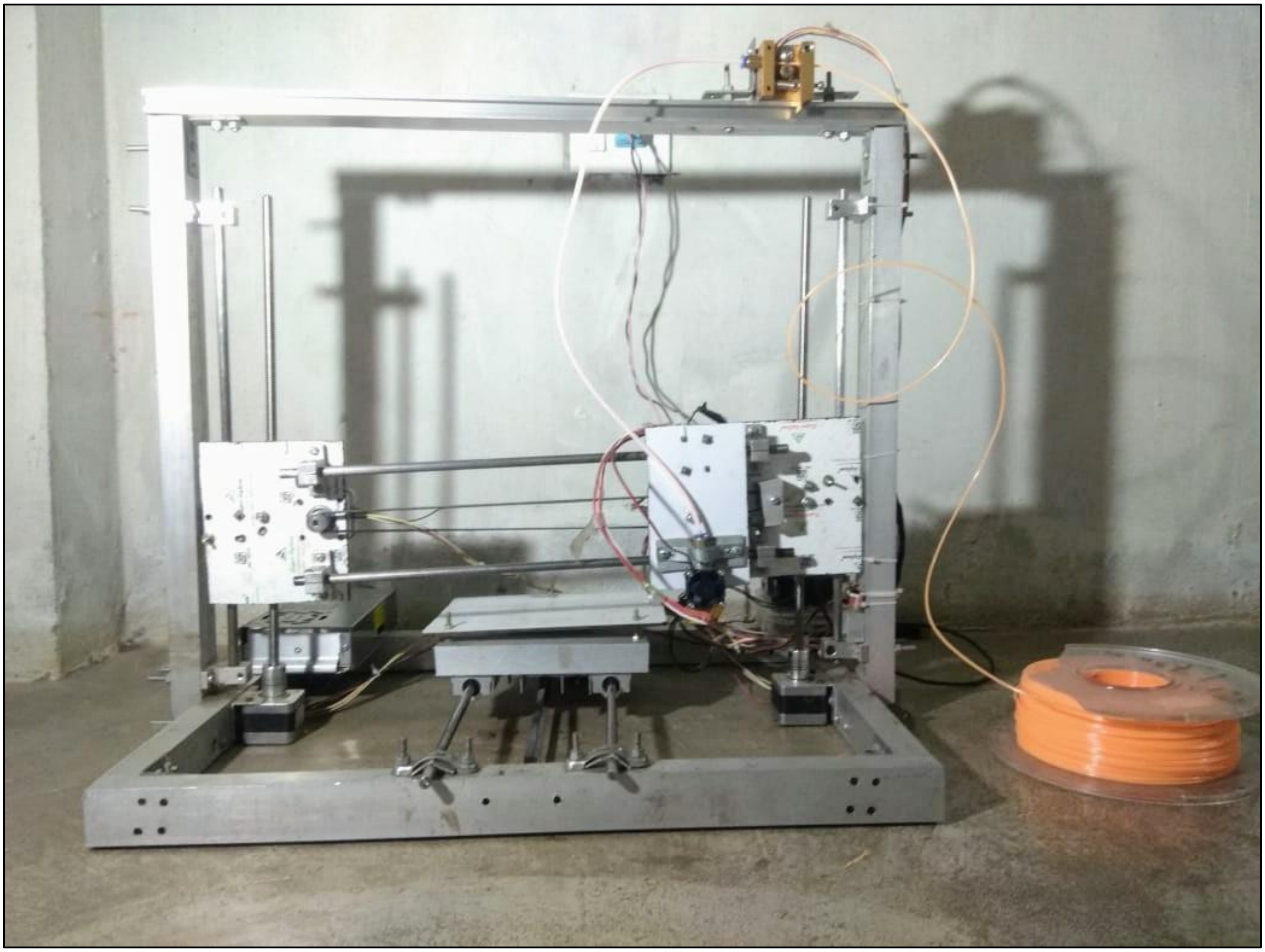

Fig. 4.1. The 3-D Printer

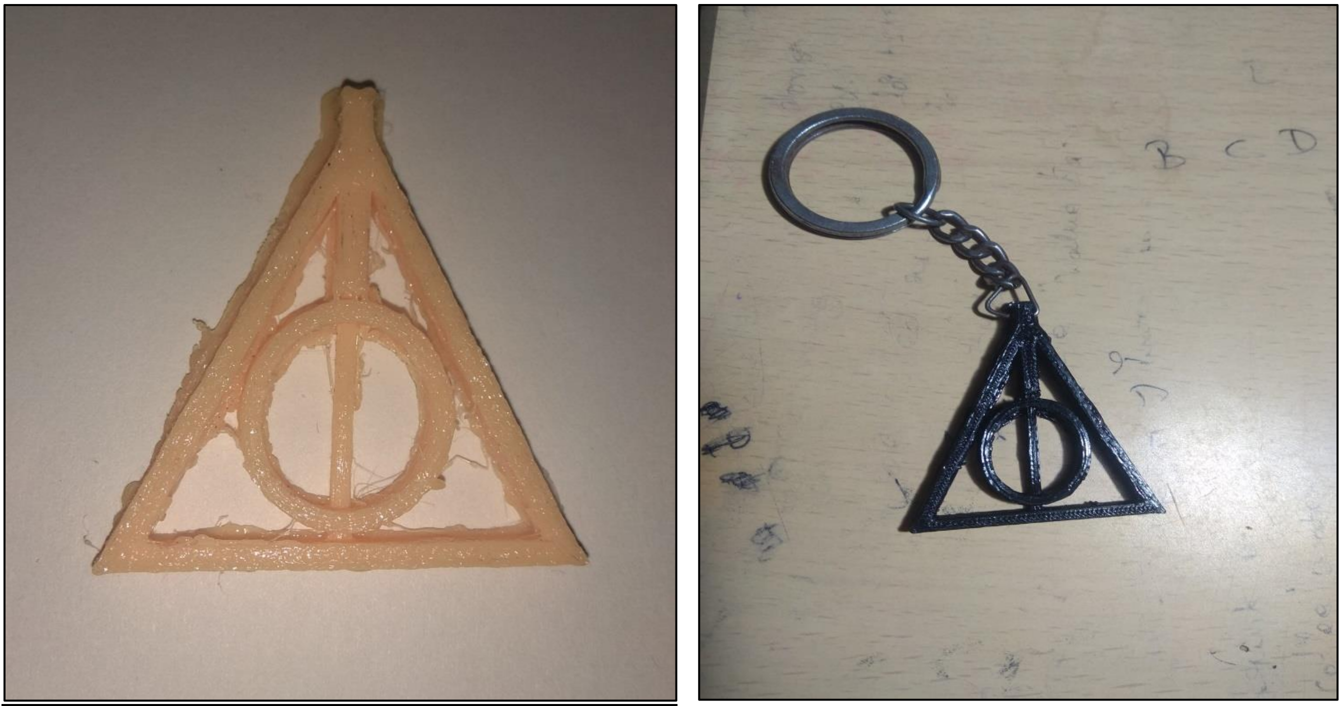

Fig. 4.2. The final products

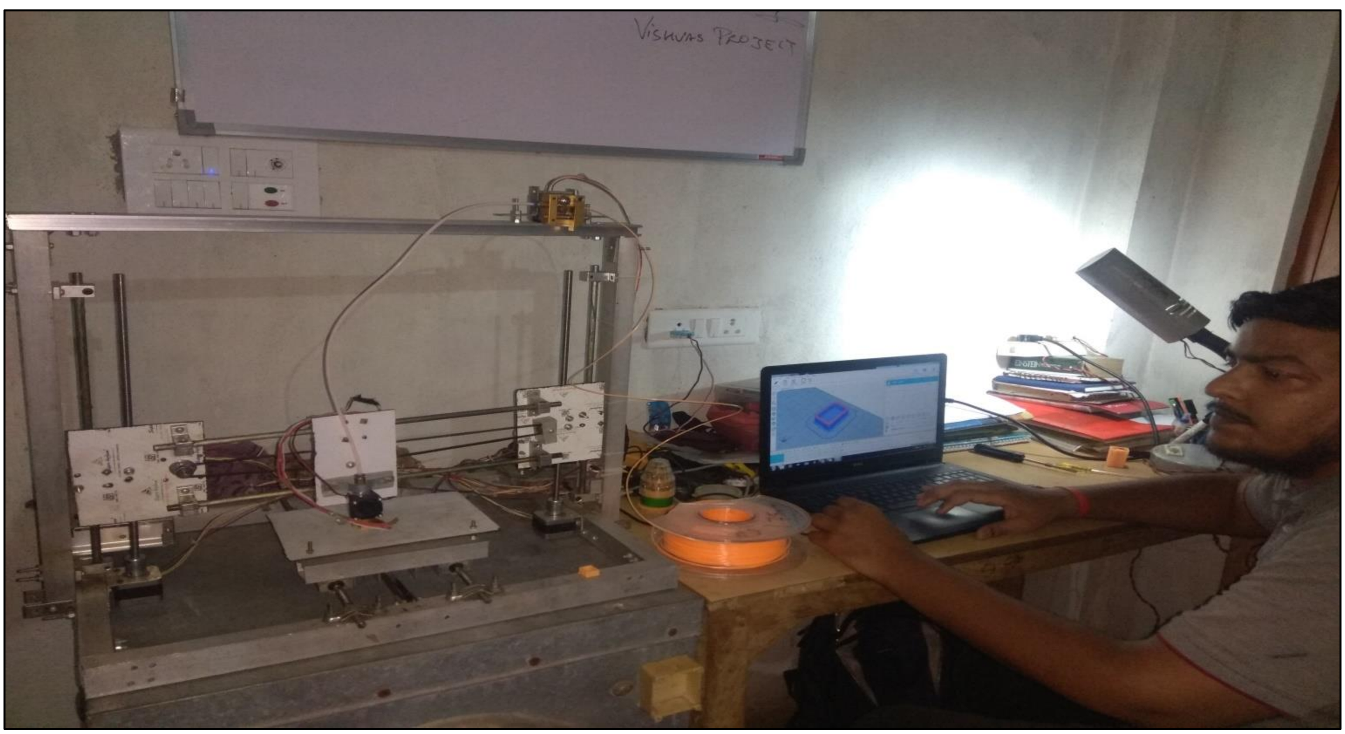

Fig. 4.3. Working on the project

4.2. APPLICATIONS

Three-dimensional printing makes it as cheap to create single items as it is to produce thousands and thus undermines economies of scale. It may have as profound an impact on the world as the coming of the factory did....Just as nobody could have predicted the impact of the steam engine in 1750 or the printing press in 1450, or the transistor in 1950. It is impossible to foresee the long-term impact of 3D printing. But the technology is coming, and it is likely to disrupt every field it touches.

Additive manufacturing's earliest applications have been on the tool room end of the manufacturing spectrum. For example, rapid prototyping was one of the earliest additive variants, and its mission was to reduce the lead time and cost of developing prototypes of new parts and devices, which was earlier only done with subtractive tool room methods (typically slowly and expensively). With technological advances in additive manufacturing, however, and the dissemination of those advances into the business world, additive methods are moving ever further into the production end of manufacturing in creative and sometimes unexpected ways. Parts that were formerly the sole province of subtractive methods can now in some cases be made more profitably via additive ones.

Standard applications include design visualization, prototyping/CAD, metal casting, architecture, education, geospatial, healthcare, and entertainment/retail.

3D printer came with immense number of applications. All the traditional methods of printing causes wastage of resources. But 3D printer only uses the exact amount of material for printing. This enhances the efficiency. If the material is very costly, 3d printing techniques can be used to reduce the wastage of material.

3D printer has numerous applications in every field it touches. Since it is a product development device, rate of production, customization and prototyping capabilities need to be considered.

4.2.1. RAPID PROTOTYPING -

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

The model is valid if for each point in 3D space the computer can determine uniquely whether that point lies inside, on, or outside the boundary surface of the model. CAD post-processors will approximate the application vendors’ internal CAD geometric forms (e.g., B-splines) with a simplified mathematical form, which in turn is expressed in a specified data format which is a common feature in Additive Manufacturing: STL (stereo lithography) a de facto standard for transferring solid geometric models to SFF machines. To obtain the necessary motion control trajectories to drive the actual SFF, Rapid Prototyping, 3D Printing or Additive Manufacturing mechanism.

Fig. 4.4. Rapid prototyping

4.2.2. MASS CUSTOMISATION -

Mass customization is the method of "effectively postponing the task of differentiating product for a specific customer until the latest possible point in the supply network." (Chase,Jacobs&Aquilano 2006, p. 419). Kamis, Koufaris and Stern (2008) conducted experiments to test the impacts of mass customization when postponed to the stage of retail, online shopping. They found that users perceive greater usefulness and enjoyment with a mass customization interface vs. a more typical shopping interface, particularly in a task of moderate complexity. From collaborative engineering perspective, mass customization can be viewed as collaborative efforts between customers and manufacturers, who have different sets of priorities and need to jointly search for solutions that best match customers' individual specific needs with manufacturers' customization capabilities (Chen, Wang & Tseng (2009)).

Fig. 4.5. Mass customization

4.2.3. WEARABLES -

San Francisco-based clothing company, Continuum is among the first to create wearable, 3D printed pieces. Customers design bikinis on Continuum's website, specifying their body shapes and measurements. The company then uses nylon to print out each unique order. Founder Mary Huang believes that this intersection of fashion and technology will be the future because it "gives everyone access to creativity."

Fig. 4.6. Wearables

Dutch designer Iris Van Herpen has already put this new material to the test in her Voltage Haute Couture collection, which raised eyebrows at Paris Fashion Week in January 2013. A frontrunner in the realm of futuristic fashion design, Van Herpen has been taking her 3D printed dresses and shoes to the runways since 2010. Still, she admits that there are challenges associated with incorporating a new medium into the manufacturing process. "I always work together with an architect because I am not good with the 3D programs myself," she said.

The idea of custom design has mass appeal and marketability. Who doesn't want to wear a one-of-a-kind, perfectly tailored piece? Perhaps the teenage girl of the future won't have to suffer the social agony of showing up to a school dance wearing the same dress as her archenemy.

4.3. ADVANTAGES

1. Create anything with great geometrical complexity.
2. Ability to personalize every product with individual customer needs.
3. Produce products which involve great level of complexity that simply could not be produced physically in any other way.
4. Additive manufacturing can eliminate the need for tool production and therefore reduce the costs, lead time and labour associated with it.
5. 3D printing is an energy efficient technology.
6. Additive Manufacturing use up to 90% of standard materials and therefore creating less waste.
7. Lighter and stronger products can be printed.
8. Increased operating life for the products.
9. Production has been brought closer to the end user or consumer.
10. Spare parts can be printed on site which will eliminate shipping cost.
11. Wider adoption of 3D printing would likely cause re-invention of a number of already invented products.
12. 3D printing can create new industries and completely new professions.
13. Printing 3D organs can revolutionarise the medical industry.
14. Rapid prototyping causes faster product development.

4.4. DISADVANTAGES

1. Since the technology is new, limited materials are available for printing.
2. Consumes more time for less complicated pats.
3. Size of printable object is limited by the movement of extruder.
4. In additive manufacturing previous layer has to harden before creating next layer.
5. Curved geometry will not be much accurate while printing.

CHAPTER 5 – CONCLUSION AND FUTURE SCOPE

5.1. CONCLUSION

As the 3D printer is a device, it should be analyzed with the advantages and disadvantages, how the device can change the society and engineering etc in mind. The very nature of 3D printing, creating a part layer by layer, instead of subtractive methods of manufacturing lend themselves to lower costs in raw material. Instead of starting with a big chunk of plastic and carving away (milling or turning) the surface in order to produce your product. Additive manufacturing only "prints" what you want, where you want it. Other manufacturing techniques can be just as wasteful. 3D printing is the ultimate just-in-time method of manufacturing. No longer do you need a warehouse full of inventory waiting for customers. Just have a 3D printer waiting to print your next order. On top of that, you can also offer almost infinite design options and custom products. It doesn't cost more to add a company logo to every product you have or let your customers pick every feature on their next order, the sky is the limit with additive manufacturing.

Whether you are designing tennis shoes or space shuttles, you can't just design whatever you feel like, a good designer always take into account whether or not his design can be manufactured cost effectively. Additive manufacturing open up your designs to a whole new level. Because undercuts, complex geometry and thin walled parts are difficult to manufacture using traditional methods, but are sometimes a piece of cake with 3D printing. In addition, the mathematics behind 3D printing are simpler than subtractive methods. For instance, the blades on a centrifugal supercharger would require very difficult path planning using a 5-axis CNC machine. The same geometry using additive manufacturing techniques is very simple to calculate, since each layer is analysed separately and 2D information is always simpler than 3D. This mathematical difference, while hard to explain is the fundamental reason why 3D printing is superior to other manufacturing techniques. It almost always better to keep things simple and additive manufacturing is simple by its very nature.

With so many potential benefits of 3D printing, there’s no surprise that this method is making its way through a diverse number of industries and quickly becoming a favourite tool of progressive marketers.

Comparing the numerous advantages, applications and future scope, we can conclude that the 3D printer and its technology is able to create next industrial revolution.

5.2. FUTURE SCOPE

NASA engineers are 3-D printing parts, which are structurally stronger and more reliable than conventionally crafted parts, for its space launch system. The Mars Rover comprises some 70 3-D-printed custom parts. Scientists are also exploring the use of 3-D printers at the International Space Station to make spare parts on the spot. What once was the province of science fiction has now become a reality.

Medicine is perhaps one of the most exciting areas of application. Beyond the use of 3-D printing in producing prosthetics and hearing aids, it is being deployed to treat challenging medical conditions, and to advance medical research, including in the area of regenerative medicine. The breakthroughs in this area are rapid and awe-inspiring.

Hence, rather than throwing away a broken item (something unlikely to be justified a decade or two hence due to resource depletion and enforced recycling), faulty goods will be able to be taken to a local facility that will call up the appropriate spare parts online and simply print them out. NASA has already tested a 3D printer on the International Space Station, and recently announced its requirement for a high resolution 3D printer to produce spacecraft parts during deep space missions. The US Army has also experimented with a truck-mounted 3D printer capable of outputting spare tank and other vehicle components in the battlefield.

As noted above, 3D printers may also be used to make future buildings. To this end, a team at Southborough University is working on a 3D concrete printing project that could allow large building components to be 3D printed on-site to any design, and with improved thermal properties.

Another possible future application is in the use of 3D printers to create replacement organs for the human body. This is known as bio printing, and is an area of rapid development. You can learn more on the bio printing page, or see more in my bio printing or the Future Visionsgallery.

5.2.1. ROCKET ENGINE

NASA's first attempt at using 3D-printed parts for rocket engines has passed its biggest,and hottest, test yet. The largest 3D-printed rocket part built to date, a rocket engine injector,survived a major hot-fire test. The injector generated 10 times more thrust than any injectormade by 3D printing before, the space agency announced. A NASA video of the 3D-printedrocket part test shows the engine blazing tolife at the agency's Marshall Space FlightCenter (MSFC) in Huntsville Ala.

Fig. 5.1. Rocket engine parts

SpaceX's Dragon capsule has been takingcargo to the International Space Station since 2012. Dragon V2 comes with new "SuperDraco" 16,000 lb-thrust engines that canbe restarted multiple times if necessary. Inaddition, the engines have the ability to deepthrottle, providing astronauts with precise controland enormous power.

The SuperDraco engine chamber is manufactured using 3D printing technology, the state-of-the-art direct metal laser sintering (DMLS) which uses lasers to quickly manufacture high-quality parts from metal powder layer by layer.

Totally eight SuperDraco engines built into the side walls of the Dragon spacecraft will produce up to 120,000 pounds of axial thrust to carry astronauts to safety should an emergency occur during launch. As a result, Dragon will be able to provide astronauts with the unprecedented ability to escape from danger at any point during the ascent trajectory, not just in the first few minutes.

5.2.2. 3 D BIO PRINTING

3D bioprinting is the process of generating spatially-controlled cell patterns using 3D printing technologies, where cell function and viability are preserved within the printed construct. Using 3D bioprinting for fabricating biological constructs typically involves dispensing cells onto a biocompatible scaffold using a successive layer-by-layer approach to generate tissue-like three-dimensional structures. Given that every tissue in the body is naturally compartmentalized of different cell types, many technologies for printing these cells vary in their ability to ensure stability and viability of the cells during the manufacturing process. Some of the methods that are used for 3D bioprinting of cells are photolithography,

3D-bioprinting attributes to significant advances in the medical field of tissue engineering by allowing for research to be done on innovative materials called biomaterials. Biomaterials are the materials adapted and used for printing three-dimensional objects. Some of the most notable bioengineered substances that are usually stronger than the average bodily materials, including soft tissue and bone. These constituents can act as future substitutes, even improvements, for the original body materials. Alginate, for example, is an anionic polymer with many biomedical implications including feasibility, strong biocompatibility, low toxicity, and stronger structural ability in comparison to some of the body's structural material.

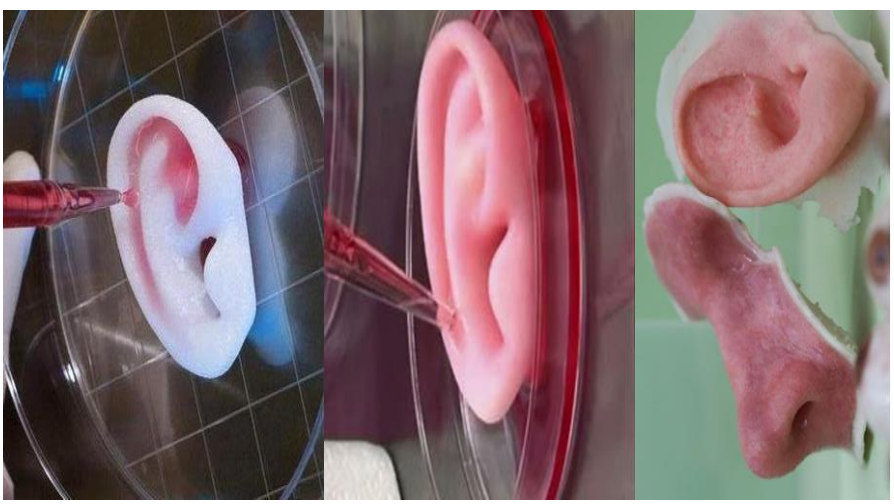

Fig. 5.2. 3D-bioprinting technique

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