PROJECT REPORT

ON

'REFURBISHMENT OF 3D PRINTER AND PARAMETER OPTIMIZATION'

Submitted by

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In partial fulfilment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

PROF. NAWAZ MOTIWALA

DEPARTMENT OF MECHANICAL ENGINEERING

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KALSEKAR TECHNICAL CAMPUS

NEW PANVEL,

NAVI MUMBAI – 410206

UNIVERSITY OF MUMBAI

ACADEMIC YEAR 2018-2019

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"REFURBISHMENT OF 3D PRINTER AND PARAMETER OPTIMIZATION"

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APPROVAL OF DISSERTATION

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ACKNOWLEDGEMENT

After the completion of this work, we would like to give our sincere thanks to all those who helped us to reach our goal. It's a great pleasure and moment of immense satisfaction for us to express my profound gratitude to our guide **PROF. NAWAZ MOTIWALA** whose constant encouragement enabled us to work enthusiastically. His perpetual motivation, patience and excellent expertise in discussion during progress of the project work have benefited us to an extent, which is beyond expression.

We would also like to give our sincere thanks to **PROF. ZAKIR ANSARI**, Head of Department, **PROF. RIZWAN SHAIKH** project coordinator from Department of Mechanical Engineering, Kalsekar Technical Campus, New Panvel, for their guidance, encouragement and support during a project.

I am thankful to **Dr. ABDUL RAZZAK HONNUTAGI**, Kalsekar Technical Campus New Panvel, for providing an outstanding academic environment, also for providing the adequate facilities.

Last but not the least I would also like to thank all the staffs of Kalsekar Technical Campus (Mechanical Engineering Department) for their valuable guidance with their interest and valuable suggestions brightened us.

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ABSTRACT

This abstract describes the project based on 3-D printing technology. The project was carried out with the fabrication of the 3-D printer. A 3-D printer is a machine which uses additive manufacturing process to create a 3-dimensional object using digital data. This 3-D printer uses the FDM technology and has 3-axis arrangement with inbuilt heating platform. The heating platform can be finely tuned for precise levelling. This 3-D printer can print things right from microns to 180mm. It is compatible with various materials having melting temperature up to 300^{o}C. The materials like PLA, ABS, HIP, etc. can be used. The structure of the 3-D printer is rigid cuboidal frame of 6065 Aluminium. The 3-D printer has the object printing volume of 180x180x180mm^{3}. The main objective of the project is to create a reliable and most cost efficient 3-D printer. This project also emphasises on design of such machines, various types of extruding materials and its application in some of the core engineering, architecture and medical fields. It also significantly challenges the mass production processes in future.

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ABBREVIATIONS

CAD-Computer Added Graphics

AM-Additive manufacturing **DARPA-** Defence

Advanced Research Projects Agency **SLS-** Selective

Laser Sintering **ABS**-Acrylonitrile butadiene styrene

PLA- Polylactic Acid

FDM-Fused Deposition Modelling

SHS-Selective Heat Sintering

SLM- Selective Laser Melting

EBM-Electron Beam Melting

SLA-Stereo Lithography Apparatus

DLP- Digital Light Processing

LOM-Laminated Object Manufacturing

RAMPS- Reprap Arduino Mega Polulo Shield

SMPS- Switched Mode Power Supply

CHAPTER 1

INTRODUCTION

1.1 Background

3D printing is a form of additive manufacturing technology where a three-dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. The 3D printing concept of custom manufacturing is exciting to nearly everyone. 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. Now, you can create a complete model in a single process using 3D printing. The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern 3D Printers are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D Scanner. It is used in a variety of industries. [1]

1.1.1 History of 3d Printing

The technology for printing physical 3D objects from digital data was first developed by Charles Hull in 1984. He named the technique as Stereo lithography and obtained a patent for the technique in 1986. While Stereo lithography systems had become popular by the end of 1980s, other similar technologies such as Fused Deposition Modelling (FDM) and Selective Laser Sintering (SLS) were introduced. In 1993, Massachusetts Institute of Technology (MIT) patented another technology, named "3-Dimensional Printing techniques", which is similar to the inkjet technology used in 2D Printers. In 1996, three major products, "Genisys" from Stratasys, "Actua 2100" from 3D Systems and "Z402" from Z Corporation, were introduced. In 2005, Z Corp. launched a breakthrough product, named Spectrum Z510, which was the first high definition colour 3D Printer in the market. Another breakthrough in 3D Printing occurred in 2006 with the initiation of an open source project, named Reprap, which was aimed at developing a self-replicating 3D printer.

Very recently Engineers at the University of Southampton in the UK have designed, printed, and sent skyward the world's first aircraft manufactured almost entirely via 3-D printing technology. The UAV dubbed SULSA is powered by an electric motor that is pretty much the only part of the aircraft not created via additive manufacturing methods. Created on an EOS

EOSINT P730 nylon laser sintering machine, its wings, hatches and control surfaces basically everything that makes up its structure and aerodynamic controls was custom printed to snap together. It requires no fasteners and no tools to assemble. [4]

Figure 1.1 world's first 3D printed plane [4]

1.1.2 Current 3D Printing Technologies

1) Stereo lithography (SLA) Technology:

SLA is a fast prototyping process. Those who use this technology are serious about accuracy and precision. It can produce objects from 3D CAD data (computer-generated) files in just a

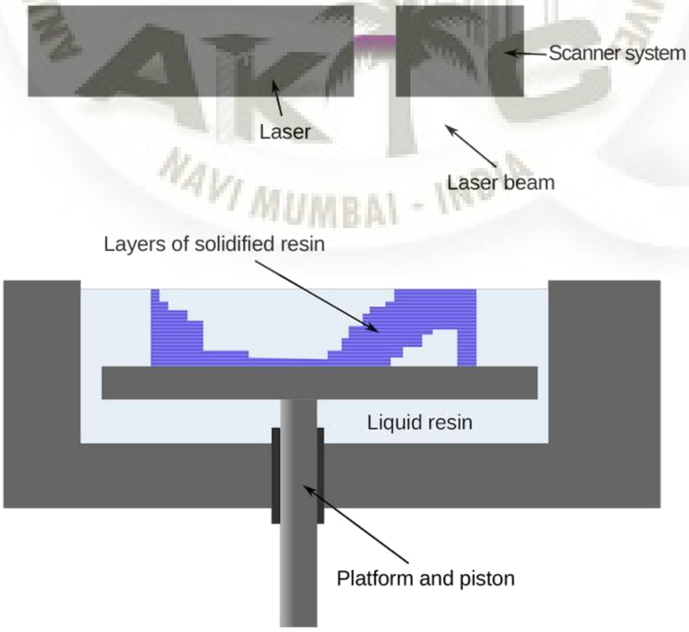


Figure 1.2: stereolithography process [2]

few hours. This is a 3D printing process that's popular for its fine details and exactness. Machines that use this technology produce unique models, patterns, prototypes, and various production parts. They do this by converting liquid photopolymers (a special type of plastic) into solid 3D objects, one layer at a time. The plastic is first heated to turn it into a semi-liquid form, and then it hardens on contact. The printer constructs each of these layers using an ultra violet laser, directed by X and Y scanning mirrors. Just before each print cycle, a recoater blade moves across the surface to ensure each thin layer of resin spreads evenly across the object. The print cycle continues in this way, building 3D objects from the bottom up.

2) Digital Light Processing (DLP) Technology:

DLP is the oldest of the 3D printing technologies, created by a man called Larry Hornbeck back in 1987. It's similar to SLA (see above), given that it also works with photopolymers. The

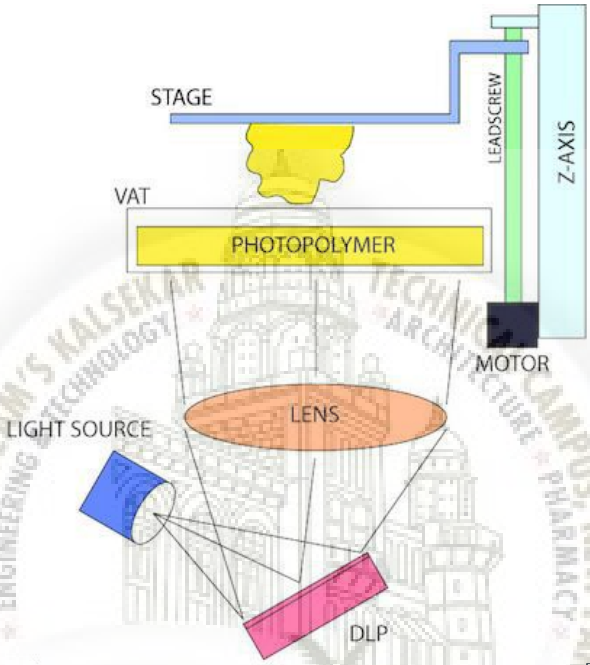


Figure1.3 Digital Light Processing (DLP) Technology [2]

Liquid plastic resin used by the printer goes into a translucent resin container. There is, however, one major difference between the two, which is the source of light. While SLA uses ultra violet light, DLP uses a more traditional light source, usually arc lamps. This process results in pretty impressive printing speeds. When there's plenty of light, the resin is quick to harden (we're talking seconds). Compared to SLA 3D printing, DLP achieves quicker print times for most parts. The reason it's faster is because it exposes entire layers at once. With SLA printing, a laser has to draw out each of these layers, and this takes time.

3) Fused Deposition Modelling (FDM) Technology:

FDM is a 3D printing process developed by Scott Crump, and then implemented by Stratasys Ltd., in the 1980s. It uses production grade thermal plastic materials to print its 3D objects. It's

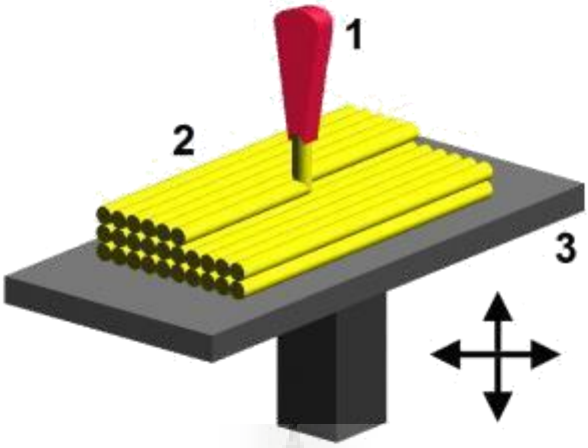


Figure 1.4 Fused Deposition Modelling (FDM) Technology [2]

Popular for producing functional prototypes, concept models, and manufacturing aids. It's a technology that can create accurate details and boasts an exceptional strength to weight ratio.

Before the FDM printing process begins, the user has to slice the 3D CAD data (the 3D model) into multiple layers using special software. The sliced CAD data goes to the printer which then builds the object layer at a time on the build platform. It does this simply by heating and then extruding the thermoplastic filament through the nozzle and onto the base. The printer can also extrude various support materials as well as the thermoplastic. For example, as a way to support upper layers, the printer can add special support material underneath, which then dissolves after the printing process. As with all 3D printers, the time it takes to print all depends on the objects size and its complexity.

4) Selective Laser Sintering (SLS) Technology:

An American businessman, inventor, and teacher named Dr. Carl Deckard developed and patented SLS technology in the mid-1980s. It's a 3D printing technique that uses high power CO2 lasers to fuse particles together. The laser sinters powdered metal materials (though it can utilize other materials too, like white nylon powder, ceramics and even glass). Here's how it works:

The build platform, or bed, lowers incrementally with each successive laser scan. It's a process that repeats one layer at a time until it reaches the object's height. There is un-sintered support from other powders during the build process that surround and protect the model. This means the 3D objects don't need other support structures during the build. Someone will remove the un-sintered powders manually after printing. SLS produces durable, high precision parts, and it can use a wide range of materials. It's a perfect technology for fully-functional, end-use parts and prototypes. SLS is quite similar to SLA technology with regards to speed and quality. The main difference is with the materials, as SLS uses powdered substances, whereas

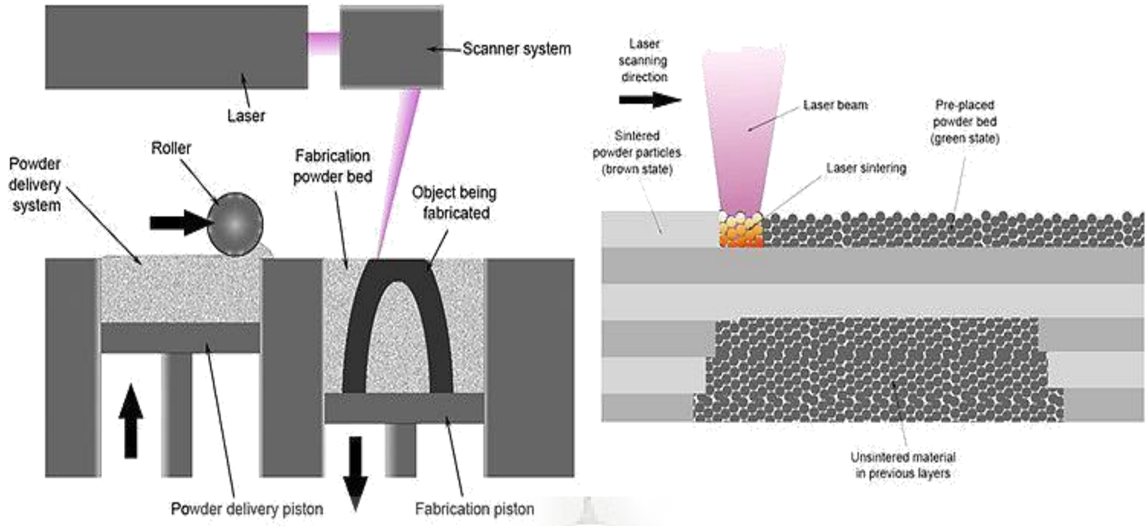


Figure 1.5 Selective Laser Sintering (SLS) Technology [2]

SLA uses liquid resins. It's this wide variety of available materials that makes SLA technology so popular for printing customized objects

5) Selective Laser Melting (SLM) Technology:

SLM made its debut appearance back in 1995. It was part of a German research project at the Fraunhofer Institute ILT, located in the country's most western city of Aachen. Like SLA (see above), SLM also uses a high-powered laser beam to form 3D parts. During the printing

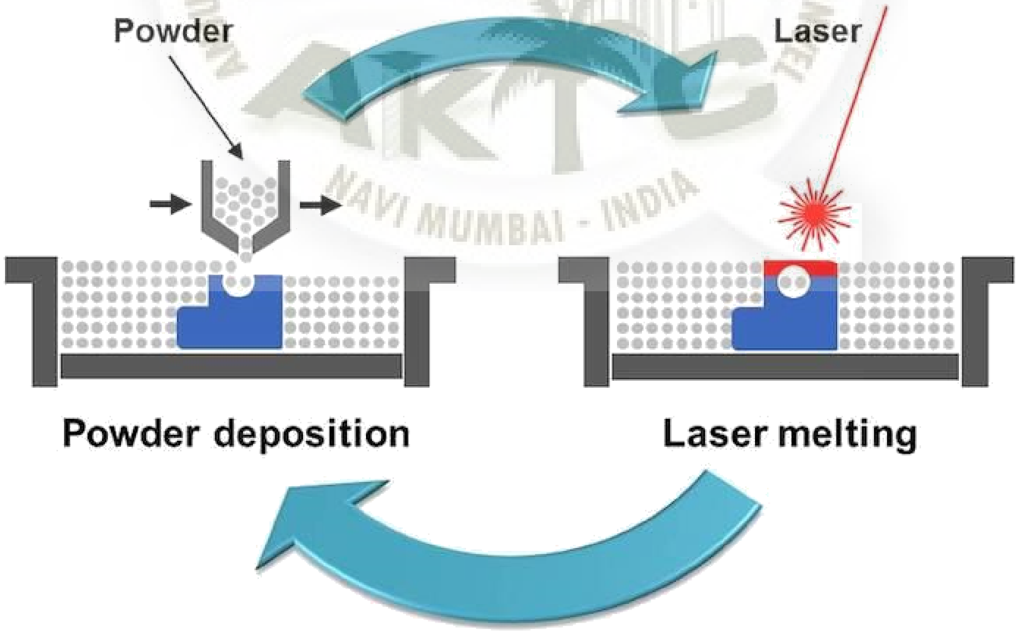


Figure 1.6 Selective Laser Melting (SLM) Technology [2]

process, the laser beam melts and fuses various metallic powders together. The simple way to look at this is to break down the basic process like thus:

Powdered material + heat + precision + layered structure = a perfect 3D object.

As the laser beam hits a thin layer of the material, it selectively joins or welds the particles together. After one complete print cycle, the printer adds a new layer of powered material to the previous one. The object then lowers by the precise amount of the thickness of a single layer. When the print process is complete, someone will manually remove the unused powder from the object. The main difference between SLM and SLS is that SLM completely melts the powder, whereas SLS only partly melts it (sinters). In general, SLM end products tend to be stronger as they have fewer or no voids.

6) Electron Beam Melting (EBM) Technology:

A Swedish company called Arcam AB founded EBM® in 1997. This is a 3D printing technology similar to SLM (see above), in that it uses a powder bed fusion technique. The

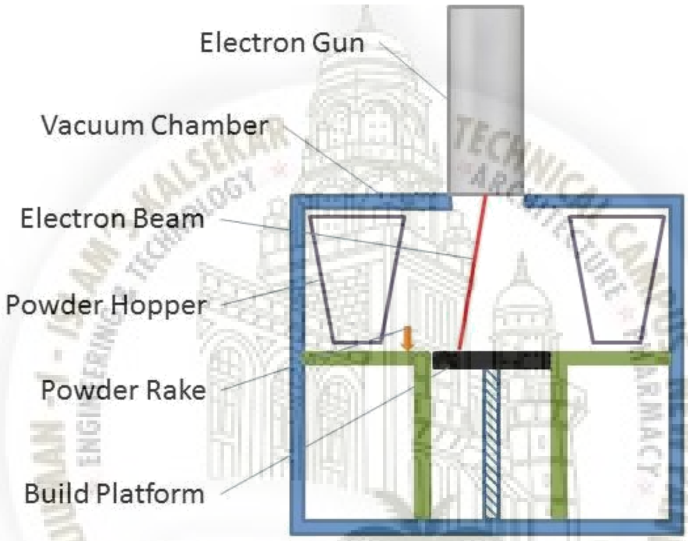


Figure 1.7 Electron Beam Melting (EBM) Technology [2]

difference between the two is the power source. The SLM approach above uses high-powered laser in a chamber of noble, or inert gas. EBM, on the other hand, uses a powerful electron beam in a vacuum. Aside from the power source, the remaining processes between the two are quite similar. EBM's main use is to 3D print metal parts. Its main characteristics are its ability to achieve complex geometries with freedom of design. EBM also produces parts that are incredibly strong and dense in their makeup.

Here are a few of EBM's other impressive features:

- Doesn't need extra auxiliary equipment for the 3D printing process
- Has increased efficiency using raw materials
- Lessens lead times resulting in parts getting to market faster
- Can create fully functional, durable parts on demand for wide-ranging industries.

(7) Laminated Object Manufacturing (LOM) Technology:

A Californian company called Helisys Inc. (now Cubic Technologies), first developed LOM as an effective and affordable method of 3D printing. A US design engineer called Michael Feygin—a pioneer in 3D printed technologies—originally patented LOM.

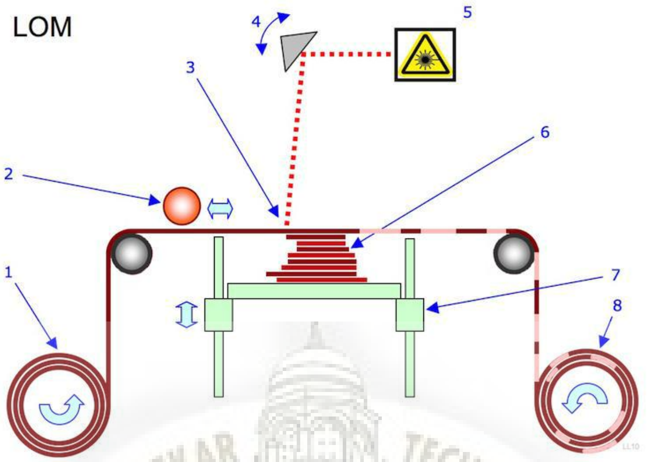


Figure 1.8 Laminated Object Manufacturing (LOM) Technology [2]

LOM is a rapid prototyping system that works by fusing or laminating layers of plastic or paper using both heat and pressure. A computer-controlled blade or laser cuts the object to the desired shape. Once each printed layer is complete, the platform moves down by about 1/16th of an inch, ready for the next layer. The printer then pulls a new sheet of material across the substrate where it's adhered by a heated roller. This basic process continues over and over until the 3D part is complete.

The LOM printing works as follows:

- Sheet is adhered to a substrate with a heated roller.
- Laser traces desired dimensions of prototype.
- Laser cross hatches non-part area to facilitate waste removal.
- Platform with completed layer moves down out of the way.
- Fresh sheet of material is rolled into position.
- Platform downs into new position to receive next layer.
- The process is repeated.

It might not be the most popular method of 3D printing today, but LOM remains one of the fastest nonetheless. It's also perhaps the most affordable method for creating 3D prototypes. The reason for this is because of the low cost of materials used (papers and plastics). It's also a process that can create fairly large 3D printed objects. Those who continue to use LOM printers today include architects, artists, and product developers.

8) Binder Jetting (BJ) Technology:

The Massachusetts Institute of Technology (MIT) first invented BJ 3D printing. You may also hear this technology referred to in other names, including:

- Powder bed printing
- Inkjet 3D printing
- Drop-on-powder
- Binder jetting (BJ).

This is the most popular name and the one we'll use to refer to it. BJ is a 3D printing process that uses two types of materials to build objects: a powder-based material (usually gypsum) and

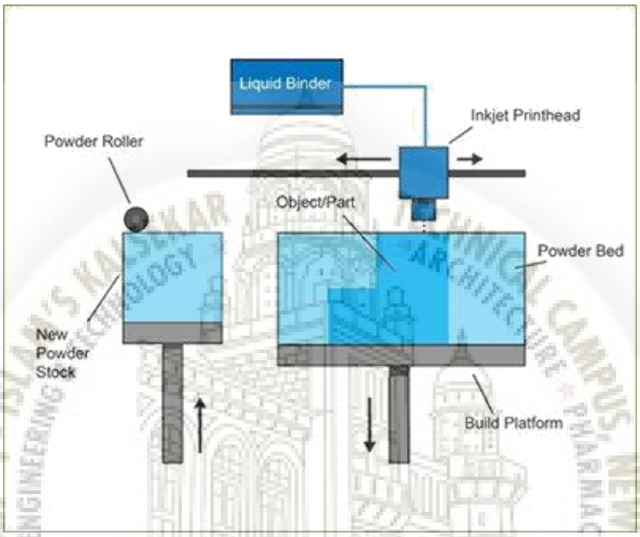


Figure 1.9 Binder Jetting (BJ) Technology [2]

a bonding agent. As the name suggests, the "bonding" agent acts as a strong adhesive to attach (bond) the powder layers together. The printer nozzles extrude the binder in liquid form similar to a regular 2D inkjet printer. After completing each layer, the build plate lowers slightly to allow for the next one. This process repeats until the object reaches its required height.

9) Material Jetting (MJ) Polyjet and Wax Casting Technology

Material Jetting referred to as wax casting. Unlike other 3D printing technologies, there isn't a single inventor for MJ. In fact, up until recent times it's been more of a technique than an actual printing process. It's something jewellers have used for centuries. Wax casting has been a traditional process where the user produces high-quality, customizable jewellery. The reason it gets a mention here is because of the introduction of 3D printing. Thanks to the arrival of this technology, wax casting is now an automated process. Today, MJ 3D printers produce high-resolution parts, mainly for the dental and Jewellery industries. [2]

1.1.3 Applications of 3D Printer:

1. Shelter:

Shelter is another basic human necessity which an interesting application for 3D printing can be. The building industry is one of the last remaining fields where human labour and skills are the norm and mass manufacturing techniques and robots are considered science fiction. Given that a large portion of world population is without permanent shelter or food, it would be logical to think that these basic necessities should be top priority for robotized manufacturing techniques yet both the construction and food industries remain labour intensive. Conventional building methods are hazardous, time consuming, and expensive; 3D printing of buildings can enable automated creation of variety of buildings quickly and efficiently. This technology has been invented and developed in the University of Southern California. A scale down version of a house 3D printing machine is shown in figure

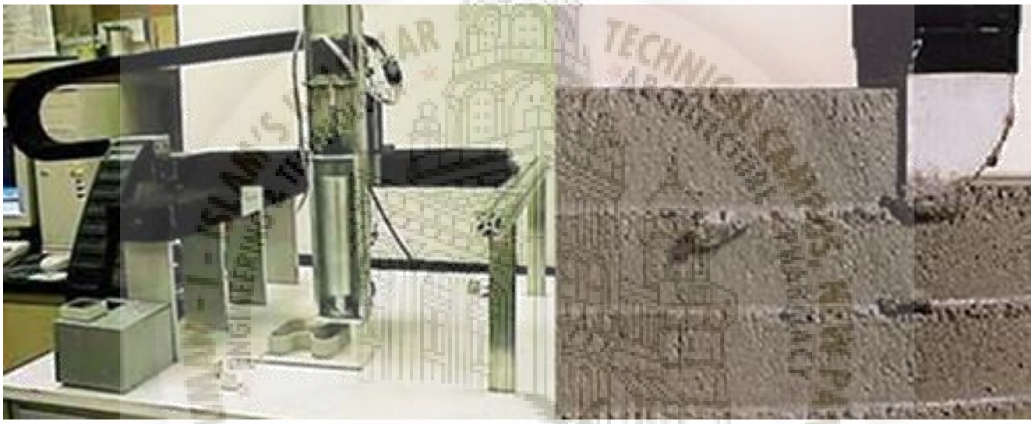


Figure 1.10 Scaled down version of house 3D printing machine (left), 3D printed concrete layers (right) [3]

2. Food:

Food is one of fundamental ingredients of life which is at the base of the pyramid of human needs. Bringing the food industry to the digital age is one of the essential and revolutionary applications of 3D printing. Applying this technology enables fast automated and repeatable processes, freedom in design, as well as allowing large and easy variability of the cooking

Figure 11 3D printing of chocolate [3]

process which can be customized for each region or individual. Using robotic layer-based food printing systems allows the recipe of the food to be digitized and saved in order to prepare very repeatable and high-quality dishes without any margin for operator error. Also, the shape and decoration of the food can be individualized based on the customer or the occasion.

A company called Choc Edge is currently marketing "the world's first commercial 3D chocolate

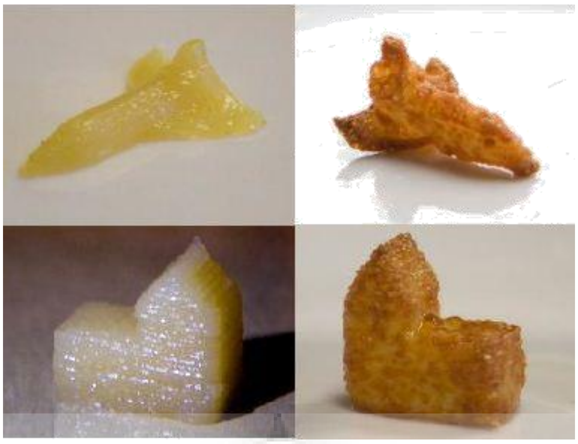


Figure 1.12 3D printing of food, before being frying (left), after frying (right) [3]

printer", the Choc Creator. It uses a nozzle to dispense molten chocolate into any pattern and shape. While the $3,500 price might be expensive for home use, it can prove to be very successful for niche shops tailoring to specific customers or events.

Researches in university of Cornell have demonstrated new materials suitable for baking, broiling and frying for use with food 3D printers. As it is shown in the figure printed objects were deep fried and retained their shape with minimal loss of detail due to deep frying.

3 Bio-Organ printing:

Organ and body tissue regeneration is an incredible ability observed in plants, vertebrates, and mammals. However, this ability is naturally very limited in human’s Regenerative science is expected to provide replacement tissue and entire organs by applying tissue engineering which begins with living cells that are multiplied. The cells are seeded into a 3D containment structure that facilitates the directed 3D growth and proliferation while also providing nutrients to the cells.

Figure 13 Bio printing machine (left), Bio-printed model of Kidney (right) [3]

3D printing of human tissue and organs can revolutionize the healthcare industry by extending the average life expectancy and greatly improving the quality of life for millions of people. Organ recipients will no longer have to wait months or years for a donor with the correct blood type, organ transplant rejection will be abolished, illegal human trafficking for organ harvesting can be minimized, and war and accident amputees can once again gain full mobility. 3D Bio-printing may have unprecedented consequences on regenerative medicine and quality of life while minimizing ethical and religious issues which currently surround human embryo techniques.

4. Dental implants:

Dental industry has been using artificial material for dentures, orthodontics, implants, crown, and bridges for many years. As these parts are custom made for each person, the process is both time consuming and expensive. Direct and indirect 3D printing, namely printing the actual part or a mould, has been shown to be a cheaper and faster alternative to conventional techniques.

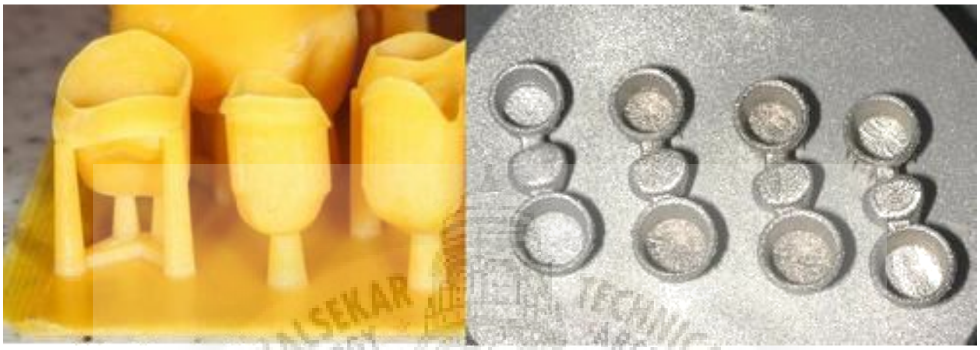


Figure 1.14 Dental implants [3]

5. Skull and jaw implants:

Researchers have shown that 3D printed parts can be used as bone replacement for people whom lost part of their skull or jaw in an accident.

6. Security and integration:

Becoming more integrated and secured implies improving life chances and providing people

Figure 1.15 Skeleton parts printed on 3D printer [3]

with equal opportunities. These opportunities may include the ability of human communication or mobility which is considerably difficult for people with various disabilities and illnesses such as considerable in disabilities cases like Arthrogryposis. Regarding this, 3D printing as an advanced technology can compensate the individual's disability or deficiency by manufacturing complex composite 3D objects using 3D scanned data. It can help people regain mobility, improve their employment and social opportunities and possibly help self-reliance and alleviate self-confidence issues. As an example, a facial reconstruction surgery using a 3D printed eye bone is shown in the figure below.

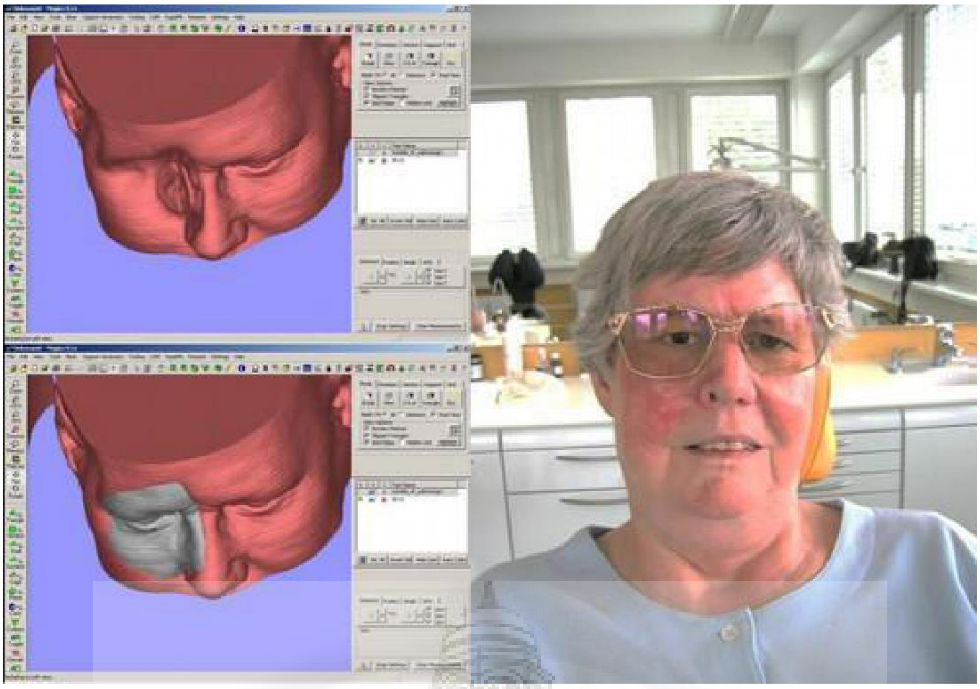


Figure 1.16 facial reconstruction surgery using a 3D printed eye bone [3]

6. Education:

The education system plays an important role in aiding people achieve their full potential. 3D printing can revolutionize the learning experience by helping students interact with the subject

Figure 1.17 architectural component [3]

matter. Affordable 3D printers in schools may be used for a variety of applications which can aid students in finding their field of interest easier and faster. Currently there are different types of educational projects in order to attract students to the various fields by giving them the opportunity to create and fabricate their own designs using 3D printing technology.

7. Creativity:

The ability to develop and present ideas is one of the most important needs in the society and human development. Regarding this 3D printing can enable the creation of complex geometries which are very difficult, expensive, or impossible to be manufactured using conventional production methods. Figure 13 shows two such ordinary products which can design and customized as per customers' demands.[3]

1.2 Motivation

Since over a century, we visualize the models and scriptures in the 2D format that is by using

Figure 1.18 3D printer for Fashion design [3]

2D printing methods we express the design aspects and data on 2D plane i.e. paper, wall, etc. but when it comes to imaging of definite and real-life models which are mainly used in design & manufacturing sectors, it become outsourced / outdated. it is difficult to represent & display any 3D model in 2D workplace. To avoid this, the 3D printing Technology came into existence, basically It is a machine which able to print 3D objects directly on print bed. but the cost for buying this machine is high in market.so, we decided to make a 3D printer which has minimum cost with maximum facilities or specification as provided by other manufacturers.

1.3 Aim and Objective:

To redesign and refurbish the 3D Printer to increase the stability and optimization.

Objective of doing this project is given as:

1. To reduce the mechanical errors made in former model.
2. To change the X-Y mechanism from two belts to single belt.
3. To change the hanging cantilever bed and redesign to more stable bed frame
4. To accommodate more durable side blocks and gantry
5. To make the printer dual extrusion compatible
6. To make the printer look aesthetically good.
7. To accommodate the opened degrading filament and make the printer compact and more easily portable.

1.4 Literature Review

Rudolf Madaj et al [5] has studied dynamic analysis of power train**.** The current situation on a 3D print field is increasing precision of printers and printing of small parts. They were decided to use reverse philosophy and build 3D printer of big dimensions. This resulted in need of performing a dynamical simulation. The goal of this paper is to perform a dynamical analysis of moving parts of 3D printer and also to find suitable type of powertrain motors.

L. M. Galantucci, et al [6] did Analysis of dimensional performance for a 3D open-source printer based on fused deposition modelling technique**.** In this paper an analytical dimensional performance evaluation and comparison is illustrated, done on benchmarks manufactured using two different 3D FDM printers: an industrial system, and an open-source one (a modified Fab@Home Model 1 printer). Using a factorial analysis design of experiment (DOE), optimum process parameters were found to improve dimensional accuracy on rectangular test specimens, minimizing changes in length, width and height. Fab@Home printer demonstrated to be a good platform, simple, flexible and inexpensive.

Felix Baumann et al [7] explained Concept Development of a Sensor Array for 3D Printer. In this paper the design and implementation of a sensor array suitable for 3D printers is presented. The sensor array includes sensors for motion/vibration, temperature, orientation and hygrometry. The sensor array is designed as an easily deployable, wireless sensor client-server system. Aggregated sensor data and print related data enable research on influencing ambient factors and quality control of the printing process. In future revisions this sensor system is intended as part of a closed-loop control system for 3D printers. The wireless connectivity enables the system to be incorporated in other machinery on moveable parts.

Paolo Minetola et al [8] used self-replicated parts for improving the design and the accuracy of a low-cost 3D printer. Low-cost entry-level 3D printers suffer from reduced optimization, that is a consequence of development cost savings. There challenge was used to modify four Prusa i3 machines with the aim of enhancing the design and performances by means of self-replicated parts. The challenge results were assessed through benchmarking of the four modified 3D printers, whose dimensional accuracy was evaluated by means of CMM measurements of 3D printed replicas of a reference part. The ISO IT grades related to the dimensional quality of the replicas were considered in the analysis of the CMM measures for the challenge assessment.

A.C. Majarena et al [9] presented an case study on error compensation for 3d printer. The paper developed presents a case study that allows students to learn an easy way to improve the accuracy of low cost 3D printers. The document detailed a methodology to achieve this goal. First, it is necessary to print an initial CAD design. A commercial scanner is calibrated and the pieces are scanned to obtain the different errors. Then, a program is generated to compensate the code numerical control of the printer. This fact allows students to print a new piece having less errors than before, which it involves improve the printer accuracy.

Xunfei Zhou et al [10] explained tensile behaviour of polylactic acid parts manufactured by fused deposition modelling using finite element analysis. With the rise of the Fused Deposition Modelling (FDM) industry, a better understanding of the relationship between FDM process parameters and mechanical behaviour especially tensile behaviour of designed parts is needed to enable development of industry specifications. To optimise and control the deposition process, modelling and predicting the mechanical behaviour of a manufactured part under various process parameters is required. Existing numerical modelling approaches either require input of extensive experimental data or lack cross-validation. In this paper, the mechanical behaviour of polylactic acid manufactured parts under tensile conditions was studied both experimentally and numerically, and the effects of printing pattern and infill density on ultimate tensile strength (UTS)-weight ratio and the modulus of elasticity were evaluated. The experimental results revealed that minimising air gaps and using a triangular infill pattern are beneficial for obtaining a good UTS/weight ratio. Of all the specimens considered, the 20% triangular pattern had the highest UTS/weight ratio. The numerical investigation revealed that the meso-structure approach described in this paper can be used to predict the modulus of elasticity and the breaking point and does not require input from the unidirectional specimen stress-strain curves. Finally, the meso-structure numerical model and artificial neural network were used to construct a knowledge-based library that can predict the modulus of elasticity of FDM manufactured polylactic acid with three infill patterns and any infill density with an average prediction error of 14.80%.

Catalin Gheorghe Amza et al [11] presented Considerations on thermic and mechanic processes that appear when 3D printing using ABS fused deposition modelling technology 3D printers are of recent history, but with an extremely rapid evolution both in technology and hardware involved. At present excellent performances are reached in applications such as 3D printing of various Acrylonitrile butadiene styrene (ABS) plastic parts for house building using Fused Deposition Modelling technology. Nevertheless, the thermic and mechanic processes that appear when manufacturing such plastic components are quite complex. This aspect is very important, especially when one wants to optimize the manufacturing of parts with certain geometrical complexity. The Finite Element Analysis/Modelling (FEA/FEM) is among the few methods that can study the thermic transfer processes and shape modifications that can appear due to non-seamar behaviour that takes place when the ABS plastic material is cooling down. The current papers present such an analysis when simulating the deposition of several strings of materials. A thermic analysis is made followed by a study of deformations that appear when the structure cools down.

Guido Herrmann et al [12] described Filament Temperature Dynamics in Fused Deposition Modelling and Outlook for Control Fused Deposition Modelling (FDM), a form of Additive Manufacture, can produce 3D components directly from CAD data. This paper investigated fluctuations in filament temperature during step changes in feed rate and start/stop motions, monitoring temperature using a thermal camera and thermistors embedded in both the block and nozzle. Temperature overshoots 12°C and 18.5°C were observed during a step increase in feed rate and a priming motion respectively. Evaluating these changes with a sintering model predicted a 20% increase in bond formation, although no significant differences of bond sizes were observed using optical measurement.

Alessandro Pegoretti et al [13] discussed Filaments Production and Fused Deposition Modelling of ABS/Carbon Nanotubes Composites. Composite acrylonitrile–butadiene–styrene (ABS)/carbon nanotubes (CNT) filaments at 1, 2, 4, 6 and 8 wt %, suitable for fused deposition modelling (FDM) were obtained by using a completely solvent-free process based on direct melt compounding and extrusion. The optimal CNT content in the filaments for FDM was found to be 6 wt %; for this composite, a detailed investigation of the thermal, mechanical and electrical properties was performed. Presence of CNT in ABS filaments and 3D-printed parts resulted in a significant enhancement of the tensile modulus and strength, accompanied by a reduction of the elongation at break. As documented by dynamic mechanical thermal analysis, the stiffening effect of CNTs in ABS is particularly pronounced at high temperatures. Besides, the presence of CNT in 3D-printed parts accounts for better creep and thermal dimensional stabilities of 3D-printed parts, accompanied by a reduction of the coefficient of thermal expansion). 3D-printed nanocomposite samples with 6 wt % of CNT exhibited a good electrical conductivity, even if lower than pristine composite filaments.

Luigi Maria Galantucci et al [14] studied for a full colour low cost open source 3D printer, based on the combination of fused deposition modelling (FDM) or fused filament fabrication (FFF) and inkjet printing. Additive manufacturing techniques (AM) have enhanced product quality and exponentially increase their application both from the industrial point of view and from the consumer point of view. A decisive development in the "consumer" sector has been observed over the last 5 years thanks to open source projects (Fab@home, RepRap), which enabled the production of low cost machines with the use of cheap electronic and mechanical components and open source software. Among the possible future developments of low cost AM technologies, there is an improvement of finished product capabilities and appearance to obtain coloured components, made directly during printing phase. This paper tries to respond to this need by assessing the feasibility of realizing a low-cost AM system that integrates automatic colouring in a consumer 3D printer. The proposed system is a hybrid between a fused filament fabrication 3D printer, derived from an open-source project, and a 2D commercial inkjet printer; the two systems share the mechanics, but keep the movement control and the three-dimensional and two-dimensional printing process separate. The study continues with the theorization, modelling and creation of the interfaces required for conversion of control signals and a first experimentation of the same control. The two systems, using a different mechanics, use different motor control systems.

Dejan Movrin et al [15] did experimental investigation of extrusion speed and temperature effects on arithmetic mean surface roughness in FDM built specimens Surface roughness remains one of the soft spots of FDM technology in general, while the problem is especially pronounced in the domain of 3D printers for personal use. Extrusion speed and extrusion temperature are two controllable parameters which, other than layer thickness, have greatest impact on the surface quality of FDM-built parts. Analysed in this paper is the influence of extrusion speed and temperature on the arithmetic average of the roughness profile (Ra) of FDM specimens. A 2^2 factorial experiment was used with two replicas and two centre points. The results indicate a dominant, statistically significant influence of extrusion speed, as well as the pronounced nonlinearity of effects.

1.5 Problem Definition

To refurbish the 3D Printer and modify the design to optimize the parameters.

1.6 Future Scope

3D printing is a new and promising technology, and as with all developing fields the scope for improvement and advancement are definitely infinite.

NASA:

Nothing incorporates innovation and advancement like our space program. In July 2013, NASA designed, printed, and tested rocket engine injectors by subjecting them to challenging pressures and temperatures of over 6,000 degrees F. In fall 2014, NASA has devised to launch and deliver a 3-D printer to the International Space Station, which will help astronauts to print replacement tools in space. [16]

BIOTECHNOLOGY:

In 2012, an elderly woman in Belgium proclaimed a 3-D printed jawbone, transplanted and specially tailored to her facial structure. This year, engineers at Princeton were able to produce an ear imprint, applying a culture of animal cells and silver nanoparticles; the experimental version was able to read audio beyond the limit of human levels, making this a “bionic” ear.

Using this method, leather could be manufactured and even meat. Engineers are working on producing non-perishable foods from powder (liquid-free) cartridges; imagine the effect that developments like these could have on global sustainability process in the future. [17]

REPLICATION:

A key idea in the flourishing field of 3-D printing is the ability for printers to reproduce themselves, or to manufacture as many essential components as possible that are required to build a machine. Many consumer 3-D printers now come assembled with components that were themselves manufactured in 3-D. This year, a functioning pistol was designed and printed, with the computer automated drawing schematics made readily available online. [18]

CHAPTER 2

PRINCIPLE, COMPONENTS AND OPERATION

2.1 Basic principle

Various 3d printing technologies are available but the most popular and reliable technique is Fused Deposition Modelling (FDM) also called as Fused Filament Fabrication (FFF). We made a 3D printer which works on FDM principle.

2.1.1 Fused Deposition Modelling:

Fused deposition modelling (FDM) technology was developed and implemented at first time by Scott Crump, Stratasys Ltd. founder, in 1980s. Other 3D printing companies have adopted similar technologies but under different names. A well-known nowadays company MakerBot coined a nearly identical technology known as Fused Filament Fabrication (FFF).

With help of FDM you can print not only functional prototypes, but also concept models and final end-use products. What is good about this technology that all parts printed with FDM can go in high-performance and engineering-grade thermoplastic, which is very 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. [1]

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 a bit similar to stereolithography. Firstly, special software "cuts" CAD model into layers and calculates the way printer's extruder would build each layer. Along to thermoplastic a printer can extrude support materials as well.

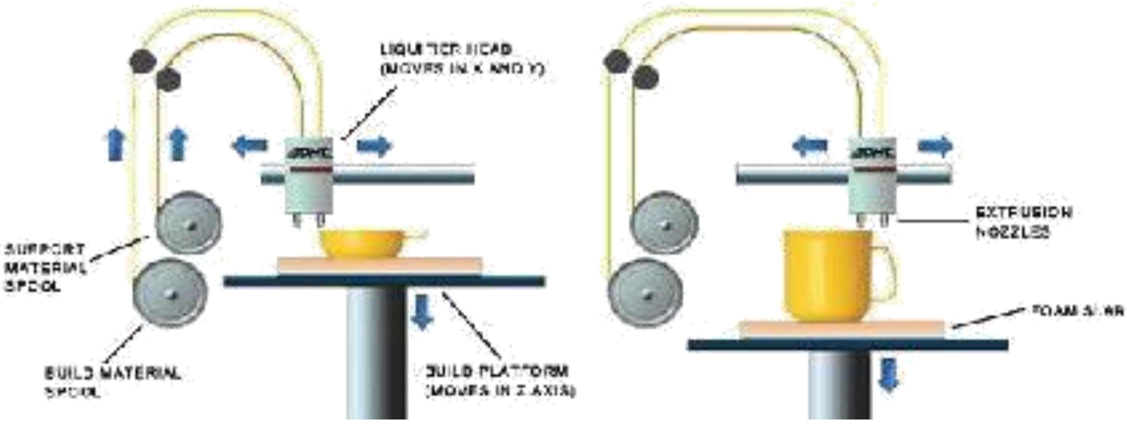


Figure 2.1 Fused deposition modelling [1]

A computer of the 3d printer translates the dimensions of an object into X, Y and Z coordinates and controls that the nozzle and the base follow calculated path during printing. To support upper layer the printer may place underneath special material that can be dissolved after printing is completed. When the thin layer of plastic binds to the layer beneath it, it cools down and hardens. Once the layer is finished, the base is lowered to start building of the next layer. Printing time depends on size and complexity of an object printed. Small objects can be competed relatively quickly while bigger or more complex parts require more time. Comparing to stereolithography this technique is slower in processing. When printing is completed support,

Figure 2.2 Object made by FDM based 3D printer [1]

materials can easily be removed either by placing an object into a water and detergent solution or snapping the support material off by hand. Then objects can also be milled, painted or plated afterwards.

FDM technology is widely spread nowadays in variety of industries such as automobile companies like Hyundai and BMW or food companies like Nestle and Dial. FDM is used for new product development, model concept and prototyping and even in manufacturing development. This technology is considered to be simple-to-use and environment-friendly. With use of this 3d printing method it became possible to build objects with complex geometries and cavities. Different kind of thermoplastic can be used to print parts. The most common of those are ABS (acrylonitrile butadiene styrene) and PC (polycarbonate) filaments. There are also several types of support materials including water-soluble wax or PPSF (polyphenylsulfone). Pieces printed using this technology have very good quality of heat and mechanical resistance that allows to use printed pieces for testing of prototypes. FDM is widely useful to produce end-use products, particularly small, detailed parts and specialized manufacturing tools. Some thermoplastics can even be used in food and drug packaging, making FDM a popular 3D printing method within the medical industry.

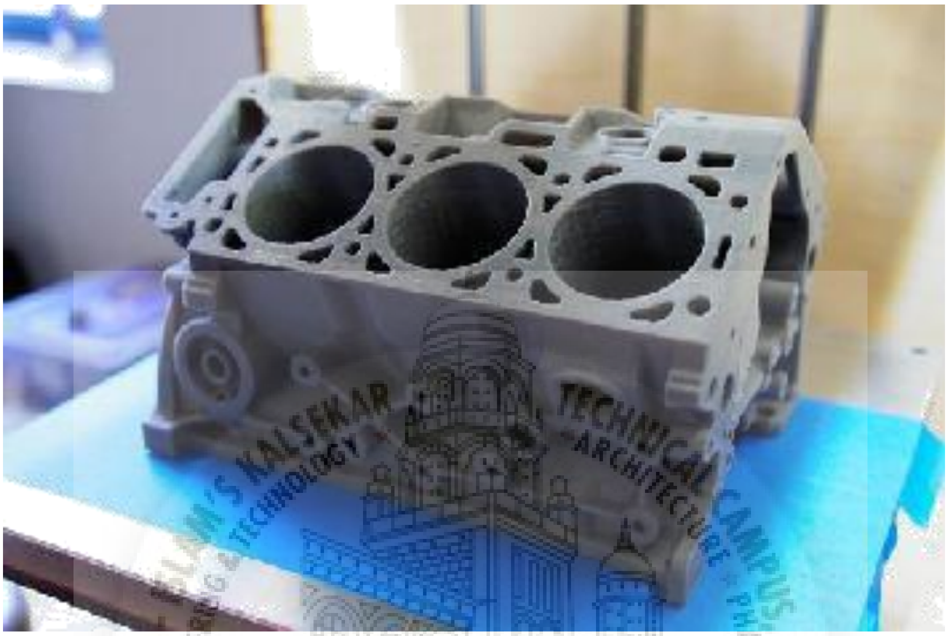


Figure 2.3 Cylinder block printed on FDM based 3D printer [1]

2.2 COMPONENTS

2.2.1 FRAME

3D printer frame design is so fascinating is the vast array of different construction/manufacturing techniques used to build the frames. Various types of frames are explained as follow:

1. Member and Joint Construction:

The simplest, most utilitarian frame designs use some kind of member a joint construction. The RepRap 3D printer designs have frames built using this technique, as well as all the 3D printers pictured above. Basically, the frame consists of a bunch of straight members, like threaded rods or smooth metal rods, connected together by joints. [19]

The construction of these frames is similar to the construction of truss bridges, and 3D printers built using a member and joint construction share many benefits with truss bridges. First of all, this type of construction is cheap. Threaded and smooth rods are readily available from many sources and because they are used for numerous applications in construction, they are inexpensive. Second, Second, this type of frame is relatively easy to design because of its simplicity. Third, also because of the frame's simplicity, it's easy to assemble this type of frame.

On other "benefit" to 3D printer frames build using member and joint construction, although it might be considered more of a feature than a benefit, is that the joints can usually be 3D printed. This means 3D printers using member and joint construction are partially self-replicating. This is, in fact, the purpose of RepRap machines; they can typically be used to produce a large portion of their own parts.

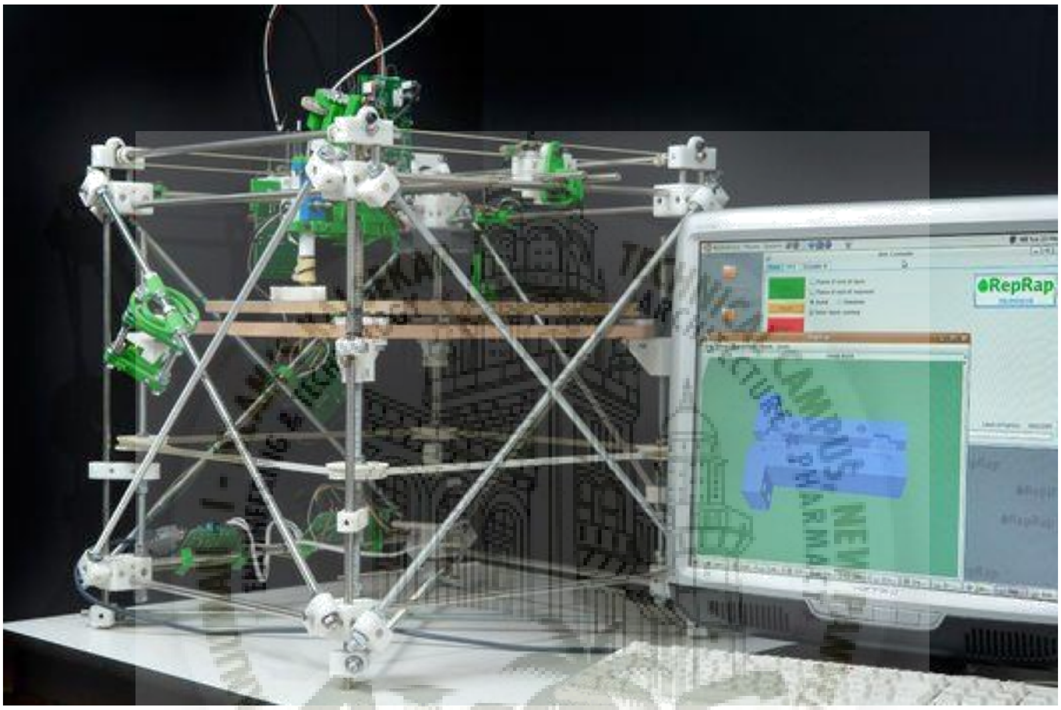


Figure 2.4 Another example of member and joint construction from the RepRap project [19]

The most obvious downside to the member and joint constructed frames is that they simply do not look good. This is probably fine for a 3D printer used as an experimental platform, but it is a significant downside for 3D printers that will be sold to the public.

Another major concern for member and joint construction is safety. First, all of the belts, lead screws, and pulleys are usually exposed with this kind of frame. This creates a danger that objects could get caught in the linear motion mechanisms, including hair or loose clothing. Second, the hot end is also exposed, making it easier for objects to come into contact with the heated nozzle.

2. Laser cut/cnc cut 3D printer frame:

Another way to design and construct 3D printer frames is with laser-cut or CNC-cut panels. The vast majority of the most successful 3D printers of only a few years ago were constructed from laser-cut or CNC-cut panels: the Makerbots Cupcake, Thing-O-Matic, and Replicator 1, the Ultimaker Original, the Printrbots Simple and Jr., the Tinkerine Ditto, and many others were all made from laser-cut or CNC-cut wood, or sometimes plastic, panels.

There are a few very good reasons why building 3D printer frames using laser cutting and CNC cutting is so popular. First, this type of construction is very inexpensive. The material most commonly used for computer-cut 3D printer frames is MDF or plywood, both of which are very cheap. Second, designing laser cut panels is extremely easy and does not require specialized software as the design work is basically done in two dimensions. Third, building frames from computer-cut panels offers easy construction while also offering a fairly good-looking (but still mostly appealing to hobbyists) finished product. Fourth, 3D printers built with this technique are, in general, safer than those built with member and joint construction because the moving parts and the hot parts of the 3D printers are typically covered by the computer-cut panels.

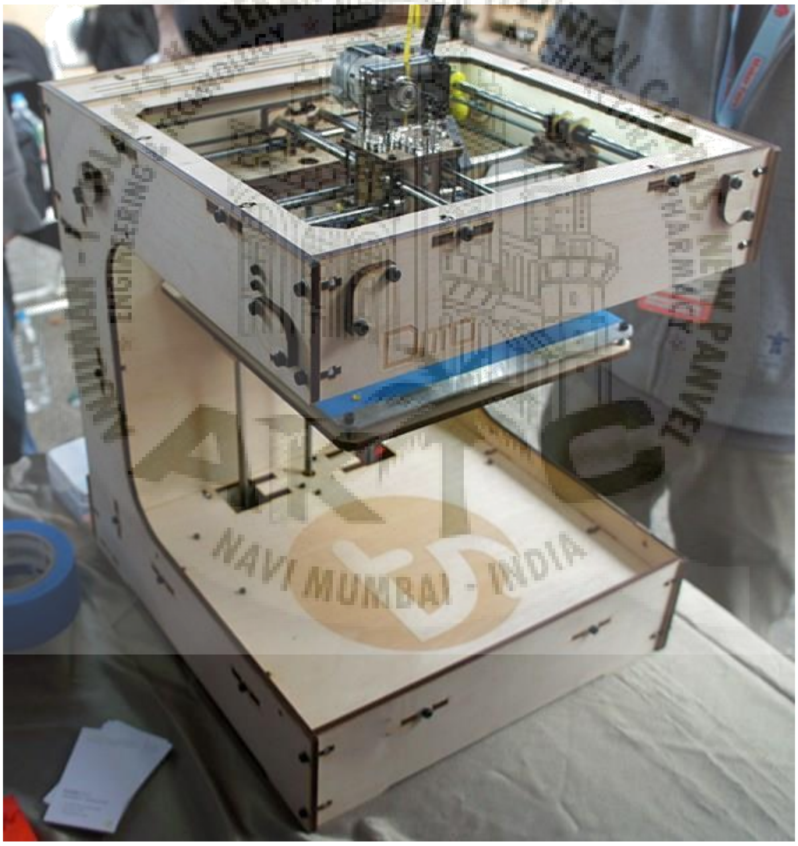


Figure 2.5 Laser cut wooden frame [19]

Last, and this item may be one of the most important benefits on the list, the barriers to entry for making 3D printers with laser-cut or CNC-cut panels is very low. The design work can be done using free or low-cost image editing software. The material, as discussed above, is inexpensive. The technique is extremely popular in the Maker community and so a lot of documentation and help is available online. And many laser cutting services exist, like Ponoko, that offer affordable light manufacturing services that do not require tooling (more on tooling in the next section). These services mean 3D printer designers do not need to purchase a laser cutter or CNC machine themselves. All of this means that a Maker can easily design a 3D printer, and possibly start a business to sell it, with minimal upfront investment. The low barrier to entry into the 3D printing market created by low-cost manufacturing techniques like laser cutting, coupled with the decrease in cost for electronics and stepper motors, is what has driven the explosive growth in the number of 3D printers on the market.

But, building 3D printer frames from laser-cut CNC-cut panels has its drawbacks as well. First, assembling 3D printer frames designed using this technique can be difficult; the frames end up being a bit like big 3D puzzles. Second, like anything build from wood, tight tolerances and precision manufacturing can be major challenges. Along the same lines, wood does not always offer a frame with the stiffness needed for high-accuracy 3D printing.

2.2.2 3D PRINTER LINEAR MOTION SYSTEM:

There are basically two different linear motions systems used in the vast majority of 3D printers on the market today, although there are a few experimental systems that will be discussed later on. Most 3D printers use combinations of lead screws and timing belts for linear motion.

1. Lead Screws:

Lead screw systems are a simple means of translating the rotational motion of the stepper motors to linear motion of the 3D printer build platform and/or extruder. A lead screw linear motion system consists of some kind of threaded rod, which is rotated by the stepper motor, and a mating nut that moves up and down the threaded rod as it rotates. [20]

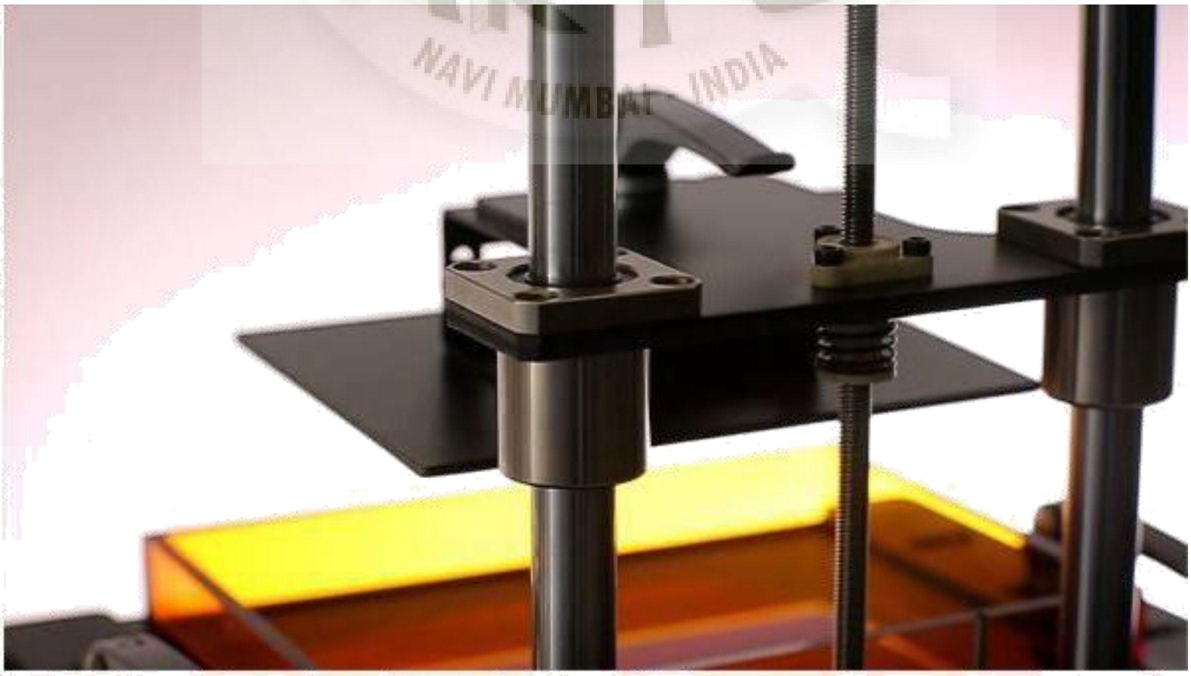


Figure 2.6 Lead screw [20]

Almost all 3D printers use at least one lead screw in their linear motion system to control motion along the z-axis. Typically, a lead screw will be used to lift the build platform or the extruder up one layer at a time during the build process.

There are several different types of lead screws, each with their own advantages and disadvantages. The three most common types of lead screws are ordinary threaded rods, trapezoidal (ACME) lead screws, and ball screws. Each of these lead screw times has its own set of advantages, but there are some advantages that all three types of lead screws share. First, lead screws are capable of delivering a large amount of force. The mechanical advantage provided by screws is the entire reason screws exist at all. Second, screws are said to be self-locking. This means that if the 3D printer loses power, the screw will stay right were it is, without moving. This is part of the reason lead screws are typically used for vertical movement of the build platform. It does not matter if the z-axis motor loses power; the build platform will stay at its current position.

All lead screws also share some disadvantages. First, they all require periodic lubrication to reduce ware and increase efficiency. Second, all lead screws wear more quickly than other linear motion systems. Third, because of the metal-on-metal contact between the lead screw and nut, lead screws are noisy. Last, lead screws are prone to backlash. This is the reason lead screws are not usually used for the x-axis or y-axis. These axes switch directions very frequently and because of the backlash most lead screws suffer from, every time the screw

Figure 2.7 Different types of lead screw [20]

changes direction, the positional accuracy decreases. This can get to be a big problem for a long print As for the unique benefits and drawbacks of each type of lead screw, ordinary threaded rods are the lowest performance, but also the cheapest, type of lead screw. Technically, threaded rods are not lead screws at all because they are not designed for use in linear motion systems. Their intended purpose is to attach things. Threaded rods have the benefit of being very inexpensive, and readily available. However, again because threaded rods are not designed for linear motion, they are not as accurate as the other lead screw types, they have a relatively large amount of backlash, they wear quickly, they require lubrication, and they are very inefficient. This last point about efficiency is actually very important. Threaded rods only have an efficiency around 20% to 30%. This means a bunch of power is wasted on fighting friction, it means the threads will were quickly, and it means moving the lead screw is taxing on the motor.

ACME lead screws are a kind of middle ground between threaded rods and ball screws. Unlike ordinary threaded rods, ACME lead screws are designed for linear motion. ACME lead screws are much more accurate than threaded rods, and they have smaller backlash. The trapezoidal thread profile also makes ACME lead screws more resistant to wear. However, ACME lead screws, like threaded rods, are still very inefficient and they require lubrication. Last, ACME lead screws are a lot more expensive than threaded rods, and the ACME nuts are more expensive than regular nuts as well.

Last we have ball screws. Ball screws have the best performance among the three lead screw types, but they are also by far the most expensive. Ball screws use a specialized type of nut that is kind of like a ball bearing. Ball screws are again much more accurate than threaded rods, and have a smaller backlash. Also though, ball screws are much more efficient than either threaded rods or ACME lead screws, about 70% efficient. For this reason they consume less power, are less demanding of the motors, and wear less. Ball screws, however, require regular lubrication to function properly and are, again, very expensive

2. Timing Belt:

Belt drives are used on the x-axis and y-axis on the vast majority of 3D printers. 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.

Belt drives have several advantages over lead screws for use on the x- and y-axes:

Belt drives are typically less expensive than specialized types of lead screws like ACME screws or ball screws. Belt drives are better suited for long travel lengths since the timing belt can easily be made as long as necessary to achieve the desired travel distance for the axis.

- ✓ Lower maintenance than lead screws; no lubrication required.
- ✓ Capable of much higher speeds than lead screws.
- ✓ Low backlash

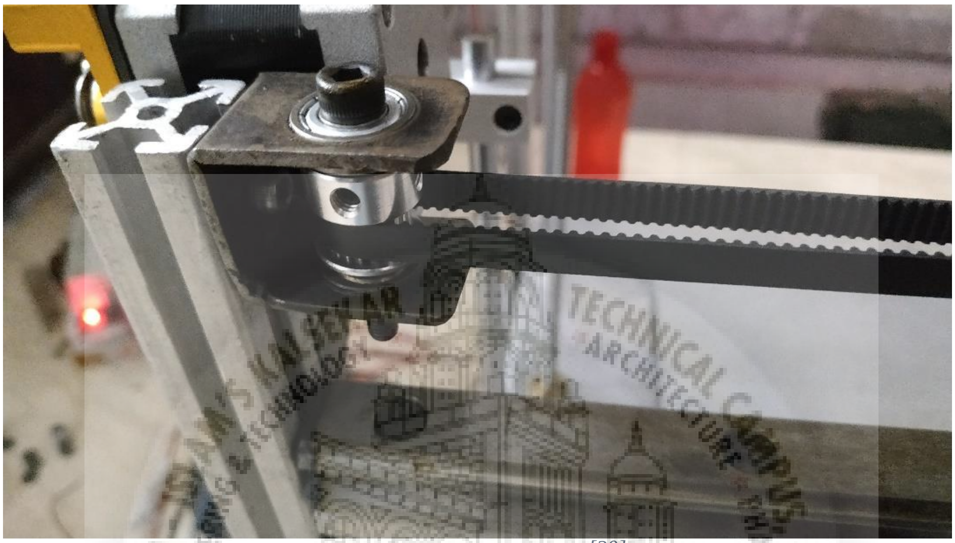


Figure 2.8 Belt and pulley [20]

This last point is of particular importance. Assuming that the belt drive system has been set up and tuned correctly, a subject we will discuss in a moment, belt drive systems have very low backlash. This makes them good for use on the x-axis and y-axes, which change direction frequently. The low backlash means the linear motion will not lose positional accuracy over time. The second to last point is also important. Belt drives can move much faster than lead screw systems, meaning prints get done in less time. Belt drives for linear motion of course have some downsides. Most importantly, a belt drive system achieves its low backlash and high accuracy only when the belt is in tension. In other words, if there is slack in the timing belt, it will ruin the accuracy of the entire system. For this reason, 3D printers using belt drive systems must incorporate some mechanism for keeping the belts in the proper tension at all times. The belts must be tight enough to avoid backlash and any kind of oscillation. On the other hand, if the belts are too tight, the motors will not be strong enough to move them and the system could miss movement commands. Therefore, one of the drawbacks to using a belt drive system is that it requires more work to tune correctly. Compounding this issue is the fact the timing belts have a tendency to stretch a bit over time. Therefore, a 3D printer operator will need to periodically re-tension the timing belts to keep the system working well.

2.2.3 BEARING AND BUSHING:

1. Bushing:

Bushings, also called sleeve bearings, slide over smooth rods and provide an extremely low friction motion which minimizes power consumption, noise, and wear on parts. Bushings look

Figure 2.9 Metal bush [21]

like plain metal tubes, but they are actually fairly sophisticated parts. Bushings are typically made from a bronze powder. The powder is fused together such that tiny pours are present in the metal. The bushings are then impregnated with oil (about 20% oil by volume). Then, as the bushing contacts a shaft, the oil is drawn to the surface of the bushing via capillary action so that the bushing constantly deposits a thin film of lubricating oil onto the shaft. In other words, bronze bushings are self-lubricating. Self-lubrication is the first major advantage of using bushings over ball bearings. Another major benefit is cost. Bronze bushings cost between six and ten times less than linear ball bearings. The third major benefit to bushings is that they are generally quieter than ball bearings. Fourth, bushings can be used on either hardened or non-hardened shafts, whereas linear ball bearings can only be used on the more expensive hardened shafts. Finally, bushings generally require less maintenance than linear ball bearings. Bearings have a couple of downsides as well. First, bushings can have what is commonly referred to as the “stick and slip” problem. Bronze bushings, unlike linear ball bearings, need to overcome static friction forces before moving. Especially if the linear motion system is worn, or not properly aligned, this means the bushings can move in a kind of jerky, uneven movement. Second, bushings, especially cheap ones, can have wider tolerances making for a slightly worse fit on the smooth rods. [21]

2. Linear Ball Bearing:

Linear ball bearings have a number of advantages over bushings. First and foremost, the motion provided by linear ball bearings is generally smoother than bushings. Since linear ball bearings roll instead of sliding, they do not have static friction to overcome before moving like bushings

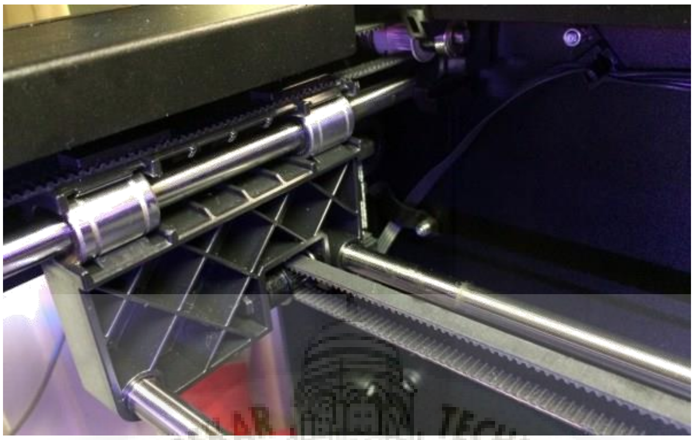


Figure 2.10 Linear ball bearing [21]

do. Second, linear ball bearings are also generally built to tighter tolerances than bushings. The tighter fit on the smooth rods means less slop and less backlash. Linear ball bearing has a few disadvantages as well, chief among them is cost. As mentioned above, linear ball bearings cost between six and ten times as much as bushings, assuming you are purchasing decent bearings. Adding to this increased cost is the fact that linear ball bearings *must* be used with hardened, preferably chrome-plated, shafts. If linear bearings are used on softer metal shafts, the balls will basically cut into the shaft over time, which increases backlash. The second disadvantage is that linear ball bearings require more maintenance than bushings. Inside a linear ball bearing, the ball bearings themselves contact the smooth shaft directly. This means the shaft must be lubricated from time to time in order to keep the system running well. This also means dirt and dust can make its way into the ball bearings, which again hurts performance. Along the same lines, linear ball bearings can have problems if not properly maintained. With lack of maintenance, the linear ball bearings can lose their smooth motion, can run louder, and could even jam.

2.2.4 ENDSTOPS:

3D printers are extremely accurate and precise positioning systems, but the way 3D printers track their position is different than many people think. The way a 3D printer controller tracks the position of the print head is much different than how a human might do the same thing. A 3D printer does not move the print head to a location in absolute coordinates. Rather, movements are made relative to the current position of the print head. So, for example, you cannot tell a 3D printer to move the print head to the coordinates (15mm, 10mm, 12mm). You can only tell the 3D printer to move 15mm up, 10mm right, and 12mm forward. Therefore, at the beginning of every print, the 3D printer must move the print head to a starting position, which the 3D printer firmware considers to be the origin, (0, 0, 0). The origin point for most 3D printers is on one corner of the build platform, at a height above the build platform equivalent to one-layer height. This origin point is called "home." Starting every print from the same home position allows the 3D printer to reference its movements. So, at the beginning of every print, each of the 3D printer's axes backs up until each axis reaches its zero position. Some kind of switch or trigger is placed at the zero position of each axis so that the 3D printer knows when the zero position is reached. [22] These switches are called "endstops."

There are three different types of endstops: mechanical, optical, and Hall effect.

1. Mechanical Endstops:

Mechanical endstops are the simplest and most commonly-used type of endstop. Mechanical endstops are simply switches placed on each axis. At the start of each print, the 3D printer moves each axis until the carriage hits the switch.

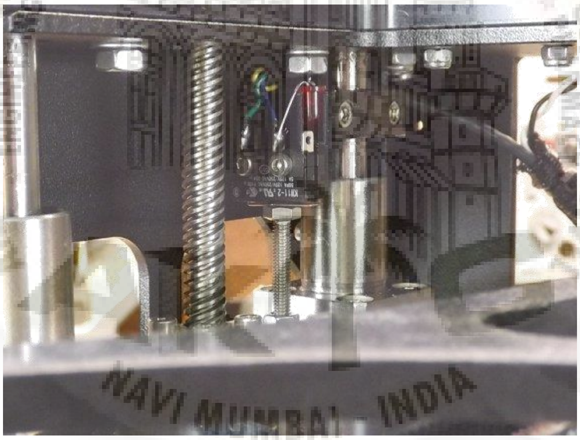


Figure 2.11 Mechanical endstop [22]

The actual switches used for mechanical endstops are micro switches. Micro switches have a thin metal lever that presses on a small button to actuate the switch. Micro switches are a good choice because they require very little force to actuate. This means the endstops can be triggered without the carriages crashing into them too hard. Mechanical endstops are a popular choice in 3D printers because they are very inexpensive and simple to use. Mechanical endstops connect to the 3D printer motherboard with just two wires. Therefore, in terms of setup, one mechanical endstop is mounted to each axis and wired to the motherboard. Often it is desirable, sometimes even necessary, to adjust the actuation distance for the endstops. This is usually accomplished by installing a bolt on the carriage such that the bolt contacts the mechanical endstop to trigger it. By screwing the bolt in or out, the actuation distance for the endstop can be adjusted, thus adjusting the home position.

2. Optical Endstops:

The second type of endstop is the optical endstop. Optical endstops are the least popular type of endstop because, honestly, they are more expensive and more complicated than mechanical endstops and offer few benefits to offset these disadvantages. The only real advantage to using optical endstops is that optical endstops can be triggered without any physical contact between

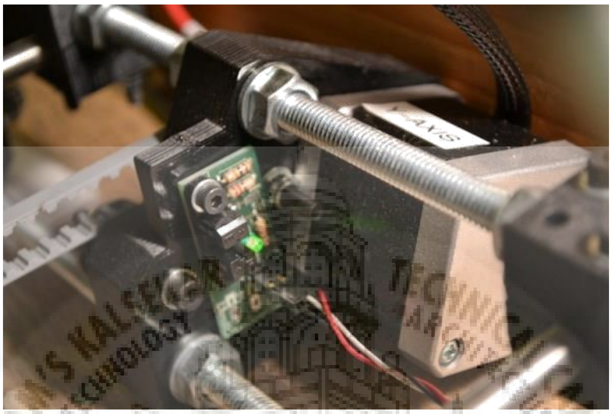


Figure 2.12 Optical endstops [22]

the carriage and the endstop. This can increase the life of the endstop and decrease the chance of any components being broken from bumping into each other. The most important part of an optical endstop is a U-shaped optical sensor called a photointerrupter. The U-shaped photointerrupter has an infrared emitter on one side, and an optical detector on the other side. The endstop is triggered with the light beam between the two sides is broken.3D printers using optical endstops typically have some kind of thin blade mounted on the carriage. The blade breaks the photointerrupter beam to trigger the endstop.

3. Hall Effect Endstops:

The final type of endstop is the Hall effect endstop which is a fairly popular option, but not quite as popular as mechanical endstops. Hall effect endstops consist of two main parts. The

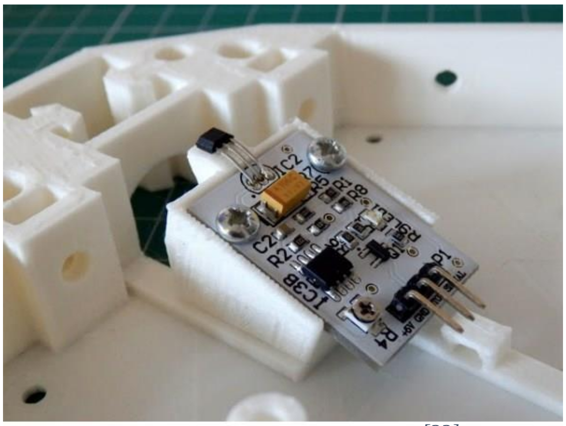


Figure 2.13 Hall effect endstops [22]

switch itself uses a magnetic sensor called a Hall effect sensor, which is triggered in the presence of a magnetic field. The second part is a magnet mounted on the carriage. When the carriage nears the endstop, the Hall effect sensor detects the magnetic field and triggers the endstop. Hall effect endstops, like optical endstops, have the advantage of being non-contact endstops. This means the endstop will be triggered without physical contact from the carriage, which can reduce wear on parts. Also, because Hall effect endstops do not make physical contact with the carriage and work over a distance (unlike an optical endstop), they can be calibrated to trigger at an exact distance from the carriage. The main advantage of Hall effect endstops is that they allow the home position of each axis on the 3D printer to be precisely controlled and they allow the home position to be reached with a high degree of repeatability. The downside to using Hall effect endstops is that they are more complex and somewhat more expensive than mechanical endstops – but they are less expensive then optical endstops. Hall effect endstops require a PCB with a few other components in addition to the Hall effect sensor itself, like an operational amplifier and a few resistors. That said, simple Hall effect endstops can be constructed for under $2, so the endstops only account for a very small portion of the total cost of a 3D printer.

2.2.5 STEPPER MOTOR:

A **stepper motor** or **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 then 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 carefully sized to the application in respect to torque and speed.

There are five stepper motors used in the 3D printer are One to control the Y-axis, one to control the X-axis, two to control the Z-axis, one to control the extruder.

2.2.6 STEPPER MOTOR CONTROLLER:

Controlling a bipolar stepper motor is truly muddled, particularly in the matter of smaller scale venturing mode. Unipolar stepper motors are much simpler to control however they give lesser torque given the motor size is same. Exceptionally outlined stepper motor controllers are being utilized to assume control over the troubles of directing a stepper motor. With the assistance of such controller stand out small scale step can be made. Consequently, controlling of a stepper motor has been rearranged.

2.2.7 HARDWARE:

The electronics board known as microcontroller controls the entire printing process. Several electronics options do available for 3D printers which are all open-source. [7]

Presently the most popular are:

1. RAMPS, a DIY shield board for Arduino MEGA.
2. Sanguinololu, a DIY board with microprocessor on board.

1. MICROCONTROLER:

Functions of a 3d printer electronics board:

1. Processes G-code instructions.
2. Controls and regulates the four stepper motor controllers where both Z-axis motors are essentially connected to the same stepper motor controller.
3. Monitors the end-stops
4. Controls the temperature of the heated bed The electronics board is connected to the PC using a USB-to-serial converter. [24]

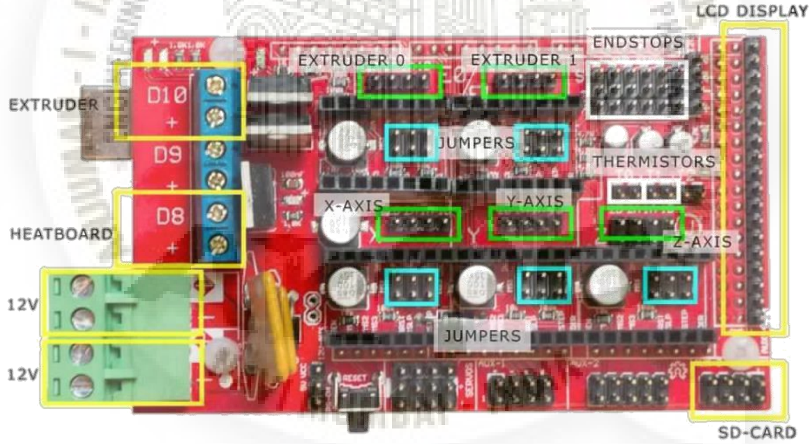


Figure 2.14 microcontroller [24]

2. ARDUINO:

RepRap Arduino MEGA 2560 Pololu Shield or RAMPS for short Microcontroller:

Figure 2.14 Arduino MEGA 2560 [24]

Operating Voltage:	5V
Input Voltage (recommended):	7-12V
Input Voltage (limits):	6-20V
Digital I/O Pins:	54 (of which 15 provide PWM output)
Analog Input Pins:	16
DC Current per I/O Pin:	20 mA
DC Current for 3.3V Pin:	50 mA
Flash Memory:	256 KB of which 8 KB used by bootloader
SRAM :	8 KB
EEPROM:	4 KB
Clock Speed:	16 MHz
LEDs:	13

3. GRAPHICS CONTROLLER:

This full graphic Smart Controller contains a SD-Card reader, a rotary encoder and a 128 x 64 dot matrix LCD display. You can easy connect it to your Ramps board using the "smart adapter" included. After connecting this panel to your Ramps, you don't need your pc any more, the Smart Controller supplies power for your SD card. Furthermore, all actions like calibration, axes movements can be done by just using the rotary encoder on the Smart Controller. Print your 3D designs without PC, just with a g-code design stored on the SD card.

Figure 2.15 Graphical controller[24]

2.2.8 EXTRUDER AND HOTEND:

Figure 2.16 Nozzle [12]

Figure 2.17 Hot end [12]

Fused filament fabrication is a 3Dprinting process that uses a continuous filament of a thermoplastic material. This is fed from a large coil, through a moving, heated printer extruder head. Molten material is forced out of the print head's nozzle and is deposited on the growing workpiece. The head is moved, under computer control, to define the printed shape. Usually the head moves in layers, moving in two dimensions to deposit one horizontal plane at a time, before moving slightly upwards to begin a new slice. The speed of the extruder head may also be controlled, to stop and start deposition and form an interrupted plane without stringing or dribbling between sections. 3D printer extruder is a part in material extrusion-type printing responsible for raw material melting and forming it into a continuous profile. A wide variety of Materials are extruded, including thermoplastics such as acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), high-impact polystyrene (HIPS), thermoplastic polyurethane (TPU), aliphatic polyamides(nylon)and recently also PEEK. Paste-like materials such as ceramics and chocolate can be extruded using the fused filament process and a paste extruder. Flow geometry of the extruder, heating method and the melt flow behaviour of a non-Newtonian fluid are of main consideration in the part. A plastic filament is supplied from a reel, either commercially available or homemade, and fed into a heated liquefier where it is melted. This melt is then extruded by a nozzle while the incoming filament, still in solid phase, acts as a ‘‘plunger.’’ The nozzle Is mounted to a mechanical stage, which can be moved in the xy plane. As the nozzle is moved over the table in a prescribed geometry, it deposits a thin bead of extruded plastic, called a ‘‘road’’ which solidifies quickly upon contact with substrate and/or roads deposited earlier. Solid layers are generated by following a rasterizing motion where the roads are deposited side by side within an enveloping domain boundary. Once a layer is completed, the platform is lowered in the z direction in order to start the next layer. This process continues until the fabrication of the object is completed. For Successful bonding of the roads in the process control of the thermal environment is necessary. Therefore, the system is kept inside a chamber, maintained at a temperature just below the melting point of the material being deposited.

2.3 3D MODEL DESIGNING PROCESS:

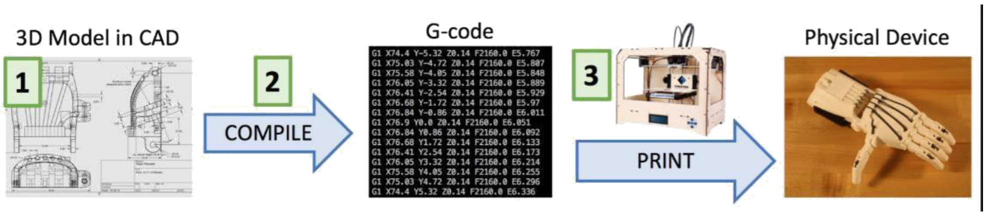


Figure 2.19 3D printing process [24]

The 3D Printing Development Cycle, to print a 3D model:

An engineer first designs a 3D model using standard CAD tools (e.g., SolidWorks , sketchup, slice) This model is compiled into a sequence of low-level G-code commands that corresponds to basic actions the printer can take (move the print head, start/stop extrusion, lower the build plate, etc.).

The printer directly executes the G-code, producing a physical object.

2.3.1 DESIGN:

Design Users first design their model using CAD tools. There is a diverse array of available CAD tools including freely available options such as OpenScad or SketchUp and SolidWork. In this paper, we focus on sketchup, openscad and slicer since it conveniently represents CAD model.

Models as programs and is widely used on design sharing websites Figure shows two CAD programs in. OpenSCAD provides various primitive 3D structures (e.g., cube), transformations (e.g., translate) and combinators (e.g. Difference), that can be used together to create complex 3D models. they only describe the 3D structure and parameters of a model, not how to manufacture it.

2.3.2 SLICING:

At a high level, common slice takes a 3D surface geometry in STL and divide it into a sequence of 2D slices parallel to the xy-plane at regular intervals of height h (typically h ≈ 0.1mm). Thus, the i th slice represents the perimeters of the object to be printed at height i To generate G-code, the slicer computes tool paths to trace the perimeters at each height and fill the space between perimeters with a regular pattern at some user-specified density (see Figure 2 b). Within these layers, the slicer inserts G-codes to start and stop extrusion during movements along perimeters and over fill areas. The slicer then inserts additional G-code between the instructions for each layer to increment the printer’s z axis by h. Finally, the slicer inserts an initial preamble to set fan speeds as well as build plate and extruder temperatures to appropriate values for the material being printed. Throughout the slicing process, the compiler performs optimizations to minimize the travel time of the print head.

2.3.3 COMPILATION:

Compilation happens in two phases:

A CAD model is translated to an intermediate representation, typically in Stereolithography(STL) format. This represents the surface mesh in the form of polygons in a 3D coordinate system.

The STL is “sliced” to obtain G-code. The G-code is a sequence of imperative commands that control extrusion, movement and temperature. The slicer determines the tool path which refers to the path the print head should follow while printing.

2.3.4 PRINT:

The printer runs firmware that interprets the G-code and sends low-level hardware control signals to motors, heating elements, and cooling fans. An extruder melts print material and pushes it through a nozzle to build up the part layer-by-layer starting with the first layer directly on the build plate. There are many physical phenomena involved in this step that affect the print quality—the inertia on the print head, thermal expansion of the print material, the temperature and humidity of the environment, etc.

2.3.5 ITERATE:

Finally, there is an implicit fourth step which is to repeat the above steps until the 3D object comes out as expected.

CHAPTER 3

SPECIFICATIONS, MATERIALS AND DESIGN

3.1 SPECIFICATIONS

Before starting the designing process, we need to know the basic need of printer i.e. its specifications. Specification of the printer are as follows:

Table 3.1 Specifications of 3D printer

1. Build	Volume	180mm X 180mm X 180mm
	Environment	Room temperature
	Built surface	Aluminium bed
2. Temperature	Bed temperature	30-80 ^{o}C
	Nozzle temperature	30-300 ^{o}C
3. Print Accuracy/Resolution	Layer resolution	50 microns to 600 microns
	3d printer part accuracy	+/-0.5mm
	Wall thickness	Depends upon nozzle diameter
4. Machine accuracy	XY positioning accuracy	Within 100 microns
	Z positioning accuracy	Within 50 microns
	Repeatability accuracy	Within 100 microns
5. Nozzle supported	Nozzle diameter	0.1mm,0.2mm,0.35mm,0.4mm,0.6mm
	Head and extrusion	Single head single extrusion
	Printing mode	Single colour & single material
6. Material	Filament diameter	1.75mm
	Material supported	PLA, ABS, HIPS, PVA, NYLON
7. Bed levelling	No. of adjuster	4 screws at each corner

8. Command	Computer	Directly from cura or proterface
	Graphical controller	From memory card

3.2 MATERIALS

3.2.1 ABS:

Its strength, flexibility, machinability, and higher temperature resistance make it often a preferred plastic for engineers, and professional applications. The hot plastic smell deters some as does the plastics petroleum-based origin. The additional requirement of a heated print bed means there are some printers simply incapable of printing ABS with any reliability.

It is strong, flexible, with good machinability and a higher temperature resistance. These properties can make it more popular for use in professional applications. It's plastics petroleum-based origin cause it to have a less pleasant hot plastic smell. The 3D printer requires a heated print bed for use with ABS.

3.2.2 PLA:

The wide range of available colours and translucencies and glossy feel often attract those who print for display or small household uses. Many appreciate the plant-based origins and prefer the semisweet smell over ABS. When properly cooled, PLA seems to have higher maximum printing speeds, lower layer heights, and sharper printed corners. Combining this with low warping on parts make it a popular plastic for home printers, hobbyists, and schools.

3.3.3 PROPERTIES

Table 3.2 Properties of Printing Material

Material Property	**PLA (Polylactic Acid)**	**ABS (Acrylonitrile Butadiene Styrene)**
Density ρ (Mg/m_3)	1.25	1.01-1.21
Young's Modulus E (GPa)	3.5	1.1-2.9
Elongation at break (%)	6	3-75
Melting (softening) temperature T_m (ºC)	160	88-128
Glass Transition Temperature ($_o$C)	60	100
Yield Stress σ_y (MPa)		18.5-51
Tensile Strength σ_{ts} (MPa)	36-55	25-50
Ultimate Tensile Strength UTS (MPa)	35	33-110
Fracture Toughness (Plane strain) K_{IC} (MPa√m)		1.19-4.3
Thermal expansion (μm/m-K)		83-95
Strength to weight ratio (kN-m/kg)	40	31-80
Shear modulus G (GPa	2.4	

3.3 DESIGNING PROCEDURE

After deciding the various specifications and features, next steps is designing of individual components of 3D printer.

3.2.1 Feeding Mechanism and Hot End:

Feeding mechanism is called as extruder, which extrude the filament into the hot end in desired rate. Based on requirement MK8 extruder assembly is available in market. Components of extruder assembly is given as follow:

1. Frame:

Frame is supporting part which supports other accessories and it gets mounted on motor.it is made up of aluminium or brass.

2. Driving Gear:

It is used to push the filament or retract the filament. It have 20 V-shaped teeth.it is mounted on motor shaft & driven by motor.

3. Idler Pulley:

It is used to provide support to the filament and to maintain filament wire align with gear teeth. It is fitted on roller bearing and these bearing and pulley arrangement is mounted on the pivoted lever through a screw which can be tighten or loosen based on requirement.

4. Pivoted lever:

These lever is pivoted at one corner of the frame and the idler pulley is mounted over it from one side and on other side it is fixed with spring arrangement for adjustment of gap between gear & pulley and also to maintain filament in contact with gear teeth and idler pulley.

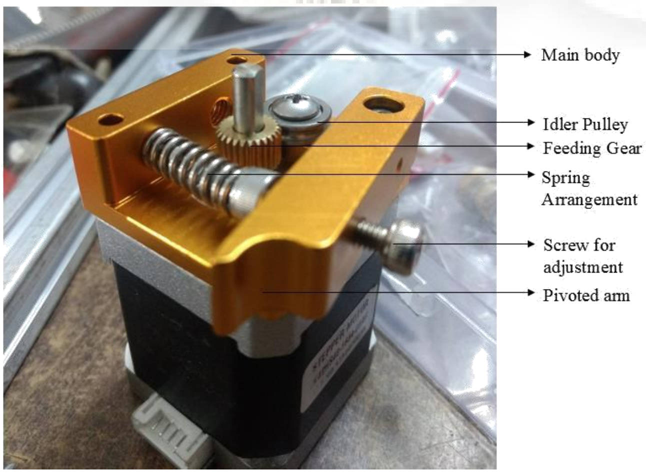


Figure 3.1 Extruder assembly mounted on motor

5. Spring Arrangement:

These arrangement is used to maintain proper gap between the idler pulley and driving gear and to maintain force on filament.

6. Motor for extruder:

NEMA-17 with torque 4.7 kg-cm is selected as per the manufacturer's catalogue.

7. Hot end:

MK3 V6 is the most advanced hot end available in the market. It can reach up to the temperature 300^0 C. It comes with 0.4mm nozzle diameter and does not have jamming problem. Because of all these advantages, we have selected MK3 V6 hot end.

3.2.2 Selection of driving mechanism:

1. ***For X & Y Axis:***

X & Y axis drives the hot end and print the actual cross section of the object. It has to move rapidly from one point to another. It experiences jerks during sudden change in direction.it have to carry small load i.e. of around 300 grams. Belt drive is selected for X & Y axis drive because

1. No backlash problem
2. Sudden change in direction is efficient
3. can be driven at high speed
4. no lubrication required
5. Sufficient breaking strength.

2. For Z Axis:

Z axis moves the platform on which object is made. It should have fine movement of around 10 microns. It does not have to move rapidly like X & Y axis. But load on platform increases as the object building starts. Lead screw drive is selected for the Z axis because

1. High load carrying capacity
2. Provides fine movement
3. long rated life
4. tensioning is not required

3.3.3 Bed arrangement and design of platform elements:

1. **Bed Arrangement:**

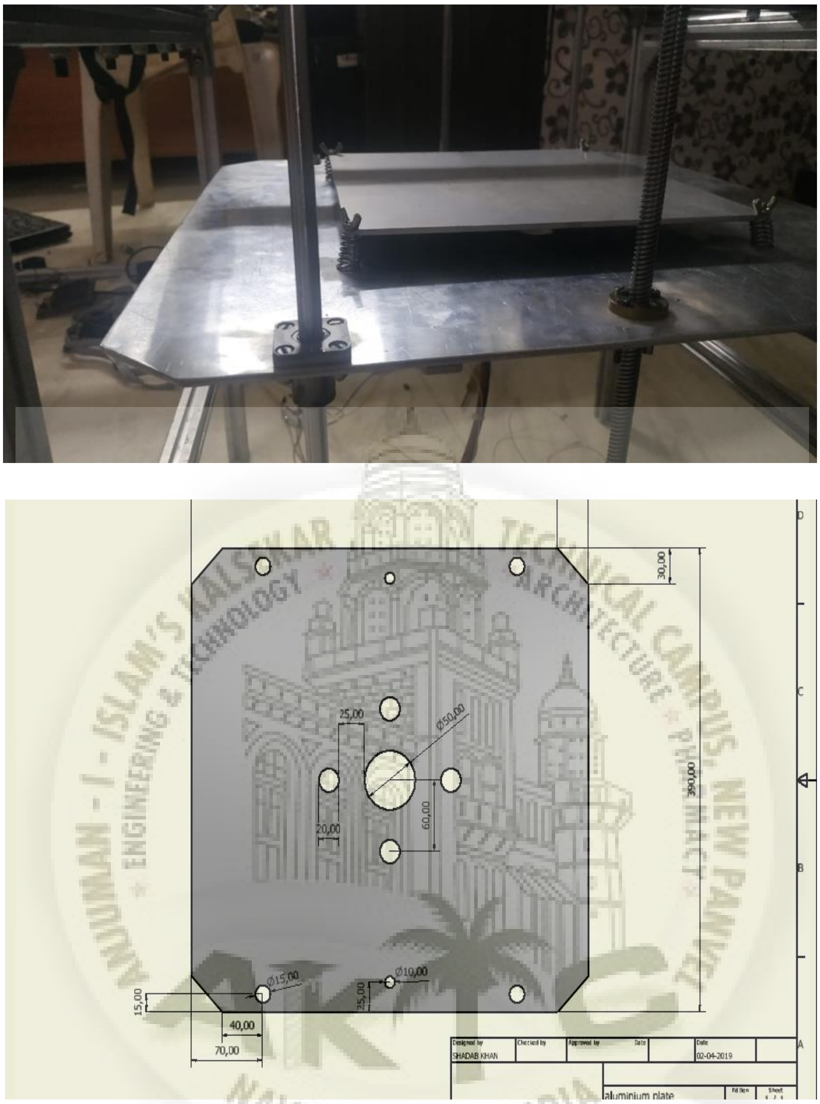


Figure 3.2 Bed arrangement

2. **Design of platform:**

Material: Aluminium

Shape: Square

Maximum dimensions of plate:
Side: 390 mm
Thickness: 3 mm
Density: 2.7 g/cm³
Mass of platform: 1.085 kg
Weight of platform: 10.645 N
Mass of Hot bed: 0.371 kg
Weight of Hot bed: 3.638 N

3.4.4 Load on the Bed arrangement:

Total mass of the Bed arrangement:
Mass of Hot Bed + Mass of Platform = 0.371 + 1.085 = 1.456 kg
Total weight of the Bed arrangement:
Weight of the Hot Bed + Weight of the Platform = 3.638 + 10.645 = 14.283 N

Lead screw and shaft arrangements for Z-axis:
Number of lead screws: 2
Number of Shafts: 4
Number of motors used in Z-axis: 2

Maximum Printing Volume:

Length: 180mm

Width: 180mm

Height: 180mm

Volume = 180*180*180 = 583200 mm^2

= $5.832*10^{-3} m^2$

Maximum weight of printed object:

Weight = density * volume (Density of the material to be printed)

=$1250 * 5.72 * 10^{-3}$

=7.29 kg = 72.9 N ≈ 73 N

Minimum and Maximum Load on the lead screws:

Minimum load to be carried by the lead screws when there is no printing: 14.283 N

Minimum Load at each lead screw = 14.283/2 = 7.1415 N

Maximum load to be carried by the lead screw: 73 + 14.283 = 87.283 N

Minimum load at each lead screw: 87.283/2 = 43.6415 N

I. ***Design of MK3b heat Bed:***

$\Phi = \tan^{-1}(p/\pi D_m)$ ……………………………………………Equation 3.1

$= \tan^{-1}(2/\pi * 7.183) = 5.1^o$

$\Phi = \tan^{-1}\mu = \tan^{-1}(0.25) = 14.03^o$

Torque required to raise the load $T_{raise} = (FD_m / 2)\tan(d+\varphi)$ …………………Equation 3.2

$= [(73 * 7.183) / 2] * \tan(5.1 + 14.03)$

$= 90.94$ N/mm

$= 0.09094$ Nm

$= 0.9094$ kg.cm

There are some extra load acting on the motor due to the machining error or misalignment by considering all these aspects

We are selecting NEMA–17 motor with holding torque of 5.5 kg-cm.

3.3.6 Design of chrome platted hardened shaft (for Z-axis)

$\sigma_y = 700$MPa taking FOS = 2

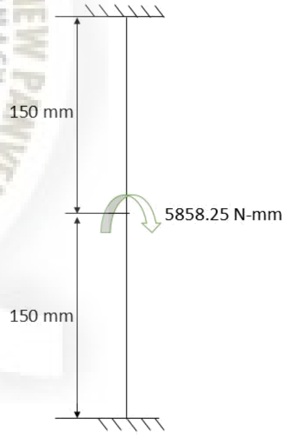
$[\sigma_t] = 0.72$, $[\sigma_t] = 252$MPa

$M/I = \sigma_b/y$

$(11716.5/2)/(\pi/64) * d^4 = 252/(d/2)$

$d^3 = 236.79$

$d = 6.186$ mm ≈ 8mm



3.3.7 Design of belt and pulley:

As per application GT2 pulley and belt are suitable for application.

Specification:

Number of teeth=20

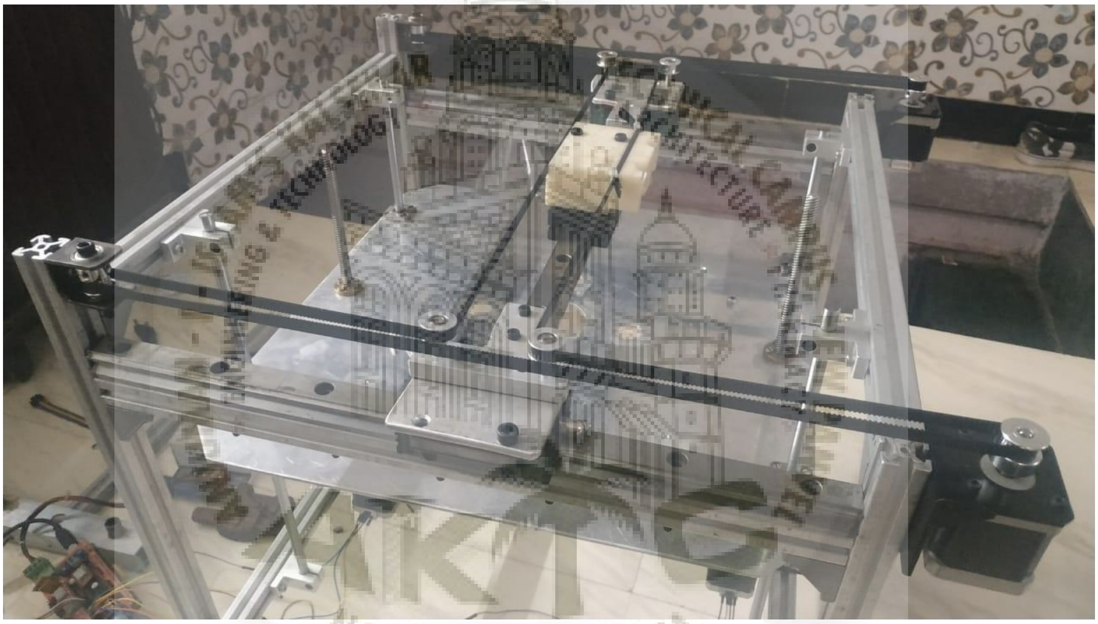
Pitch=2mm

Pulley Material: aluminium

Belt Material: Composite of Polyurethane and Rubber.

3.3.8 Design of linear rail guide for X and Y axis:

1. ***Arrangement:***



2. ***Design:***

a. **Linear rail guide:**

Material: Stainless steel
Quantity: 3
Size:
Length: 400 mm
Breadth: 20 mm
Height: 17 mm

b. **Linear guide block:**

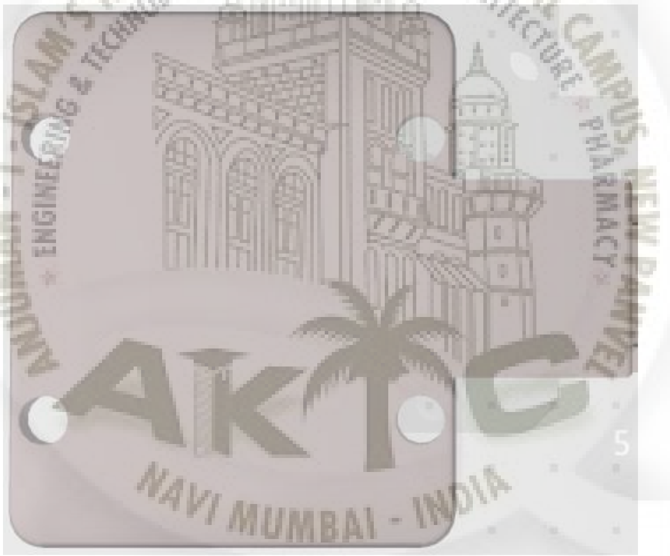
i. HGW20CA

Material: Stainless steel
Quantity: 2
Size:
Length: 75 mm
Breadth: 62 mm
Height: 25 mm

ii. HGH20CA

Material: Stainless steel
Quantity: 1
Size:
Length: 75 mm
Breadth: 40 mm
Height: 25 mm

Moving block plate:



Maximum dimensions:
Length: 102 mm
Breadth: 75 mm
Height: 16 mm
Material: Aluminium
Quantity: 2

Gantry (Centre block):

Material: PLA
Dimensions:
Length: 75 mm
Breadth: 65 mm
Height: 30 mm

Pulley:

1. **GT2 Pulley:**

Material: Aluminium
Size:
Width: 6 mm
No. of teeths: 20
Pitch: 2 mm
Inner bore diameter: 5 mm
Quantity: 4

GT2 Toothless Pulley:

Material: Aluminium
Size:
Width: 6 mm
No. of teeth: Toothless with plain surface
Inner bore diameter: 5 mm
Outer diameter: 18 mm
Bearing: Fitted inside

2. Design:

3.3.9. Motor selection for X and Y axis:

Force to moved F= 4N.

Diameter of pulley D= 16mm.

Torque required T = F*r

= F*(D/2)

= 4*(16/2)

= 32 N-mm=0.32 kg-cm.

Therefore, selecting NEMA 17 with holding torque of 4.2 kg-cm.

3.3.10 Design of aluminium t slot section for frame

Figure 3.5 T-slot aluminum extrusion

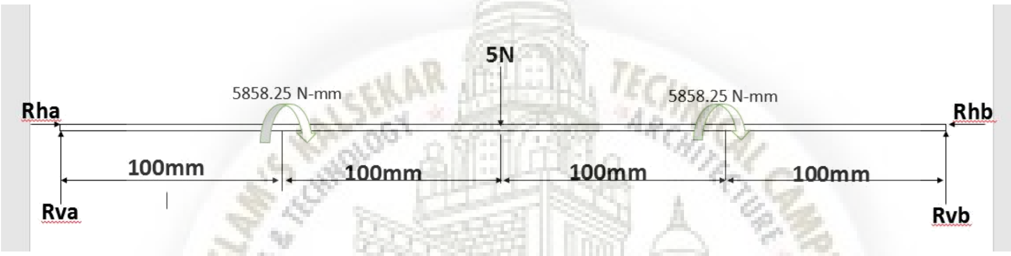
Aluminium 6065

. σ_{yt} = 380MPa

N= 2

[σ_{yt}] = 190MPa

[σ_b] =0.72[σ_{yt}] =136.8MPa



Checking of

bending stress

$M/I = \delta_b/y$

= 2.5 * 400

$R_{HA}=R_{HV}$= 2.5N

BM_{MAX}=13716.5 N-mm

. y= 10mm I=6227.25mm^4

13716.5/6227.25 = σ_b/10

. σ_b = 22.02MPa < [σ_b]

CHAPTER 4

FABRICATION

4.1 FRAME

Frame is a platform which supports all the electrical and mechanical components which does the actual printing job, therefore very first thing to fabricate is “Frame”.

4.1.1 Material and Dimensions:

T slot aluminium extrusions are selected for frame members because of its inherent advantages which are as follows:

1. Ease of assembly and convenient installation.
2. High strength to weight ratio.
3. Lighter in weight.
4. Easy to cut.
5. Adaptability to changes and attractive appearance.
6. Easy maintenance.

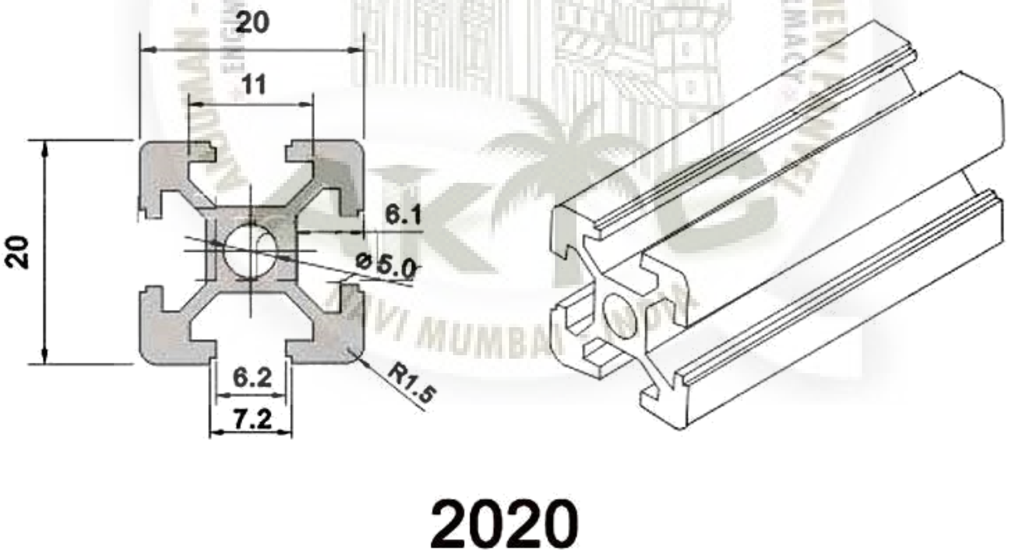


Figure 4.1 Section of 2020 aluminum T slot extrusion [19]

Based on design and calculation we are selected 2020 series t-slot aluminium extrusion of material grade aluminium 6065T.

4.1.2 Steps in frame assembly:

Step1- Cutting of extrusion into required size:

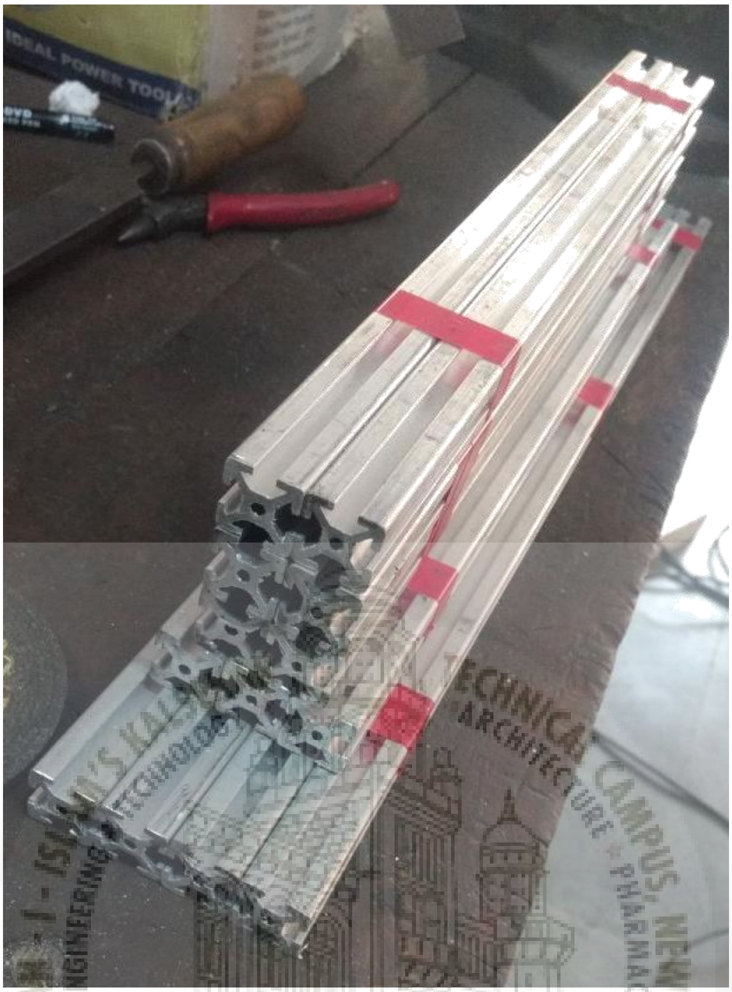


Figure 4.2 Members of frame after cutting

Extrusion comes in a length of 10 feet, therefore it has to cut in the required length.it can be cut directly with the hacksaw or with the help of cutting machine with specified rotor blade. if material is cut with hacksaw then it needs further operation like grinding and polishing to make surface proper flat and to remove extra burr. If we are cutting with rotary blades then it will require less post processing. Required length and quantity of extrusion are given as follow:

Sr. no.	Length(mm)	Quantity
1	500	4
2	400	9

Step 2- Grounding and polishing of end faces:

Some errors are introduced during cutting with hacksaw, therefore it requires further postp rocessing like grinding of faces to make its length exact and proper plane surface. extra burrs are also removed with smooth file.

Step3- Assembly of all the members:

Now, all the members should assemble as per the design. Three accessories are used for assembling the members

1. T-slot nut: T-slot nut is special type of nut which have trapezoidal section & threaded hole in centre of specified dimensions. It can slide in t slot section and then placed on the required place and fastened.

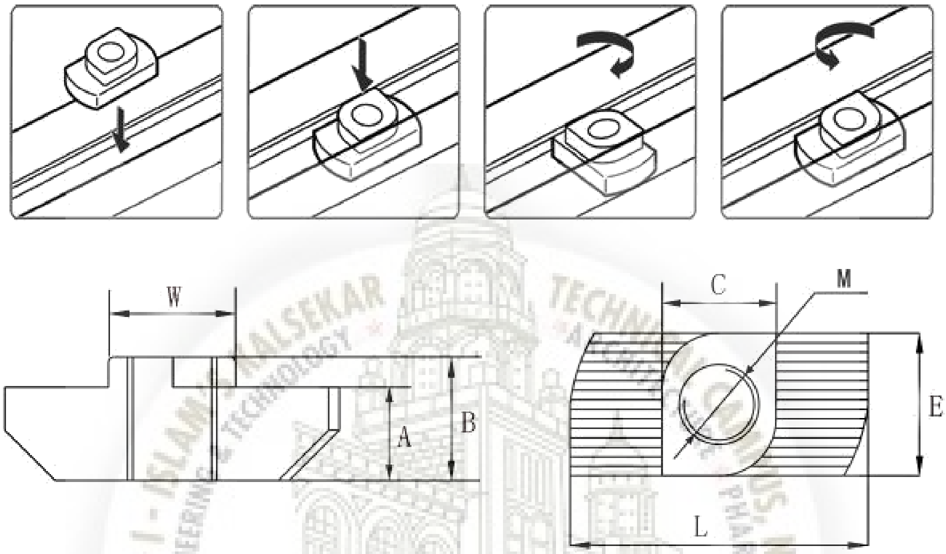


Figure 4.4 T slot nut

2. Allen bolts: Allen bolts are used in such application due to constraint radial space around bolt.

3. Corner brackets: these are specially design and casted for t slots which allows member to get assembled in 90^0.

Figure 4.5 Corner Brackets

To fasten all the bolts and nut allen keys are used.By using all these accessories frame members are assembled.

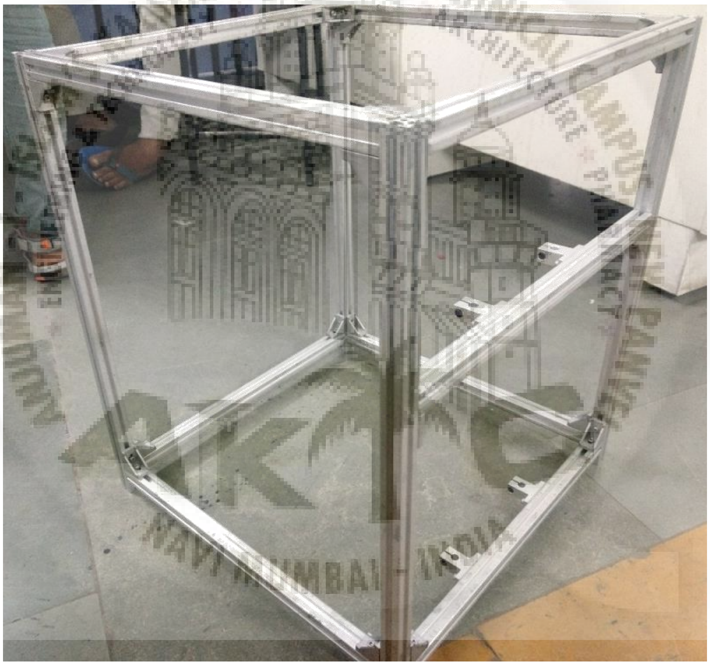


Figure 4.6 Frame after assembly of members

4.2 BED:

4.2.1 Bed assembly:

bed consist of two parts

1. Heat bed: Heat bed is the platform which on which actual printing is done. This are basically aluminium beds with hating coil in back side. As per the design heat bed is available in the market. MK3B heat bed is using for this purpose.

2. Supporting bed: supporting bed is driven by the lead screw and supported by chrome platted shafts. Supporting bed supports the heated bed and connected by nut and bolt with springs in between them.

Supporting bed is made by a uniform flat aluminium square plate. Steps in bed fabrication are as follows:

1. Cutting of aluminium plate in calculated dimension.
2. Drilling in holes for members for fasteners, bronze nut and flanged bearing.
3. Drilling the slots in the centre of the plate to reduce some weight and for ventilation.
4. Fastening of bronze nut and fanged bearing
5. Fixing heat bed on supporting bed

Figure 4.7 Bed assembly

4.2.2 Bed mounting:

Bed is used for Z-axis movement. It is driven by lead screw which provide up and down movement and chrome 4 plated shafts are used for providing required balanced reaction and guide the bed.

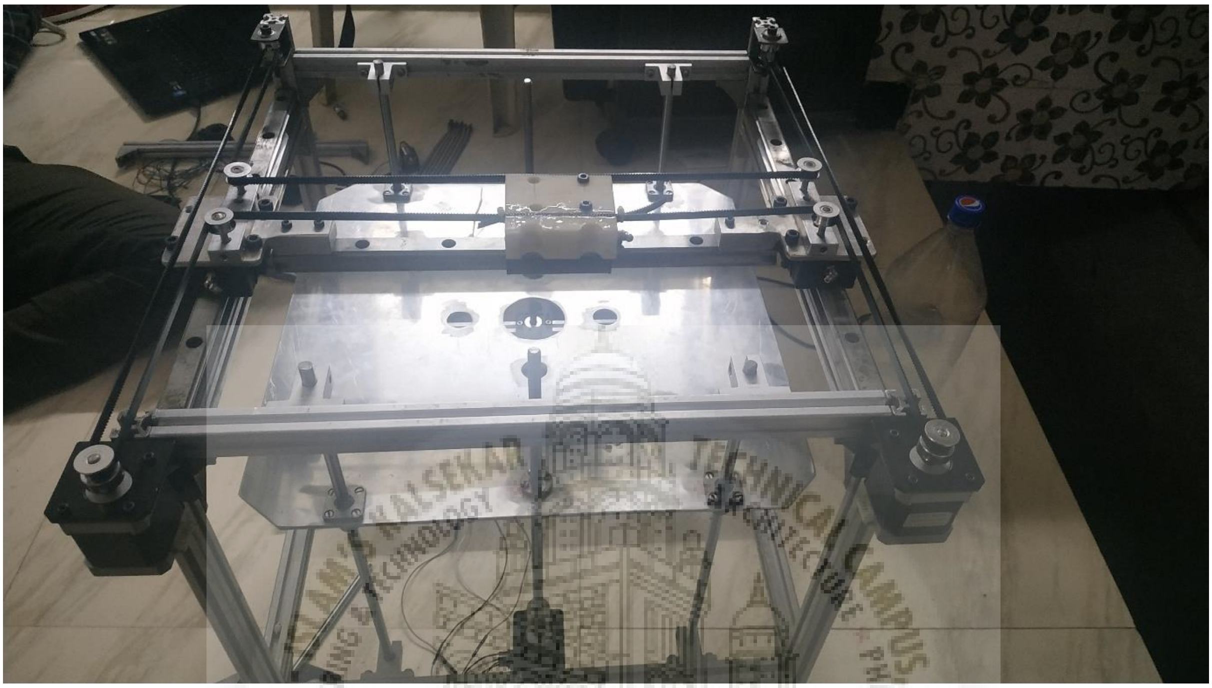


Figure 4.8 Bed mounting

- Chrome platted shafts are directly mounted on frame by vertical axis bracket of SK series.
- One end of lead screw is mounted on the motor and the other end mounted on roller bearing to keep it parallel with chrome platted shaft.

4.3 MOVING BLOCKS:

Sliding blocks are the blocks which slides on linear guide and driven by the belt drive.

There are two side blocks for driving purpose and one centre block for mounting of hotend.

4.3.1 Side Blocks:

Side blocks are used for driving and to support centre block. It is made up of stainless st

Figure 4.9 Side block

4.3.2 Centre Block:

Centre block is the block which support the actual printing head i.e. hotend. It gets X & Y axis drive from side blocks.it is also made by wood.

Figure 4.10 Centre block

4.4 MOUNTING OF XY AXIS:

After fabrication of block and preparation of chrome platted shaft, next step is assembly of all these component into frame.

4.4.1 Brackets to support shafts:

SK brackets cannot be used for XY axis due to practical difficulties. Therefor we made a customized bracket for XY axis as shown below. It is made up of aluminium.

Figure 4.11 Brackets for shaft support

4.5 MOUNTING OF BELT AND PULLEY:

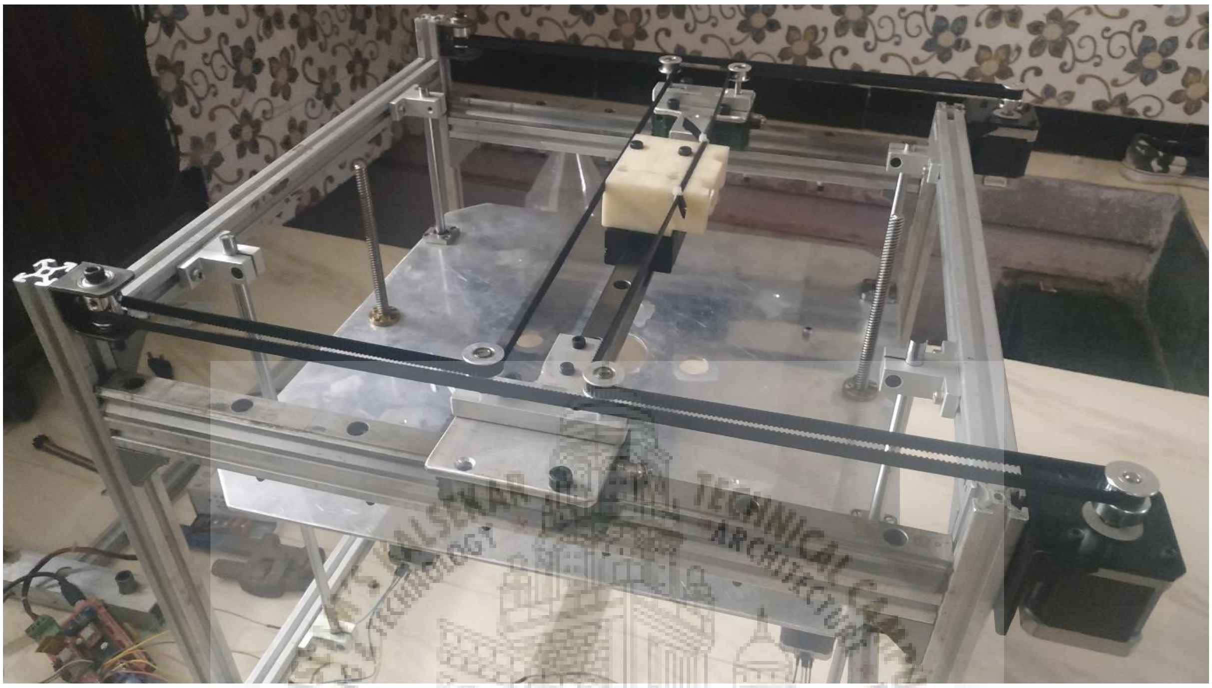


Figure 4.14 Belt and pulley arrangement

Belt and pulley are used for converting rotary motion into linear motion. It consists of mainly motor, pulley, belt, rail guide, centre block and side blocks

4.5.1 Motor Mounting:

Motors are mounted on frame by special type of bracket. This bracket allows tensioning of belts.

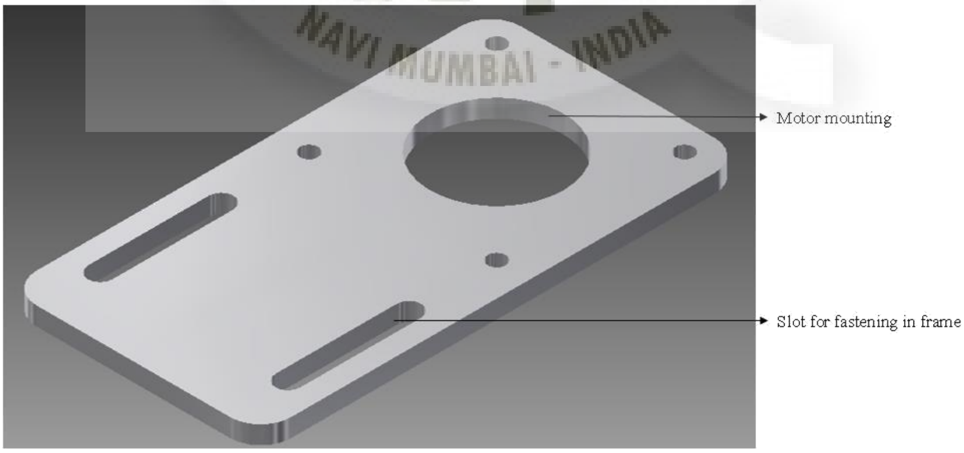
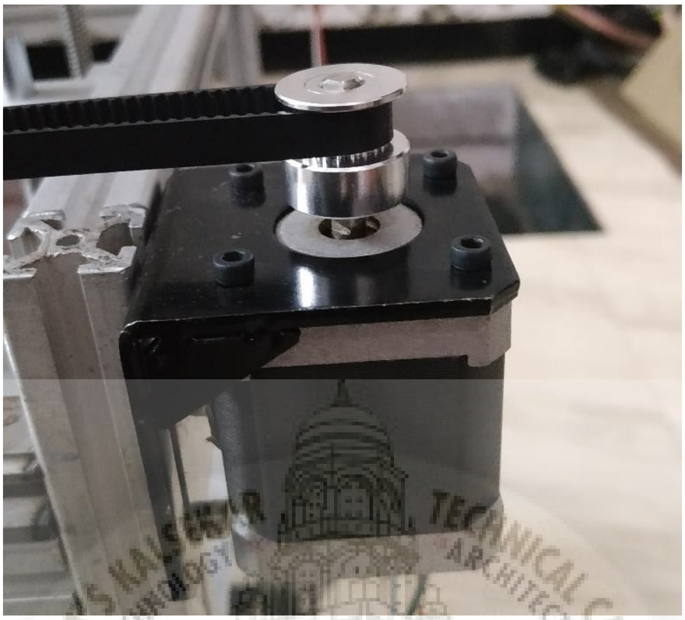


Figure 4.15 Motor mounting

4.5.2 pulley:

Pulley are mounted on motor shaft and on other side it is mounted on C bracket as shown below.



4.5.3 Belt:

Belt are tightened to the side block using toothless pulley as shown below:

4.6 EXTRUDER ASSEMBLY ON MOTOR

Extruder is a feeding device which push the filament into hot end. It consists of feeding gear, idler pulley, spring arrangement and main body. These elements are arranged as shown in figure.

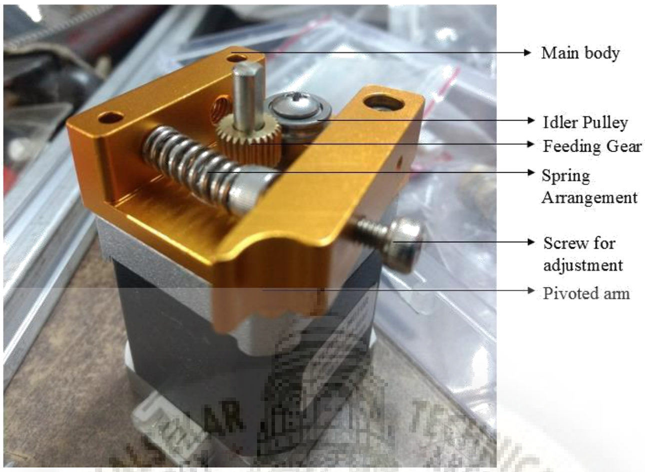


Figure 4.19 extruder assembly on motor

CHAPTER 5

INTERFACING AND COST REPORT

5.1 INTERFACING

After fabrication & assembly of all mechanical and thermal parts, next very important step is interfacing between electrical, electronic, mechanical and thermal parts. Interfacing is discussed in detail in this chapter.

5.1.1 RAMPS 1.4

RAMPS 1.4 is probably the most widely used electronics for RepRap machines as of March 2014. It consists of a RAMPS 1.4 shield, an Arduino Mega 2560 board (or a clone), and a max of five Pololu Stepper drivers. It can control up to 5 stepper motors with 1/16 stepping precision and interface with a hotend, a heatbed, a fan (or a second hotend), a LCD controller, a 12V (or 24V with appropriate modification) power supply, up to three thermistors, and up to six end stoppers.

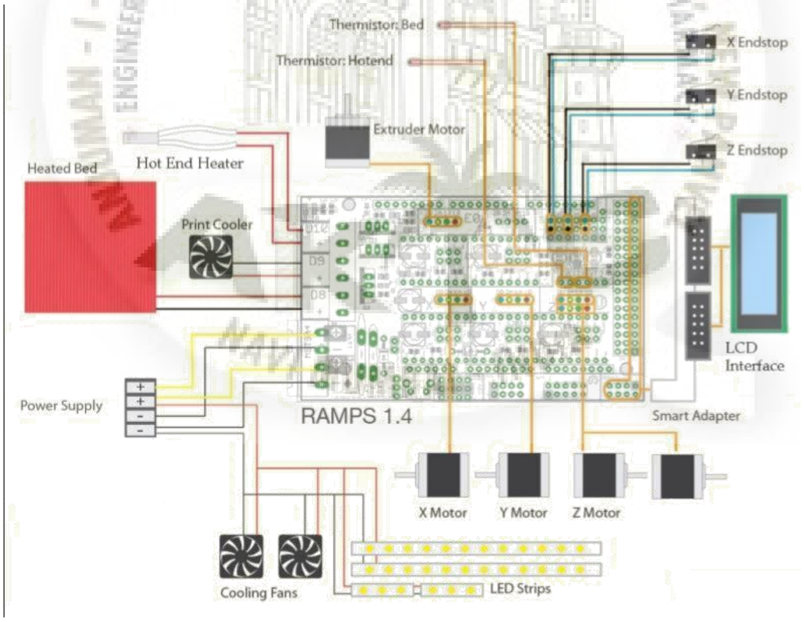


Figure 5.1 Interfacing map [24]

Install all jumpers to the orange area to ensure the most precise stepping.

1. Insert jumpers to RAMPS 1.4:

The jumpers (in the plastic bag below) control the precision of the motor movement. To have the most precise stepping (1/16 micro stepping), insert three jumpers to each of the areas outlined below:

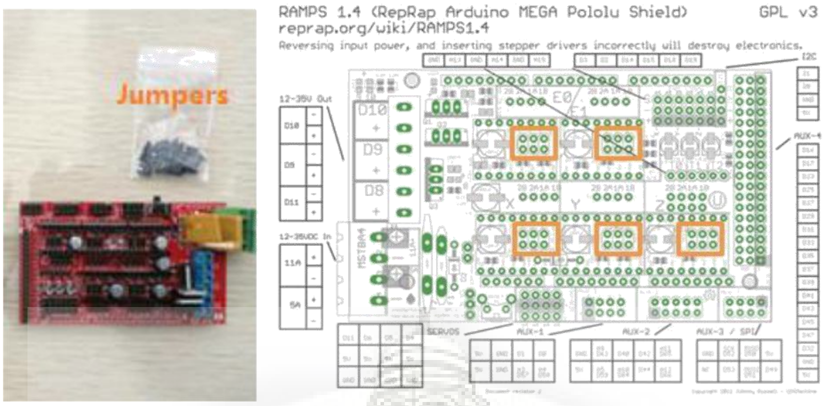


Figure 5.2 Jumper connection

2. Connect the Boards:

Stack the RAMPS 1.4 shield on top of the Arduino Mega 2560 board. Make sure the orientation is correct as shown above. The Mega 2560 board's USB side is directly under RAMPS 1.4 shield's "D8 D9 D10" area.

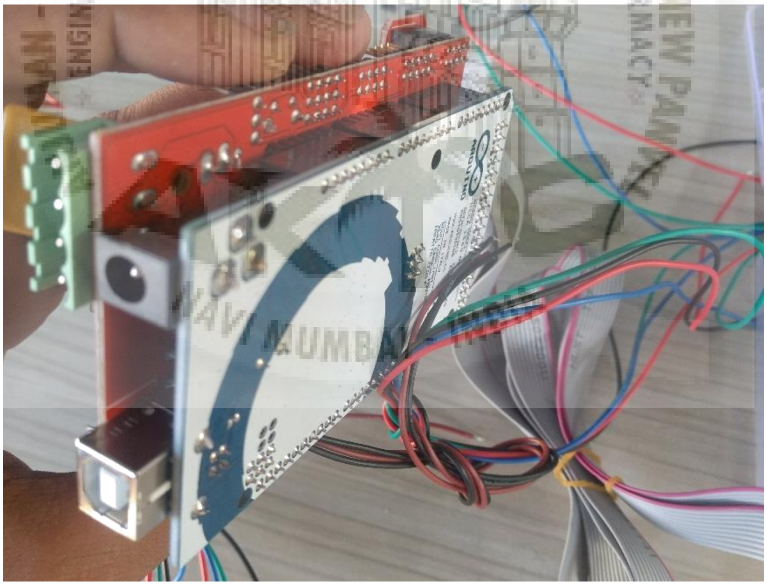


Figure 5.3 Connection of Arduino and microcontroller

Next stack the Pololu steppers on top of the RAMPS 1.4 shield. **Make sure the orientation is correct as shown below!** The potential meter (outlined in red on the right picture below) should be facing away from the "D10 D9 D8" side on the RAMPS 1.4 shield. We have heard numerous cases where these steppers got fried because of incorrect orientation. Install the heat sinks on the Pololu steppers, and make sure the heat sink is not touching multiple components on the Pololu stepper (the clearance could be small, but it is there!)

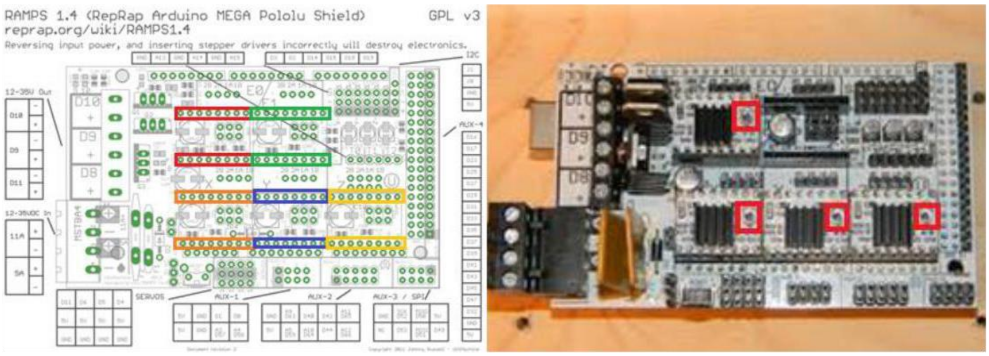


Figure 5.4 Install the Five Pololu steppers in the boxed pins shown on the left picture. Make sure the Potentiometer on the Pololu stepper is away from the side labeled "D10 D9 D8".

3. Connect the Power Supply:

3d printer required 12v and 10A power supply. Power supply connect to the Microcontroller ramps 1.4 and supply the power to the 3d printer. In the power supply there is 4 pins where having alternative positive and negative output. This output connects to the RAMP1.4 green pin.

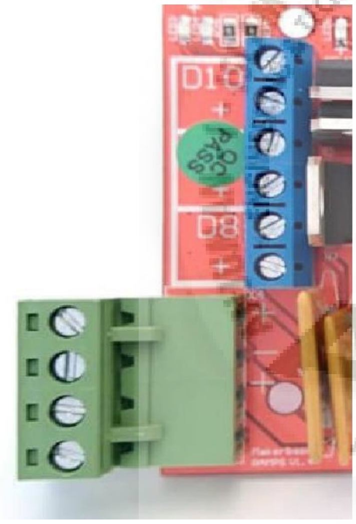


Figure 5.5 Power Input module

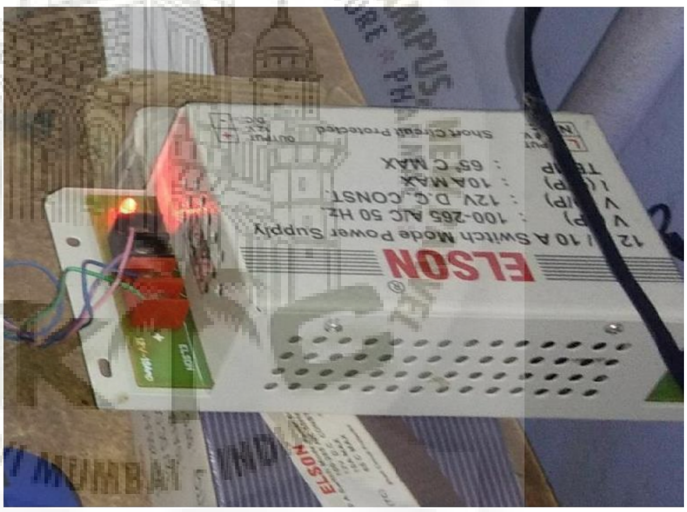


Figure 5.6 Power Supply

4. Connection of Motors, Thermistors, Hotend, Heatbed, and Fan.

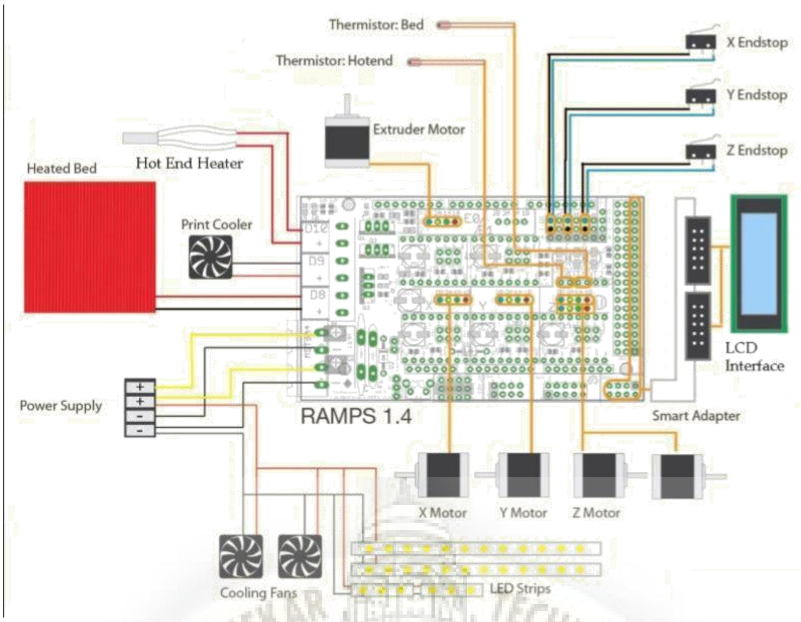


Figure 5.7 Connection of Motors, Thermistors, Hotend, Heatbed, and Fan .[24]

I. NEMA 17 Stepper Motor Connection

motor connection is done in X Y Z direction in the ramps1.4 having xyz pin a where we have to connect the wire which are coming to the motor it contains. Blue, red, green and black pin Which have to connect to the Microcontroller. If you find motors spinning in a different direction, please switch the power off and simply flip the motor connector. There are two connectors in parallel for Z axis, since most RepRap machines use two motors to move in Z direction.

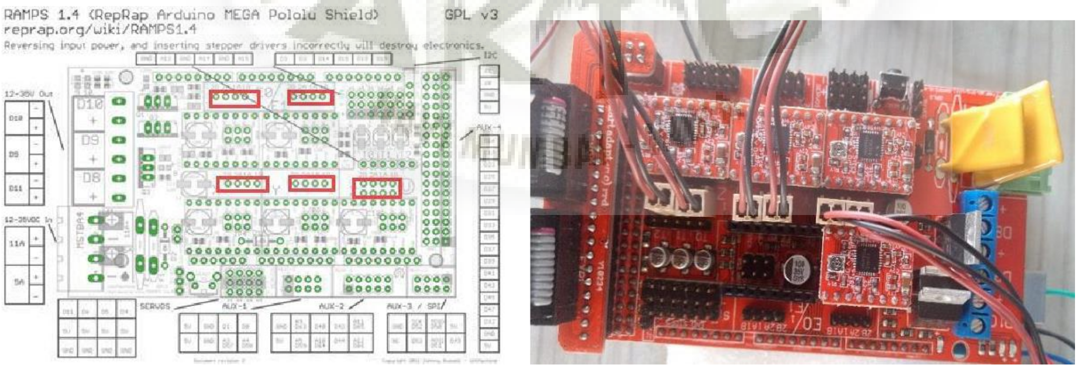


Figure 5.8 Top left: extruder 1. Top right: extruder 2. Bottom left: X-motor. Bottom middle: Y-motor. Bottom right: Z-motors.

II. Thermistor Connection:

There are three thermistor connector pins. From left to right: extruder 1, heatbed, and extruder 2. These are not polarity-sensitive.

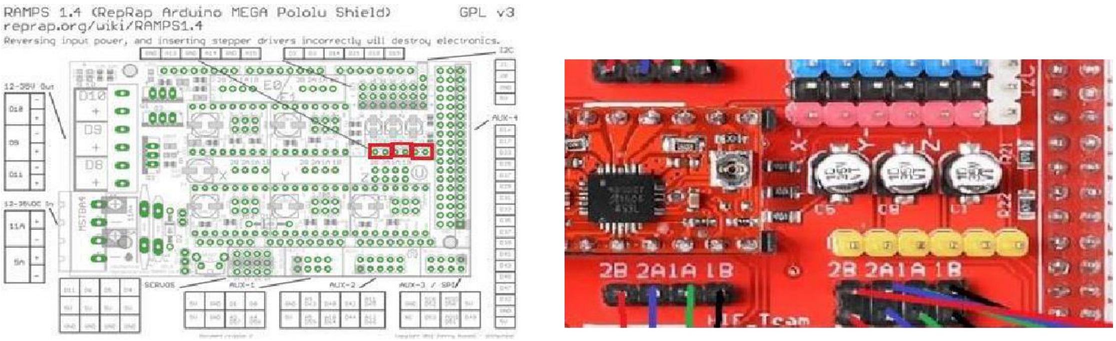


Figure 5.9 From left to right: Extruder 1 thermistor, heat bed thermistor, and extruder 2 thermistor

III. Extruder and heat bad connection:

Plug in extruder 1 heater to D10, heatbed heater to D8, and fan (or a second extruder) to D9. Only the fan is polarity-sensitive.

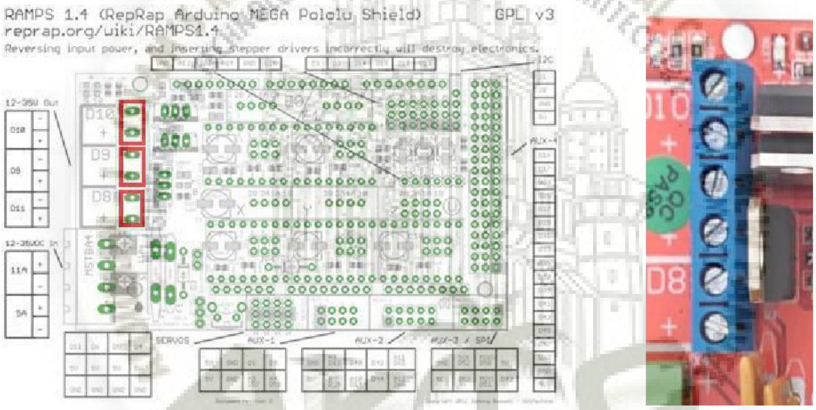


Figure 5.10 From top to bottom: extruder heater 1, fan, and heatbed heater

IV. Mechanical Endstoppers Connection:

The mechanical endstoppers are polarity sensitive. Solder wires to the “COM” and “NC” leads. Connect these two leads to the top two rows in the endstopper area outline below, with COM on the bottom and NC on top. From left to right, each column corresponds to xmin, xmax,

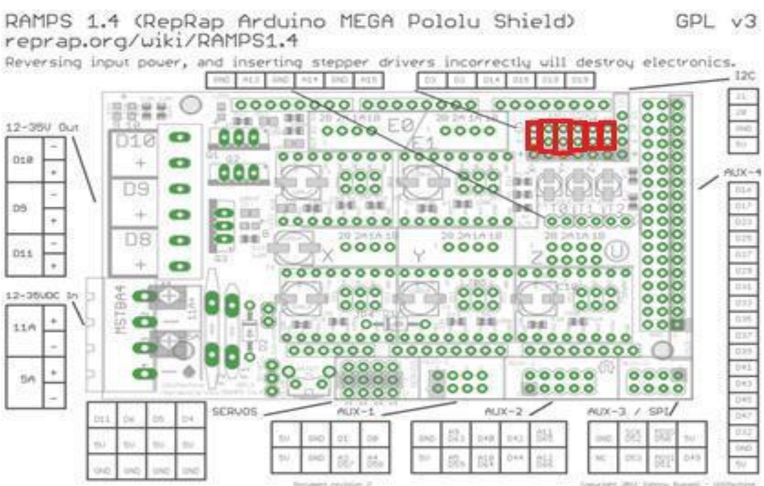


Figure 5.11 From left to right: X-min, X-max, Y-min, Y-max, Z-min, and Z-max.

ymin, ymax, zmin, and zmax. If you are using optical end stopper, then you will need all three pins. You only need to connect all max or all min end stoppers. The other limit will be specified in your firmware.

5.2 COST REPORT

Table 5.1 Cost Report

Sr. No.	COMPONENTS OR PARTS	AMOUNT
1.	2x NEMA17 Stepper motor 0.4 Nm 1.7A	1125
2.	3x Linear Rail Guide 400 mm	2700
3.	4 x 6mm GT2 belt pulley 20 teeth 5 mm bore	600
4.	4x 6mm GT2 toothless pulley 5 mm bore	730
5.	2x HGW20 Linear block	2100
7.	1x HGH20 Linear block	1000
9.	Aluminium extrusion 400 mm	420
10.	4 meters 6 mm GT2 belt	600
11	Lead screw with Flange	650
12	1 metre Shaft 8 mm diameter	300
13	4x flange linear bearing	600
14	4x SK8 Shaft end support	400
15	MK8 Extruder frame block	445
16	Aluminium plate 3 mm thick	500
17	3D printed Moving blocks and gantry mounting	1000
18	Aluminium moving block and gantry mounting	250
19	10x Dowel pin & 4x bearing	200
20	2x NEMA 17 Motor L brackets	300
21	2x Flexible coupling	360
22	35 x Allen Bolts of different sizes & 5 grub screws	350
23	15x Anti vibration nylon nuts of different sizes	90
24	4x Jumper wires strip	200
25	2x Pneumatic quick release fittings 4mm OD (1/8" or 5mm thread)	160
26	4m PTFE tubing ID=0.3mm OD=0.6mm (20 cm needed)	240
27	Acrylic sheets for covering	1200
27	Miscellaneous cost	2500
TOTAL		**19020**

CHAPTER 6

RESULTS

After redesigning the 3D printer, it is found the load on the bed arrangement is now uniform and it is no more hanging and the plate design is symmetric about the horizontal central axis. It is moving smoothly in Z axis direction as the number of shafts to guide the plate is increased to four and lead screw to two. Earlier, the X-Y motion was controlled by two belts driven by two motor that caused jerk in the motion. After the modification, the belt mechanism is changed to H-Belt Mechanism that runs on single belt.

Earlier, wooden blocks were used to slide on the cylindrical guide. It is now replaced with a linear rail guide and industrial linear block HGH20 and HGW20 are used that is more durable, accurate and moves smoothly on the rail guide. The moving blocks accommodate the gantry that holds the nozzle for filament deposition and side blocks to mount toothless pulley. Two extruder motors are used for dual nozzle printing. The nozzle gantry is 3D printed PLA that is more durable than the former used wooden block. The side moving block plate made by the aluminium which gives more strength to the motion with less addition of load on the design.

CONCLUSION

In this report, we shed light on all the technical and non-technical information about the 3D Printing technology which is based on method called fused deposition modelling (FDM). Our 3D printer has accuracy of up to 100 microns. After redesigning the printer, the movement this design optimisation will make the printer work more precisely and smoothly. The improvement in the field of 3D printing would be helpful in society and in the field of manufacturing. In near future it may be possible that the portable 3D printer can easily be installed in household at cheaper cost. Since this Additive Manufacturing Technology is growing day by day, it creates great impact in field of medicine and surgery, manufacturing and production process.

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