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Design and Fabrication of Low Cost Additive Manufacturing Machine

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***Abstract:** This paper describes the design of a 3D printer by reducing its cost to the optimum level. 3D printing technology has become an emerging topic in today's technological discussion. All over the world companies and individuals are doing experiments by extruding plastics, metal objects for prototyping or their own needs. To satisfy these demands we have developed a machine named as "Additive Manufacturing Machine" based on 3D printing technology. Using this machine user can turn any digital file into a three-dimensional (3D objects) physical products. In this paper, we will look for the additive manufacturing. First, we will define what we mean by this term. Then the methods used in this technology and how we have reduced its cost. Then we will delve a bit into the advantages over conventional methods of manufacturing. We shall observe a lot of applications in today's world. Finally, the future potential of this technology is outlined.*

***Keywords:** 3D Printing, Additive Manufacturing, Fused Deposition Modelling, Rapid Prototyping.*

I. INTRODUCTION

Subtractive manufacturing methods (e.g. milling, drilling, and cutting) has serious drawbacks, as it affects economically and it is time-consuming. Hence productivity and profit decrease so it creates limitations to manufacturing a product. To overcome these limitations**,** manufacturing industries required such a new method which adds a material instead of removing it. A method of manufacturing known as 'Additive manufacturing', in which instead of removing material to create a part, the process adds material in successive patterns to create the desired shape. Additive manufacturing includes 3d printing technology which makes objects of almost any shape from a 3d model. The starting point for any 3D printing process is a 3D digital model, which can be created using a variety of 3D software programs in an industry that are CAD, Solid works, Catia. The model is then 'sliced' into layers, thereby converting the design into a file readable by the 3D printer. The material processed by the 3D printer is then layered according to the design and the process. There are different methods which are used in 3D printing technology but we used one of them that is FDM (fused deposition modeling). The main objective was to reduce the overall cost of the machine so we have made the major changes in the design by replacing different materials.[1]

II. METHODS OF 3D PRINTING

1 Fused Deposition Modelling
3 Stereolithography
2 Selective Laser Sintering
4 Binder Jetting

Table 1 Comparing different methods

2.1 Comparing different methods

Sr. No.	Parameters	FDM (fused deposition modeling)	SLS (selective laser sintering)	SLA (Stereolithography)
1	Material Used	**Thermoplastics**	Metal powders, Thermoplastic	Photopolymer
2	Surface Finish	**Good**	Very good	Average
3	Speed	**Average**	Good	Fair to good
4	Cost	**Affordable**	Costly	Costly
5	Thickness Of Layer	**0.1mm-0.4mm**	.06mm-.15mm	0.06mm-.15mm
6	Size	**Compact**	Larger size	Wider space

2.2 FDM (FUSED DEPOSITION MODELING)

While selecting a method we have a number of options, but we want such a method which satisfies all the requirements listed below:

1. The method should be a simple one for implementation.
2. It should satisfy all the desired demands like low cost, accuracy, and precision etc.
3. Availability of components was the main factor.

After comparing all the above technologies and the above factors we have selected FDM as an optimized technology.

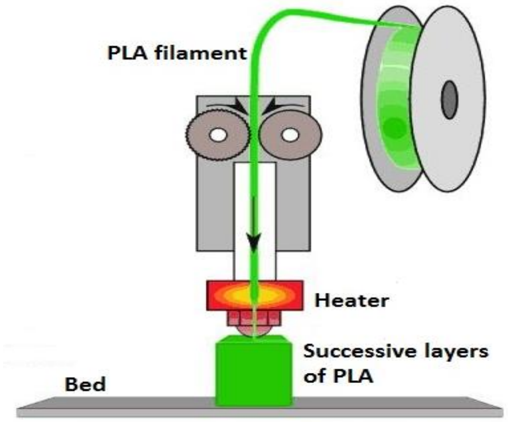


Fig. 1 Fused Deposition

Modeling

FDM works on an "additive" principle by laying down material in layers. In this method, a plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism. According to model or design, the material gets layered down on the platform. Sometimes, it requires support (depends on part design). Stepper motors or servo motors are typically employed to move the extrusion head. [2]

III. DESIGN AND COST REDUCTION

3.1 BASE TABLE

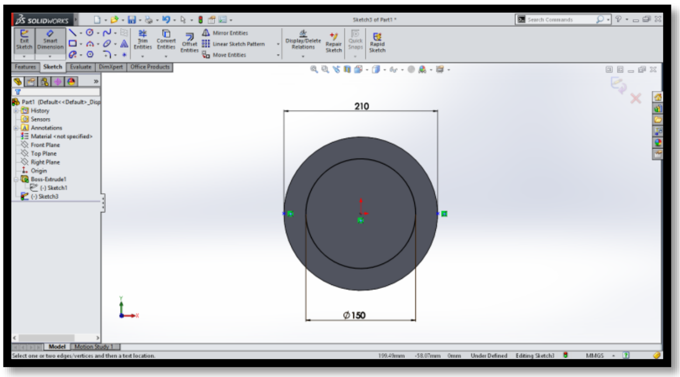


Fig. 2 Base table design

The dimensions of the base are decided on the basis of the maximum size of the object to print on it. We have decided the maximum size of the object to be 150x150x250 mm. So the diameter of the table is taken as 210mm. The material used for the table is aluminum since it is corrosion resistant and light in weight.

3.2 FRAME PLATES

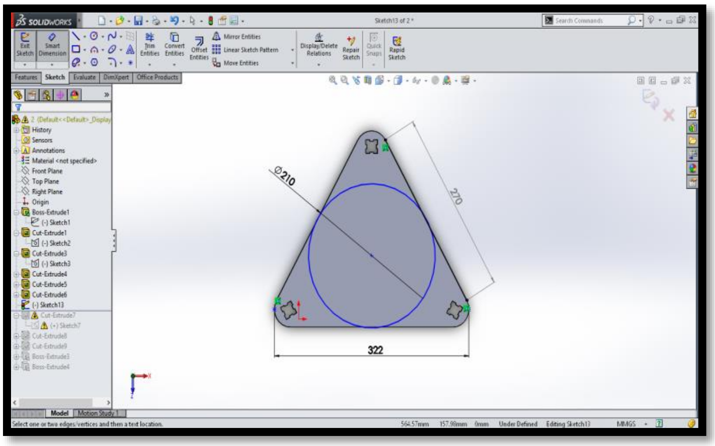


Fig. 3 Frame plate design

The dimensions of frame plates are decided such that the base table is inscribed inside the frame plate; it is good from the aesthetic view. It is made in the triangular shape since we are making a delta printer which has only 3 pillars, so we have decided the shape of the frame plate to be triangular. Each side of the triangle is taken to be 322mm, and the corners are smoothened with a radius of 52mm**.** The material used for making these plates is acrylic instead of steel as steel is costlier than acrylic. As our main objective to reduce the cost so we have used this acrylic.

3.3 ARM LENGTH

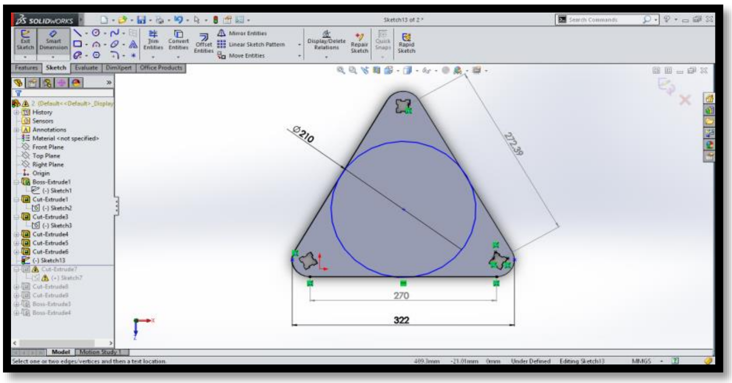


Fig. 4 Arm length Design

The center distance between two smooth rods is come to be 272.39mm. And the length of the arm is taken as 80% of this distance. [4]

Length of the arm (L) = center distance between two smooth rods *(80/100)

L= 272.39x (80/100)

L= 217.91≈218mm

3.4 PILLAR OR SMOOTH ROD

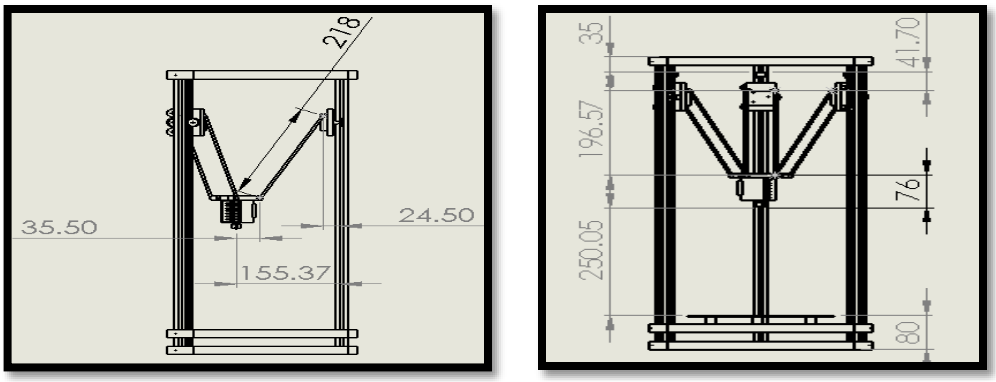


Fig. 5 (a) Offsets carriage, effectors (b) Rod length In ▲C, using Pythagoras theorem

(AB*AB)= (BC*BC) + (AC*AC)
AC=√ [(AB*AB)-(BC*BC)] --------------------- (1)
BC= (155-35.5-24.5) =95
From equation (1)
AC=√ (218*218-95*95)
AC=196.57≈197
Total length of the smooth rod is given by-
L=80+250+76+197+42+35
=680mm

Since we have decided the maximum size of the object to print is 250mm, but a more clearance is left between the limit switch and the top face of the slider so that the sliders can move freely while printing the object of 250mm. The material used for the pillar is aluminum to reduce the overall weight of the frame.

3.5 BELT CALCULATIONS

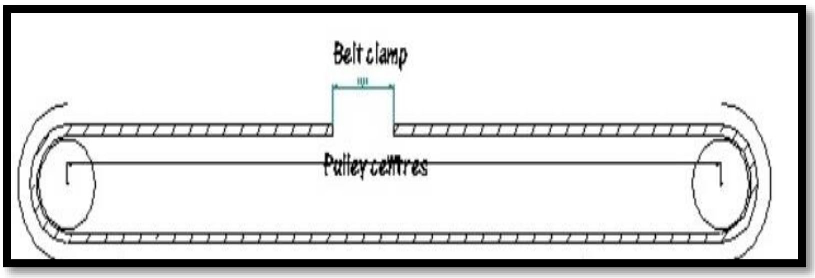


Fig. 6 Belt calculations

PC=pulley circumference
PD=distance between pulley centre
BCD=belt clamp distance
PC= (pulley teeth x belt pitch) OR (pulley diameter x pi)
PC= (20 x 2)
=40mm
PD= 640mm
BCD=5mm
Excess belt used for clamping= 100mm
Length of belt (L) = [PC + (PD X 2) – BCD]
= [40 + ((640 X 2) +100)-5]
=1415mm

The material used for the belt is nylon since it has higher strength and timing belt is used for the precise motion of the extruder. [5]

3.6 MOTOR SELECTION

m= total mass (Kg)

a= acceleration (m/s^2)

d=diameter of geared toothed pulley (cm)
T=torque (N-cm)

Acceleration is taken as 9000 mm/s^2 ie. 9m/s^2 as per the marlin file configuration. Diameter of the pulley is measured from the top of the tooth and comes to be 12.2 mm.[6]

Total mass on the motor pulley = mass of extruder + mass of carbon rods
m =0.5+0.13
m =0.63Kg
Force acting on pulley=m x a
=0.63 x 9
=5.67 N
Torque required= F x d/2
= 5.67 x 1.22/2
= 3.46N-cm

Most of the NEMA 17 motors used, have 45Ncm or more, so around 25x as much as calculated. So we have selected the NEMA 17 with holding torque 45Ncm along with 1.8° step angle.

3.7 3D PRINTERS

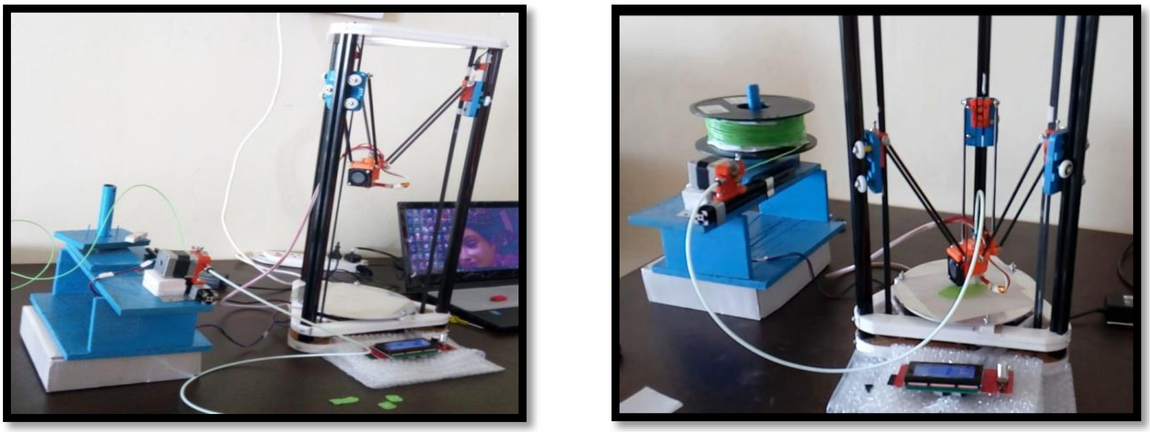
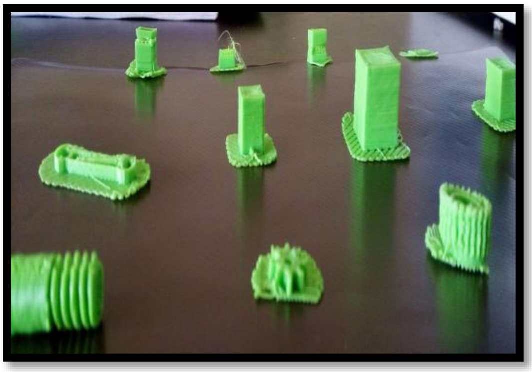


Fig. 7 Actual photograph of 3D printer

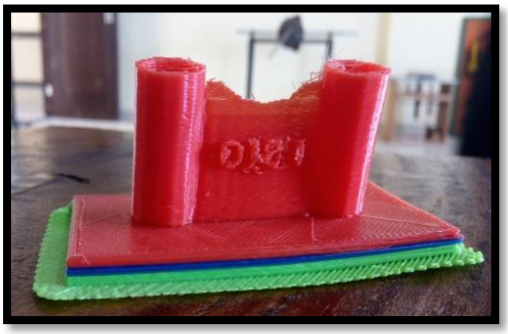
3.8 MAJOR FACTORS THAT REDUCED COST ARE AS FOLLOWS

1. We have used keep it simple slicer to slice the .stl file, there are other slicers but they need the laptop to be attached to the circuit board whose cost ultimately added into the overall project cost. So we have used keep it simple slicer which requires only an additional display attached to the board.
2. We have used the foam sheet for the slider (blue colored), which is very cheap, light in weight and easily available.
3. We have used the waste sketch-pen caps as the spacer.
4. Smooth rods used are the window sliding bars which are cheap and easily available.
5. We have replaced the steel arms by the carbon rods.
6. We have used the acrylic sheets for making the frame instead of steel plates.

3.9 OBJECT GALLERY



(a)



(b) **(c)** **(d)**

Fig. 8 (a), (b), (c), (d) object gallery

IV. ADVANTAGES OVER CONVENTIONAL METHODS OF MANUFACTURING

4.1 CUSTOMIZATION
3D printing processes allow for mass customization. It is the ability to personalize products according to individual needs and requirements of the user.

4.2 COMPLEXITY
We can easily print any complicated designed part. For any complicated design, we just have to draw it in any 3D modeling software and give it to the printer after slicing. This advantage is also used by the designers to impressive visual effects.

4.3 TOOL-LESS
For industrial manufacturing, one of the most costs, time and labour intensive stages of the product development process is the production of the tools. For low and medium level applications, industrial 3D printing or additive manufacturing can eliminate the need for tool production and, therefore, the costs, lead times and labour associated with it.

4.5 SUSTAINABLE / ECOFRIENDLY
3D printing is also an energy-efficient technology that can utilize up to 90% of standard materials, and therefore, create less waste.

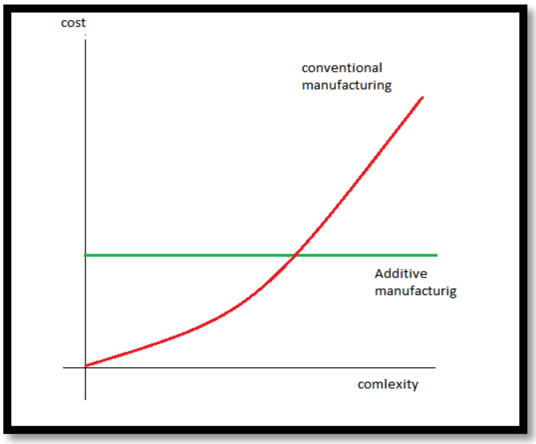


Fig. 9 Conventional manufacture/additive manufacturing

The above graph shows the relation between the cost and complexity. It is clear from the graph that as the complexity increases the cost of the production also goes on increasing but additive manufacturing does not have any effect of the complexity of its cost of production.

V. APPLICATIONS

5.1 MEDICAL SECTOR
This technology is also proved to be very useful in Medical science. With this technology, patients around the world are experiencing 3D printed implants and prosthetics like never before. Sciences scientists are making a shift from printing tiny sheets of tissue to entire 3D organs. [3]

5.2 AEROSPACE & AVIATION INDUSTRIES
The developments in the metal additive manufacturing sector have largely boosted the utilization of 3D printing technology in the aerospace and aviation industries. NASA has printed combustion chamber liners using selective laser melting. [3]

5.3 AUTOMOTIVE INDUSTRY
This technology is also useful in the automotive sector for making the 3D printed components such as dashboard, bumpers etc. [3]

CONCLUSION
The aim of this paper is to reduce the overall cost of the 3D printer by replacing few components by other material instead of costlier materials. As our aim was to build such a machine, which can print 3D object with low cost. So we have designed and fabricated this machine. This paper covers the design calculations of the 3D printer and factors that reduce the overall cost of the additive manufacturing machine. This machine can print any complicated object with desired quality (like surface finish, dimensional accuracy, and strength).We have succeeded to print a layer of 200 microns.

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