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Design of 3D component manufacturing system based on FDM Technique

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Abstract: Fused Deposition Modeling (FDM) is an Additive Manufacturing technique for printing 3D objects layer by layer. The key purpose of the study is to design & develop a 3D Printing system using easily available parts and conventional methods of manufacturing which can be used to print objects confined within 220 x 220 x 300 (in mm) Printing Area. Many Industries uses traditional methods for developing prototype for analysis rather than using technologies like 3D printing because it is expensive. After thorough market survey, we came to a conclusion that 3D Printers available in the Indian market are priced around Rs. 50,000 to 60,000 due to type of supporting material used. Initially we designed our 3D Printer completely in 3D Modelling Software CATIA and selected readily available material appropriately so as to develop a cost-effective printer. Main objective of research is to design & develop a 3D component manufacturing system which is cost effective and to encourage manufacturers to adopt the method of 3D Printing.
Keyword: Arduino UNO, Repramp, CATIA, CURA

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I INTRODUCTION

3D printing is the "process of joining the materials to make object from 3D model data, layer by layer".Technology has affected recent human history probably more than any other field. Various technologies and creative inventions have made our lives better in many ways, opened up new avenues and possibilities. It is widely believed that 3D printing or additive manufacturing (AM) has the vast potential to become one of these technologies. Experts in the field have that claimed 3D printing would replace many of the existing traditional manufacturing methods and revolutionize design and impose economic, social, environmental and security implications to our day to day lives

II LITERATURE SURVEY

In their work titled "3D printing of polymer matrix composites: A review and prospective" have discussed about„additive manufacturing (AM)‟ [1] which is very trending topic in today‟s manufacturing world. They have provided insight into history of 3D printing and then discussed about importance of the technology. Further they have discussed about the number of ways in which 3D printing is done and materials used for the process chosen. Also advantages of 3D printing as compared to conventional methods of manufacturing are stated. Then numerous applications and future scope of the technology is outlined. In their work titled "Economic Implications of 3D printing: Market structure Models in light of additive manufacturing Revisited", [2] have made detailed analysis about the parameters of additive manufacturing technology. From the study of previously established economic models, they have given technological and economic characteristics of AM. Also, four key principles that critically assess the effects of AM to the manufacturers at industry level are given. By their remarkable work they have provided a great support to a firm to evaluate their current manufacturing process against the potential of 3D printing technique to maximize their profit margin. In this paper [3] 3D printers allow researchers to produce parts and concept models rapidly at low-cost and allow rapid prototyping of many designsfromthecomfortoftheirdesk.3Dprintingtechnologieshave been explored for a wide range of applications including robotics, automobile components, firearms, medicine, space, etc. Owing to lower costs and increased capabilities of 3D printing technologies, unprecedented opportunities in the world of oceanography research are being created. Some examples include 3D printed components being employed in autonomous underwater (or surface) vehicles 3D printed replicas of marine organisms being used to study biomechanics, hydrodynamics, and locomotion; and 3D printed coral reef replicas being used to restore damaged coral reefs. The paper provides the review of literature concerning the application of 3D printing in education system. In The review [7] are identifies that 3D printing is being applied across K-12 spectrum and in universities, as well as libraries and in some educational systems. The review is also finds that 3D printing is being used to teach both students educators about 3D printing is being used to teach both students and educators about 3DP and 3DP skills. University libraries in particular are rich source of insight into their adoption. 3D printing is also is used to develop 3D skills 3DP methodologies for creativity and to create artefect that can be used as a learning aids or as assistive technologies in the special learning setting.

In their Work [8] they have discussed about the beneficial ability to build parts with geometric and material complexities that could not be produced by subtractive manufacturing processes. Through intensive research over the past two decades, significant progress has been made in the development and commercialization of new and innovative AM processes, as well as numerous practical applications in aerospace, automotive, biomedical, energy and other fields. This paper reviews the main processes, materials and applications of the current AM technology and presents future research needs for this technology. With desired material properties for evaluation and testing, as well as to manufacture small or medium quantities of end-use products. Currently, the direct fabrication of functional end-use products has become the main trend of AM technology.

III. ADVANCED MANUFACTURING 3D PRINTING

Different methods adopted for 3d printing: [1]

- Stereo lithography (STL)
- Selective laser sintering (SLS)
- Fused deposition modeling (FDM)
- Selective Deposition Lamination (SDL)

3.1Stereo lithography

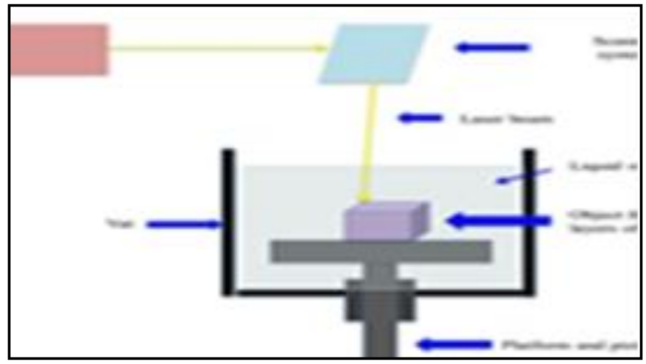

Fig 1 Stereo lithography (STL)

Ultraviolet light is used to form the object in Stereo Lithography. The laser from the scanner system is come in contact of the liquified resin the it will solidify into the layers. The layers will combine to form a 3D model object which we want. The formed layer goes down in the liquid and hence by the phenomenon of the liquid it will come back to the surface. And the process continuous till the object form.

3.2 Selective laser sintering (SLS)

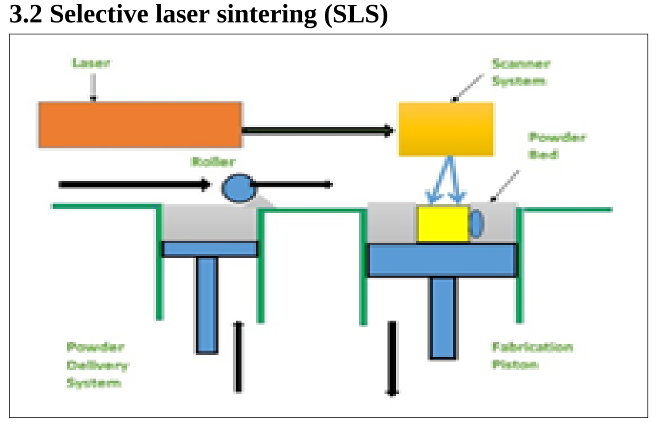

Fig 2 Selective laser sintering (SLS)

There is the two-powder blow for the Selective Leaser Sintering and Elevator is attached to it for lifting purpose. Roller is doing the work of leveler, and also has some temperature to heat the powder. which is to level the powder layer. CO_2 laser is used in SLS technique. The piston from the right side goes upward to push the powder to the left. After the contact of laser and the powder Object will form on the building platform.

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3.3 Fused Deposition Modeling

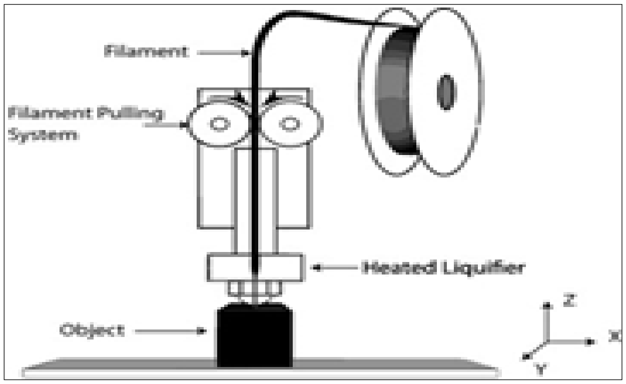

Fig 3 Fused deposition modeling (FDM)

There is the Filament which goes in the tube with the help of material feeder. After the extrusion process this wire goes to the print head which have the hot end at the bottom. Wire gets melted there to form the object. Formation of the object is occurred layer by layer. The heated bed goes down after the formation of a layer. And the process continues till the object form.

3.4. Selective Deposition Lamination (SDL)

Selective Deposition Lamination (SDL) is a proprietary 3D printing process developed and manufactured by Mcor Technologies. The SDL 3D printing process builds parts layer by layer using standard copier paper. Each new layer is fixed to the previous layer using an adhesive, which is applied selectively according to the 3D data supplied. When this cutting sequence is complete, the 3D printer deposits the next layer of adhesive and so on until the part is complete. SDL is one of the very few 3D printing processes that can produce full colour 3D printed parts, using a colour palette.

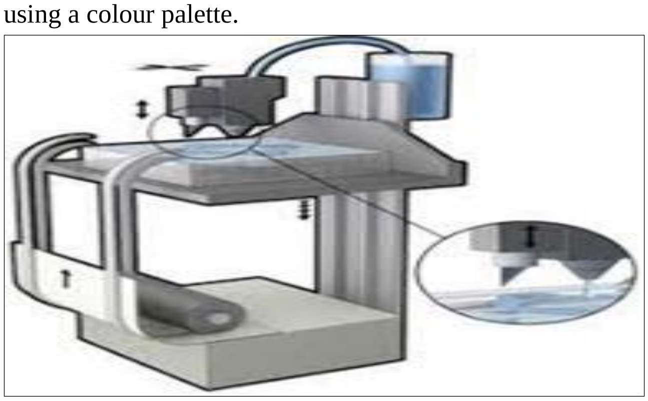

Fig 4 Selective Deposition Lamination (SDL)

IV. METHODOLOGY

41. Experiment and methodology

Our objective was to study, design and fabrication of a low cost 3d printer. We studied the history, different printing methods and overview of the past research in the previous chapter. This chapter includes design and fabrication of the same mentioned earlier. First we ordered the whole tool-kit including all the parts and components those are used to manufacture a 3d printer. It took a while to procure the whole kit. In the meanwhile a CAD model of a 3d printer has been created using CATIA. First we designed all the parts required for the assembly and dimensions were strictly taken by considering various operational parameters. Then all the parts are assembled in the CATIA to create the 3d printer assembly. Here are the real life pictures, designed model of individual parts and their working process.

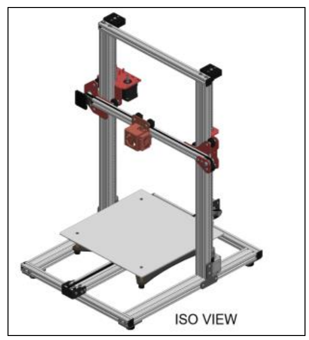

Fig 5 CAD model

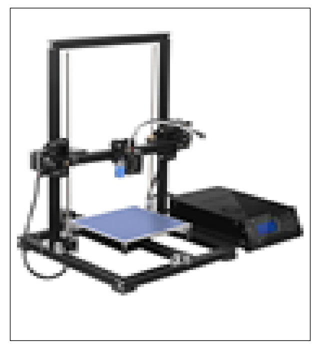

Fig 6 Working model

4.2 Flow chart

The following flow chart shows the methodology used by us in construction of 3D printer. The first step is to select one of the additive manufacturing processes among many processes explained in chapter 2. Then an appropriate mechanism is selected for X, Y and Z axis movements, considering various factors such as cost of fabrication, simplicity of design, synchronization, accuracy etc. Once the mechanism is selected the next step is integration of electronics and software then the machine is designed and fabricated. The last step is synchronization of mechanical, electrical and software elements of the machine.

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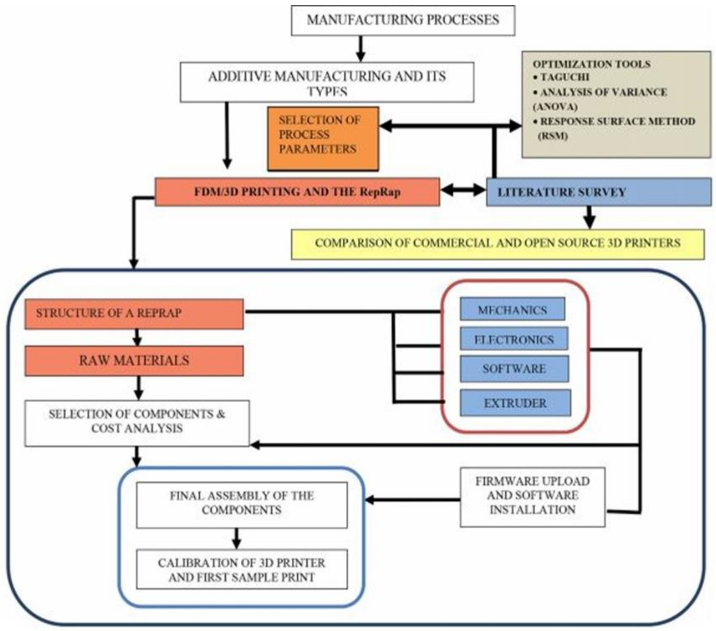

Fig 7 Flowchart of design, development and calibration of open-source 3D printer.

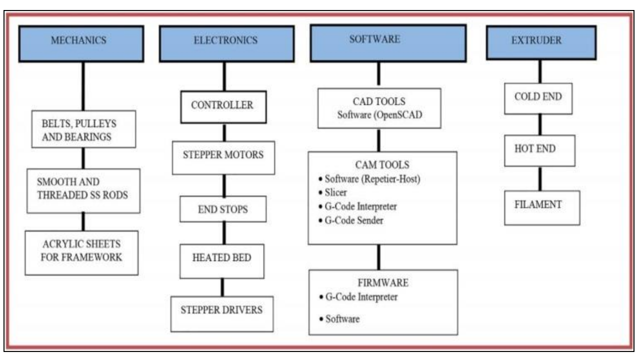

Fig 8 Structure of a RepRap.

V. ELECTRONICS SELECTION

5.1 Controller

The controller is the brains of our 3D Printer. Almost all 3D Printer controllers are based on the of the Arduino microcontroller. While a lot of variations exist. They are exchangeable and basically all do the same thing. Now and then the controller is remain solitary circuit load up with chips on it, in some cases the controller is an Arduino Mega with an extra board (called a "shield'). But in our case we used the controller board named as MKS GEN V1.4 as it performs function of both Arduino & Ramps board too with minimum space considerations. Integrate 2560 and ramps1.4 in a board, to solve the complicated interfaces and broken problem of Ramps1.4 combination. Replaceable motor driver, support 4988 driver and 8825 driver. Circuit board using high-quality 4-layer board, and specially dealing with thermal optimization; ramps is a 2-layer board.

- Using high-quality MOSFET tube, with better heat dissipation.
- Using a dedicated power chip to support 12V-24V power input, to solve the problem of Ramps voltage converted into chip heating.
- To accept 24V input, hot bed current can be reduced to 1/4 under the same system power, effectively solve the heating problem of hot bed MOS tube.
- Firmware can use open-source firmware Marlin, and its configuration is exactly the same as ramps1.4, which can directly replace Ramps1.4.
- Can directly connect to Ramps1.4, 2004 LCD control board and 12864LCD control board.
- Set aside the motor pulse and direction output port, convenient to facilitate external high current to connect external high current (such as 2A, 5A) motor drive circuit.
- Reserve the Servos, AUX-1, AUX-2 interfaces on Ramps1.4, providing three 5V output, three 12V output interfaces.

- This board is an upgrade part of the MKS Gen V1.2 board, improving the performance of power protection and USB communication stability.

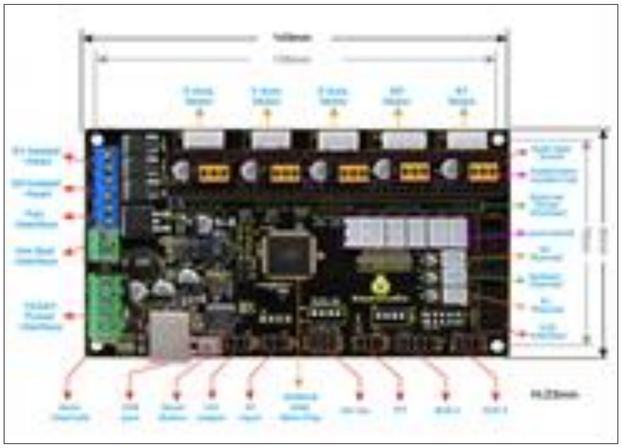

Fig 9 MKS GEN V1.4 Motherboard

5.2 Stepper Motors

A stepper motor (or step motor) is a brushless DC electric motor that partitions a full pivot into a numerical of equivalent advances. The motor's position would then be able to be instructed to move and hold at one of these means with no criticism sensor, as long as the engine as deliberately measured to the application. Stepper motor moves a known break for each beat of vitality. This beat of vitality is given by a stepper driver and is suggested as a stage. As every movement moves the motor a known partition it makes them helpful gadgets for repeatable arranging. We will utilize stepper motor to move the bed carriage and different gatherings in their individually X - Axis, Y - Axis, Z-Axis.

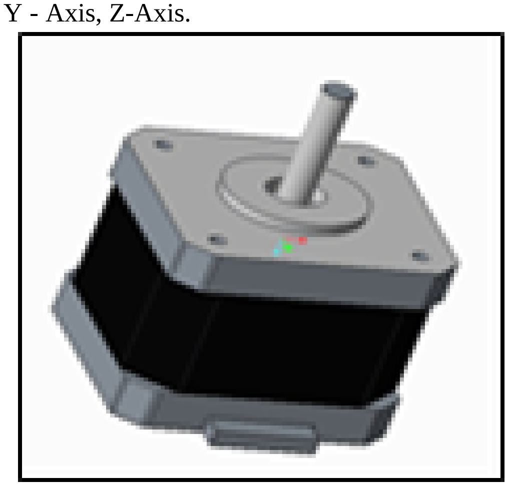

Fig 10 Stepper motor

5.3 Stepper Drives

A stepper driver is a motor that acts as the kind of intermediate person between a stepper motor and the controller. It streamlines the signs that should be sent to the stepper motor keeping in mind the end goal to motivate it to move. Here and there the stepper drivers are on independent circuit sheets that are connected to the controller through links. Now and then the stepper drivers are on little circuit sheets that connect straightforwardly to the controller itself. For this situation, the controller will have space for no less than 4 of these little circuit sheets (one for every stepper motor). Finally, sometimes the stepper drivers are soldered right onto the controller itself.

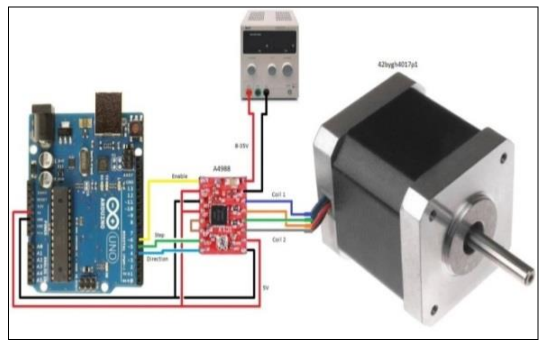

Fig 11 A4988 stepper driver Fig 6.3.2 A4988 with Arduino interfacing

VI. DESIGN

6.1 Conceptual Design

The design of the model has to be done in software where the actual model with the required dimensions is developed so that it can be used to print the model. To develop and fabricate the model there are many process and parameters involved mainly design of the model. The design process started by keeping the print volume as a basic design parameter. As the objective of the project is the construction of economical and sizable 3D Printer, a print volume of 220 x 220 x 220 mm3 is selected. The 3-Dimensional motion is achieved by synchronization of movements in X, Y and Z directions. Hence mechanism of our 3D Printer is Z plus core XY. This mechanism uses 5 stepper motors, one for Y-axis movement (to and fro movement), one for X-axis movement, two for Z-axis movement (Vertical movement) and one for Extruder filament. This mechanism uses two stepper motors to control lead screws to which the X Carriage is connected through threaded couplers to have movement in Z-direction. The lead screws are driven by the motor which in turn moves the X carriage assembly in the vertical direction. The conceptual design has been initially visualized in CATIA software.

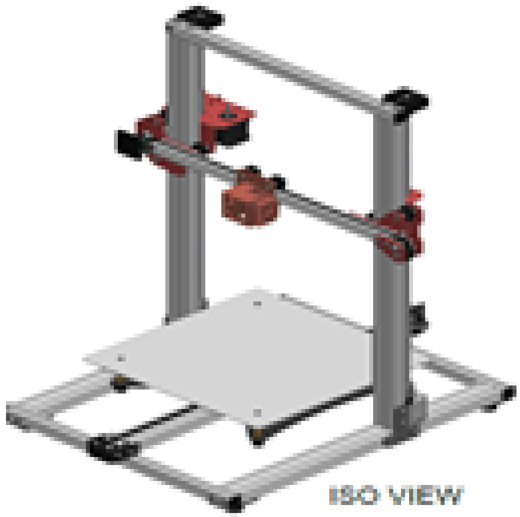

Fig 12 Conceptual view

6.2 Detail design

6.2.1 Selection of Motor for X and Y axis

Assumptions:

Constant speed of the motor = 400rpm=6.667rps

v = r ω

ω = [2πN]/60

= 41.908rad/s

Therefore;

400 = r*41.908

r = 9.547mm

Torque = Force*Radius

Force = 41.87N (considering NEMA 17 stepper motor having torque = 0.4Nm)

Conclusion for motor design

4.2 kg can be pulled over a distance of 500 mm in 1 second using NEMA 17.

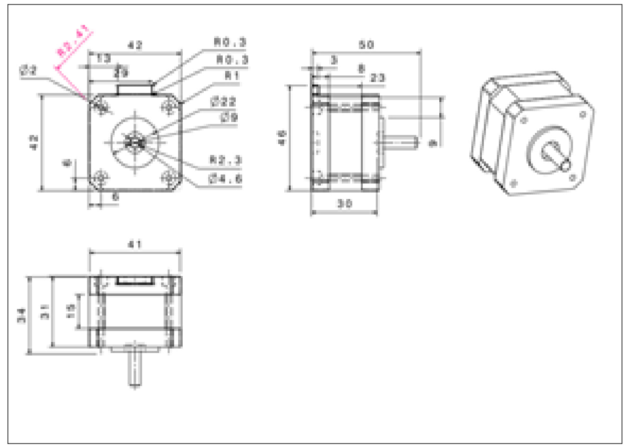

Fig 13 Detailing of NEMA 17

6.2.2 X-axis Movement

Figure 8.1.3 shows the CAD model of the mechanism of Lateral movement. It consists of the pulleys, timing belt, carriage, 20×20 extrusion profile, and extruder nozzle (used in FDM process) arranged as shown. The rotary motion from the motor in the y-axis is converted into linear sliding motion and this linear motion is transfer by flange bearing by timing belt- pulley connection as shown in figure 8.1.6. The extruder nozzle is the main printing part of the machine For its movement in a horizontal direction, the carriage is provided. The extruder nozzle is mounted onto to the carriage on one side; this may result in imbalance and failure of the machine. To avoid this, the carriage is mounted on 20×20 square extrusion profile instead of using sliding rods and designed for balance. The carriage slides in the horizontal direction over 20×20 extrusion profile. This 20×20 extrusion profile is fixed rigidly into the holes present in the carriages that move in the Y direction. The timing belt is mounted on the pulley which is driven by the motor on one side and a support pulley on the other side. The carriage is fixed to the lower timing belt of the loop, such that the belt movement results in the movement of the carriage. When the motor rotates in clockwise direction, since the carriage is connected to the lower belt in the loop, it moves from right to left.

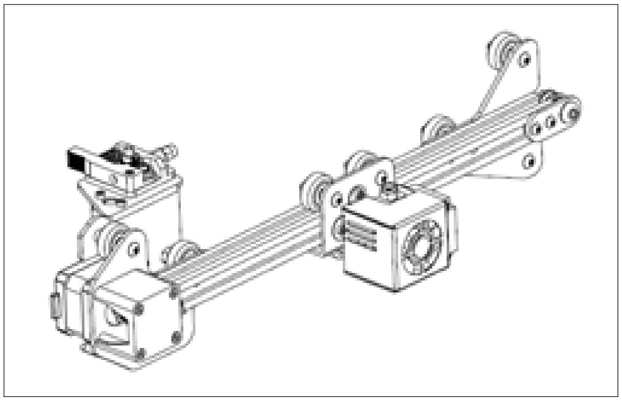

Fig 14 X-Carriage assembly

When the motor rotates in an anticlockwise direction, the carriage moves from left to right. To design this mechanism for horizontal movement, the carriage is designed first for balance, so that the weight of the carriage and the extruder nozzle is distributed equally on 20×20 extrusion profile. The weight of the extruder nozzle is found and accordingly, the carriage is designed. The carriage is designed using the free body diagram of the carriage. Figure 8.6 shows the free body diagram of the carriage. The thickness of the carriage is decided based on the diameter of the rods. The width is decided based on the dimensions of the extruder nozzle.

6.2.3 Y – Axis Movement

Following figures shows the details of the mechanism for Y-axis movement. It consists of Carriage, Pulleys and Timing Belt to have precise table movement.

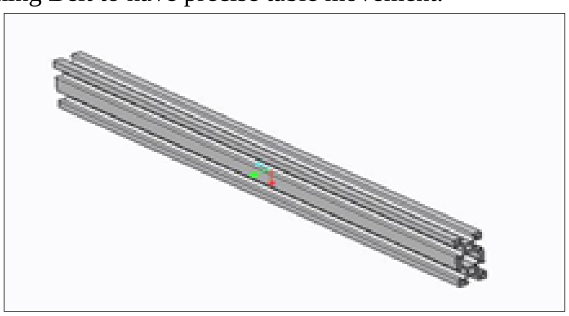

Fig 15 Extrusion profile 40×20

The rotary motion of motor is converted into linear sliding motion by timing belt pulley connection as shown in figure 4.13. The carriages will slide along the Y-axis over the 40×20 extrusion profile. This 40×20 extrusion profile is fixed rigidly to the frame. The timing belt is mounted onto the pulley which is driven by the motor on one side and a support pulley on the other side. The carriage is fixed to the lower timing belt of the loop, such that the belt movement results in the movement of the carriage. When the motor rotates in one direction, the carriages are connected to the lower belt in the loop moves from front to back or in opposite direction depending on the motor orientation. The two motors should be in perfect synchronization for high quality printing.

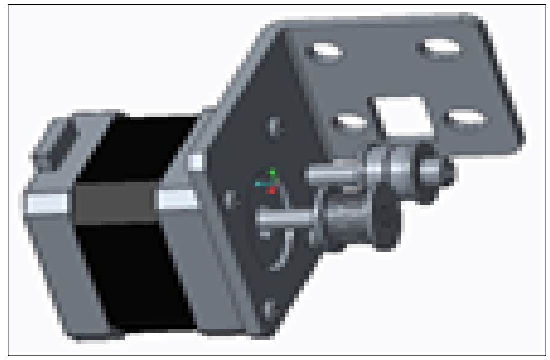

Fig 16 Back end stepper motor

To design this mechanism for Y – axis movement, first the carriages are designed. The carriages are designed to mount the motor, pulley and to hold X – axis rods. Since these carriages are symmetric there is no problem of imbalance and hence the carriage dimensions are determined by the mounting area required by the motor, supporting pulley and the holes to hold the X -axis rods rigidly.

6.2.4 Z-axis Movement

Figure shows the CAD model of the mechanism of vertical movement. It consists of lead screws, shaft coupler, flange nut and print bed arranged as shown in the image. The rotary motion of the motor is transfer by rotating the lead screws connected to the X-carriage by using flange nut and shaft coupler as shown.

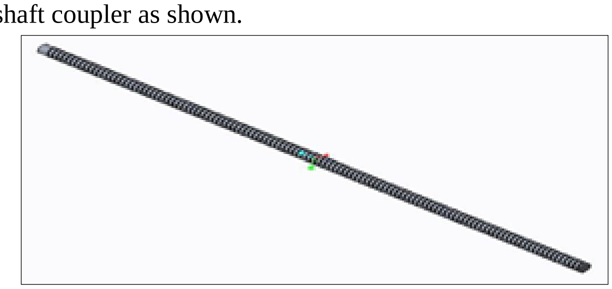

Fig 17 Lead screw

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The torque produced by the motor is transmitted to the lead screws by using shaft coupler and flange nut. When the motor rotates, say in a clockwise direction, shaft coupler rotates lead screws in the same direction, say in a clockwise direction. The X-carriage is connected to the lead screws using threaded couplers; this makes the X-carriage move in a vertical direction when the lead screw rotates. The stepper motor will turn the strung pole around its own particular pivot which thus will permit the X-end idler climb and down. Collected X-end idler is indicated in figure 4.17 The X-end motor is assembled of the comparable two areas and is assembled in a comparative manner. As we can see from the figures, Z-axis is controlled by 2 stepper motors. It results out to be less expensive and improvement of precision to have 2 stepper motors on the Z-axis rather than one motor and a belt, on the grounds that the later one requests an extremely complex development and an extravagant belt too. The Y and X-hub are commonly controlled by one motor and a belt drive.

6.3 Design of pulley for X and Y axis

From section 4.2.1 we have the radius of the pulley,

Radius = 9.55mm = 10mm

Diameter = 20mm

Pitch = 2mm

Circumference = $2\pi r$

= 62.84mm

Number of teeth = [circumference/pitch]

=31.42

≈32 teeth

6.4 Extruder

Extrusion is a procedure used to make objects of a settled cross-sectional profile. A material is pushed or pulled through a die of the desired cross-sectional profile. The two main advantages of this process over manufacturing processes are its ability to create very complex cross-sections and to work with materials that are brittle. Because the material only encounters compression and shear stresses. It also forms parts with an excellent surface finish. Commonly extruded materials include metals Polymers, ceramics, concrete, play dough, and foodstuffs. The products of extrusion are generally called “extrudates". Drawing metal is the main way to produce wire, sheet, bar, and tube.

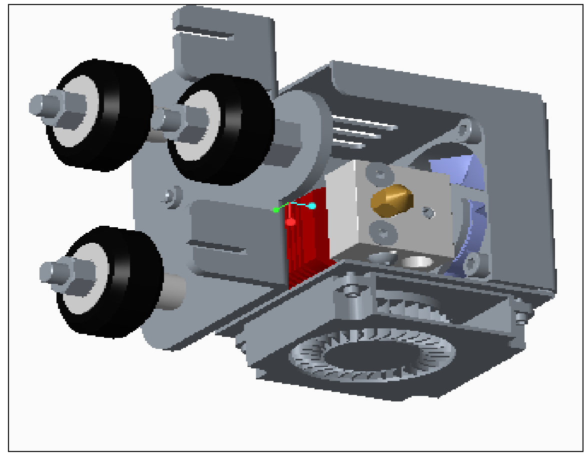

Fig 18 Extruder assembly

9.1.2 Principle of Extruder

To extrude molten plastic filament, the "Cold End" forces the raw material (usually a 1.75mm or 3mm diameter filament) into the hot end. The feeding filament should then go through the "Hot End" of the extruder with the heater and out of the nozzle at a reasonable speed. The extruded material falls onto the fabricate stage (now and again warmed) and after that layer by layer onto the part as it is constructed.

CONCLUSION

The intention behind this research was to Design & develop a low-cost 3D Printer by Optimizing . We have been successful in reducing the cost to a considerable extent that is about 10-15 %. The parts made in 3D design software are successfully imported in the printing software and the product obtained has the same dimension given during the design stage of the product that is an accuracy close to 100%. We were able to successfully fabricate the 3D printer according to its virtual design proposed at reduced cost.

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