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Fabrication of 3D component manufacturing system based on FDM Technique

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Abstract: **Fused Deposition Modeling (FDM) is an Additive Manufacturing technology for layer-by-layer printing of three-dimensional objects. The study's main goal is to design and construct a 3D printing system that can produce objects within a 220 x 220 x 300 (in mm) printing area utilising readily available parts and traditional manufacturing methods. Because 3D printing is expensive, many industries employ traditional ways to build prototypes for examination rather than adopting technology like 3D printing. Due to the sort of supporting material employed, we got to the conclusion that 3D Printers accessible in the Indian market are priced about Rs. 50,000 to 60,000. To construct a cost-effective printer, we first developed our 3D Printer entirely in the 3D Modelling Software CATIA and then picked readily available materials. The primary goal of this study is to develop a cost-effective 3D component production system and to encourage manufacturers to use 3D printing**.

Keyword: *slicing, layer, CAM, Aurdino interfacing.*

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I INTRODUCTION

1.1 3D Printer

A 3d printer is an additive manufacturing technique where 3D objects and parts are made by the addition of multiple layers of material. It can also be called as rapid prototyping. It is a mechanized method where 3D objects are quickly made as per the required size machine connected to a computer containing blueprints of any object. The additive method may differ with the subtractive process, where the material is removed from a block by sculpting or drilling. The main reason to use 3d printer is for 90% of material utilization, increase product life, lighter and stronger. 3D printing is efficiently utilized in various fields such as aerospace, automobile, medical, construction and in manufacturing of many household products.

1.2. Application of 3d printer

3-D printing was originally developed for rapid prototyping purposes, making less complicated physical samples. It allowed designers to identify and rectify design flaws quickly and cheaply, thereby speeding up the product development process and minimizing commercial risks. Here are some applications of a 3D printer described below:

i. Aerospace and Automotive sector:

With the help of 3-D-printed components which are used for aircrafts and parts are 70% less weighing but identically tough as conventional parts, indicating cost reduction and carbon reduction and emissions of unwanted particle. It uses less raw constituents and manufactures parts which are less weight, complicated but possess more strength.

Fig 1 Jet propulsion

Fig 2 Automotive part

ii. Rapid manufacturing:

Advancements in Rapid Prototyping have presented materials those are necessary for final manufacturing, leading to the possibility of manufactured finished components and parts.

Fig 3 Industrial gears

Fig 4 Turbine blade

iii. Medicine:

Medical sector is one of the most promising areas of usage. It is being applied to face many medical situations, and develop medical research, also combining the field of "regenerative medicine". In 2012, using a 3-D printer, engineers and doctors at Hasselt successfully experimented the very first patient-specific instrument of prosthetic jaw transplant.

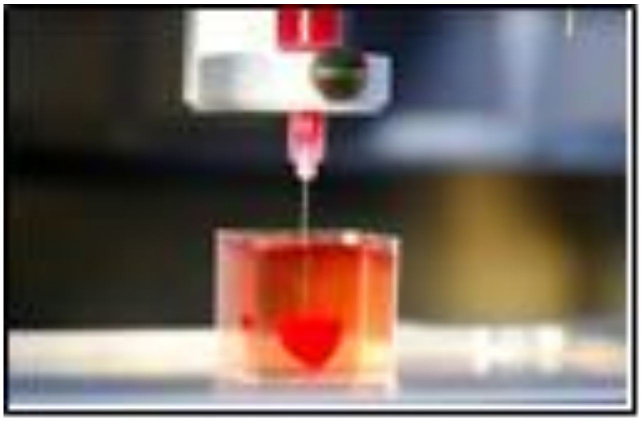


Fig 5 Regenerative medicine

iv. Mass customization:

Many industries have provided services where people can recreate their desirables implementing simple web-based customizing software. This now enables customers to replicate cases of their mobiles. Nokia has displayed the 3D designs of their mobiles so that owners will be able to recreate their own phone case.

Fig 6 Nokia phone back case

II LITERATURE REVIEW

3D printing was known as "rapid prototyping". Chuck Hull, of 3D Systems Corporation, created the first working 3D printer in 1984. Later in the 80's, Selective Laser Sintering (SLS) technology was developed by Dr. Deckard at the University of Texas at Austin during a project sponsored by Defense Advanced Research Projects Agency (DARPA). In the 1990s, the technology was further improved with the development of a method that used ultraviolet light to solidify photopolymer, a viscous liquid material. In the late 20th century, 3D printers were extremely expensive and could only be used to print a limited number of products. The majority of the printers were owned by scientists and electronics enthusiasts for research and display. Although it was still in limited development, the printing technology was a combination of modeling both science and construction technology, using some of the newest technological advancements of the time. Consequently, 3D printing began to lead a worldwide manufacturing revolution. In the past, surface design was mainly dependent on the production process. However, developments in the field of 3D printing have allowed for the design of products to no longer be limited by complex shapes or colors.

III MATERIALS USED IN FDM 3D PRINTING

Material	Description	Printing Temp	Bed Temp
PLA	PLA (Polylactic Acid) is one of the two most commonly used desktop 3D printing materials (with the other being ABS). Itis the 'default' recommended material for many desktop 3D printers, and with good	180 - 220	20 - 55

	reason - PLA is useful in a broad range of printing applications, has the virtue of both odourless and low warp and it will not require a heated bed. PLA plastic is also one of the eco-friendlier 3D printer materials available; it is made from annually renewable resources (corn- starch) and requires less energy to process compared traditional (petroleum-based) plastics.		
ABS	ABS (Acrylonitrile Butadiene Styrene) is another commonly used 3D printer material. Best used for making durable parts that needs to withstand higher temperatures. In differentiating to PLA, ABS plastic is less brittle. It can also be post-processed with acetone to provide glossy finish.	235-270 °C	60-80 °C
Nylon (Polyamide)	Nylon is an incredibly strong, durable, and versatile 3D printing material. It is very Flexible when it is thin but it is high inter layer adhesion and the nylon lends itself well to things like the living hinges and the different functional parts. Nylon filament prints as a bright natural to white with a translucent surface and can absorb colour added post process with most common, acid-based clothing dyes. Nylon filament is very sensitive towards the presence of moisture so taking drying measures during storage and immediately prior to printing is highly recommended for	235-270 °C	60-80 °C

	best results.		
PET (Polyethylene Terephthalate)	PET (Polyethylene terephthalate) is an industrial strength filament with several great features. Its strength is much higher than PLA, it is FDA approved for food containers and tools used for food consumption, it barely warps, and produces no odours or fumes when printed. PET filament is not biodegradable, but it is 100% reclaimable	230-255 °C	55-70 °C

Table 3.1 Materials used in FDM 3D Printing

IV METHODOLOGY

4.1. 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 7 Working model

4.2 Selection of process

The rundown of 3D printing innovations and procedures keeps on developing as 3D printing is continually evolving. The 3D printing industry continues upgrading its hardware and the materials and strategies to make protest or parts. Contingent upon numerous factors, for example, spending plan, outline or capacity, picking the fitting 3D printing process and also the correct material is imperative.The FDM technology is clean, simple to use and it is environmentally stable. Complex shapes and intricate parts can be printed. FDM is at the very entry of the market as it mainly used by individuals. FDM is an affordable 3D printing process compared to other 3D printing technologies. FDM starts with a product procedure which forms an STL file (stereolithography file format), scientifically cutting and situating the model for the building procedure. In the event that required, support structures might be created. The machine may apportion numerous materials to accomplish diverse objectives. The model or part is created by extruding little amount of thermoplastic material to the desired shape layers as the material solidifies promptly after expulsion from the nozzle. A plastic filament or metal wire is loosened up from a loop and supplies material to an extrusion nozzle which can turn the flow on and off. There is commonly a worm drive that pushes the filament into the nozzle at a controlled rate. The nozzle is warmed to soften the material. The thermoplastics are warmed past their glass change temperature and are then saved by an expulsion head.The nozzle can be moved in both even and vertical bearings by a numerically controlled component. The nozzle takes an instrument way controlled by a PC helped producing (CAM) programming bundle, and the part is developed from the last, one layer at any given moment. Stepper engines or servo engines are commonly utilized to move the expulsion head. The system utilized is frequently an X-Y-Z rectilinear outline, albeit other mechanical plans have been utilized. In spite of the fact that as a printing innovation FDM is exceptionally adaptable, and it is fit for managing little shades by the help of bringing down layers.

4.3 Selection of Mechanism

Presently mechanisms such as, for example, SCARA, Cartesian, Polar, Delta and so on are utilized as a part of development of FDM 3D Printers. We have chosen Cartesian arrangement of developments, where the bed moves in the vertical heading i.e., in Z pivot bearing and the extruder spout moves horizontal way i.e., both in X and Y hub course. Z hub development on such a 3D printer is extremely exact and requires low increasing speeds, however the bed should be lightweight with a specific end goal to look after precision, which makes it harder to include a completely programmed bed leveling framework. Controlling a straight Cartesian framework like this is mechanically straightforward and furthermore generally simple from a product point of view, which is the reason most 3D printers available today utilize this kind of plan. The Cartesian arrange frameworks has for quite some time been utilized for instruments like plotters, CNC processing machines, and 2D printers.

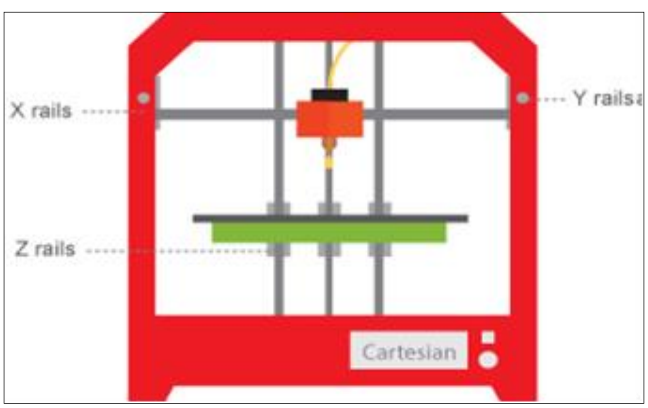


Fig 8 Cartesian Type Mechanisms

4.4 Electronics selection

4.4.1 End stops

Mechanical switches are less complicated to implement and cheaper than optical end stops because they do not require a circuit board and only use 2 wires for connecting the switch. Resistors Pull up and down can put close to the main board. Contact-less magnetic switches are called read switches. They are proximity switches that close (or switch over) if a magnet comes close enough (usually 1 mm or less) and open if the magnet moves away. Reed switches are utilized as sensors in home caution frameworks to identify open windows and doors.

Fig 9 End stops

4.4.2 Heated Bed

A heated build platform HBP improves in the printing quality of the 3d model by helping prevent warping. As extruded plastic cools it shrinks slightly. When this shrinking process does not occur throughout the printed part evenly, the result is the warped part. This warping is very commonly seen as corners being lifted off of the build platform. Printing on a warmed bed permits the printed part to remain warm amid the printing procedure and permit all the more notwithstanding contracting of the plastic as it cools underneath softening point. The warmth bed prompts higher complete quality that works with materials, for example, ABS and PLA. A HBP can likewise enable clients to print without rafts.

Fig 10 Heat bed

4.4.3 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.

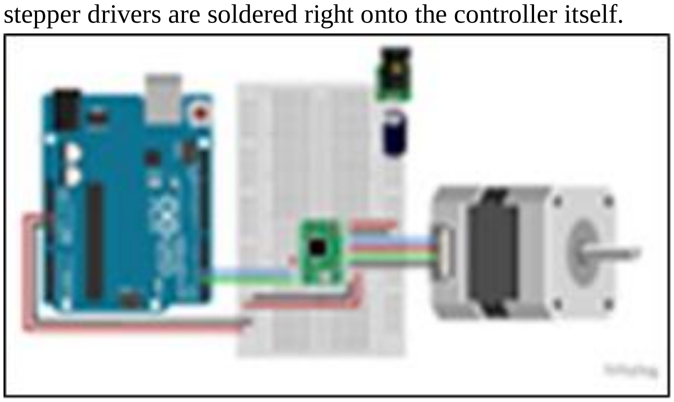


Fig 11 A4988 with Arduino interfacing

4.4.4 Thermistor

A thermistor is utilized to detect the temperature of the hot end. Frequently a Second thermistor detects the temperature of the Heated Bed. Thermistors are the resistors that difference in protection with the difference in temperature. Great characteristics of the thermistor are an anticipated precisely known protection esteem at each temperature in its working extent. The bringing down or rise relies upon the kind of the thermistor per degree Kelvin this is called as its coefficient. Positive warm coefficient PTC will increment as in protection from the expansion in temperature, negative ones NTC will diminish. The recipe by and by isn't straight so now and then a precise table of estimations is superior to the direct equation. These estimations can be normally found in the datasheet of that goes with the thermistors.

Fig 12 Thermistor

NTC thermistor for the temperature sensor is one where has the thermistor chip welded with leads by composite patching procedure and after that incompletely treated by glass fixing. They are comprised of these semiconductors which will be for the most part silicon and germanium and these offer protection esteem can be differed by numerous request of extents in their temperature run. A 100k NTC thermistor has a protection estimation of 100k ohms at room temperature and drops as low as 100 ohms at 300 degrees Celsius.

4.4.5 Power supply

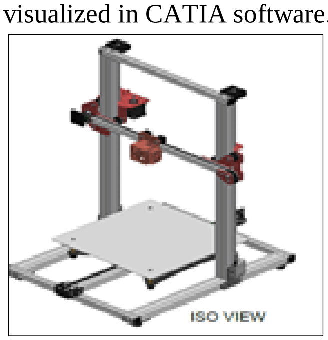
The motor plus single hot end takes up to 5A or so, The heated bed typically takes 5A-15A. For a standard setup with the heated bed, look to a total 18-30A which are about a 220-360W at 12V. for some setup might be able to use fewer power ones. Switch mode power supplies have relatively complex circuits that are to convert mains AC electricity to DC voltages that required by the Steppers and the Electronics circuit. The main advantage is that of a Switch mode power supply is highly efficient in converting energy.

Fig 13 Power Supply

V. FABRICATIONS

5.1 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.



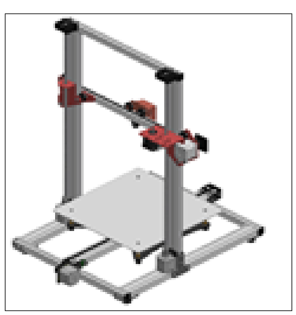


Fig 14 Conceptual view **Fig 15** Conceptual view 2

5.2.2 X-axis Movement

Figure 4.3 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 4.6. The extruder nozzle is the main printing part of the machine (fig 4.11) For its movement in a horizontal direction, the carriage is provided. The extruder nozzle is mounted onto to the carriage (fig 4.7) 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.

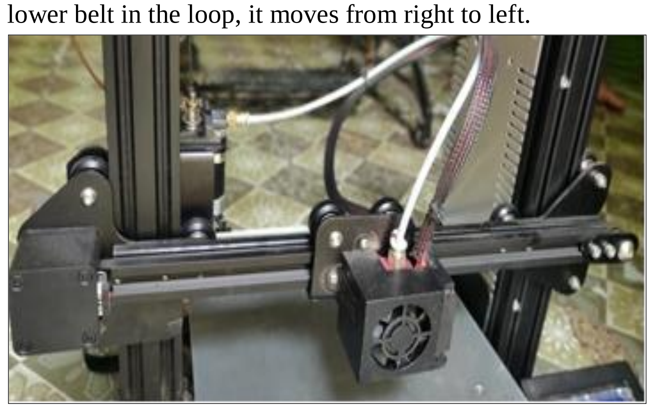


Fig 16 X-Carriage assembly

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 4.7 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.

5.2.3 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.

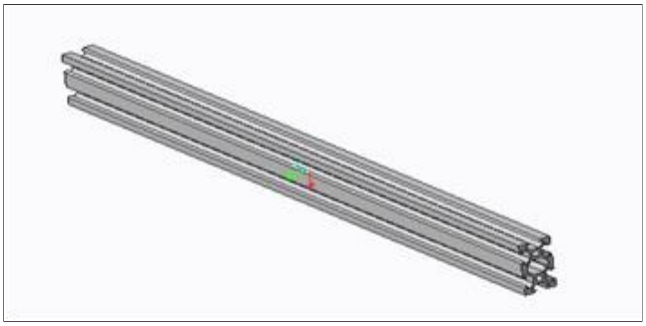


Fig 17 Extrusion profile 40×20

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 18 Back end stepper motor

Fig 19 Front end support

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.

5.2.4 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.

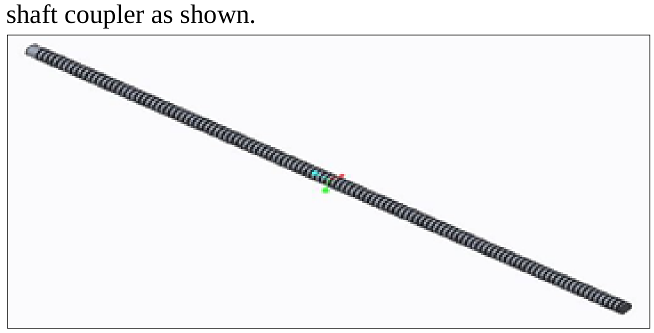


Fig 20 Lead screw

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.

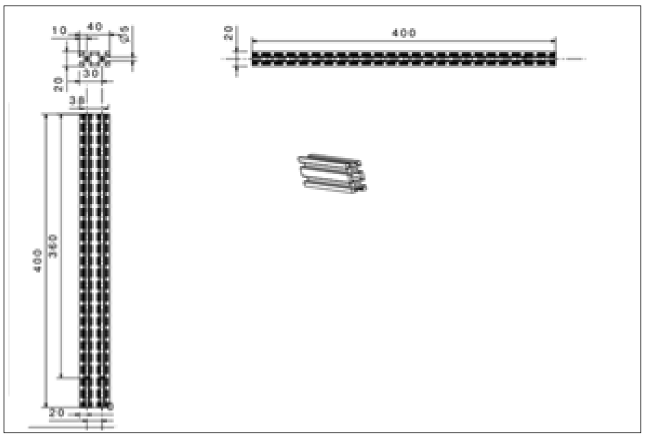


Fig 21 Extrusion profile 40×20

5.3 PULLEY

A wheel with a furrowed edge around which a rope passes, which acts to alter the course of a power connection to the rope and is utilized to raise overwhelming weights.

- Fixed pulley
- Compound Pulley
- Movable Pulley

A pulley is a wheel on a pivot or shaft that is intended to help develop and alter of course of a link or belt along its outline. Pulleys are utilized as a part of an assortment of approaches to lifting loads. Apply powers, and to transmit control. In nautical settings, the gathering of the wheel, pivot, and supporting shell is alluded to as a "piece." A pulley may likewise be known as a sheave or drum and may have a section between two ribs around its perimeter. The drive component of a pulley framework can be a rope, link, belt, or chain that keeps running over the pulley inside the section.

Fig 22 Pulley

By and large talking, for best execution, you need no less than 6 teeth in contact with the pulley at any given time. That limits the possibility of the belt slipping, and decreases kickback significantly further. By and by that implies you need at least a 12-tooth pulley. Past that base, fewer teeth are for the most part superior to more teeth, since a little pulley gives both more torque and more determination. You get more torque in light of the fact that the more drawn out your "arm", the less torque you have (Imagine the heap is mounted on an arm the length of the range of the pulley, the shorter that arm, the less demanding it is to lift the heap), and you get higher determination, since you have a settled number of steps per unrest, and a little pulley moves a shorter straight separation for every progression. A wheel with a notched edge around which a string passes, which acts to alter the course of a power connection to the string and is utilized to raise substantial weights. For the most part talking, for best execution you need no less than 6 teeth in contact with the pulley at any given time. That limits the shot of the belt slipping, and decreases kickback significantly further. By and by that implies you need at least a 12-tooth pulley. Past that base, fewer teeth are for the most part superior to more teeth, since a little pulley gives both more torque and more determination. You get more torque on the grounds that the more drawn out your "arm", the less torque you have (Imagine the heap is mounted on an arm the length of the range of the pulley, the shorter that arm, the less demanding it is to lift the heap), and you get higher determination, since you have a settled number of steps per transformation, and a little pulley moves a shorter straight separation for each progression.

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5.4 Extruder

5.4.1 Introduction

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.

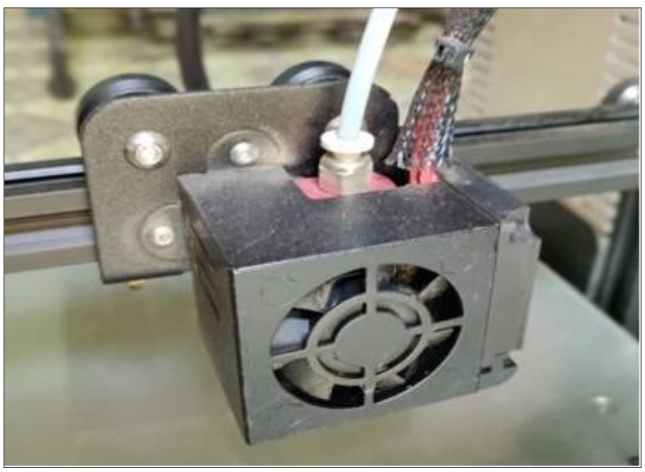

Fig 23 Extruder assembly

5.4.2 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.

5.5 Hot end

The "Hot End" is the active part of the 3D printer that melts the filament. It enables the liquid plastic to exit from the small nozzle to shape a thin and cheap dab of plastic that will stick to the material it is laid on. Researchers have also made hot ends from glass or aluminum. The hot end consists of a melting zone or chamber with two holes. The cold end forces the filament into the heating chamber of the hot end through one hole. The molten plastic exits the heating chamber through the other hole at the tip. The hole in the tip (nozzle) has a diameter of between 0.01mm and 1.0mm with a typical size of 0.4mm with present generation extruders. The heating is done by a cartridge having induction coil just outside the tip of the barrel. The required heat is use to generate in order of 20W with typical temperatures around 150 to 250 degrees centigrade. For feedback control of the nozzle temperature, a thermistor is usually attached close to the nozzle, through a thermocouple may serve as suitable control hardware. High-temperature materials are needed here. These include metals, cement, glues, glass, mineral fiber materials, PEEK, PTFE, and Kapton tape.

Fig 24 Hot End of Extruder

The intention behind this research was to Fabricate a 3D Printer by using materials which are easily available and cost effective. 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.

VI. 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.

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 [36]. 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.

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.

VII. CONCLUSIONS

The intention behind this research was to Fabricate a 3D Printer by using materials which are easily available and cost effective. 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.

REFERENCES

[1] Ramya and Sai leela Vanapalli, 3d Printing Technologies In Various Applications. International Journal of Mechanical Engineering and Technology.

[2] C.W. Hull, Apparatus for Production of Three-dimensional Objects by Stereolithography, in, Google Patents, 1986.

[3] Dr. Rajashekar Patil, Deepak D, Dharshan Gowda S, Krishna Kashyap C S, Mohammed Murtaza, Prashanth S N, Harsha N and Bharath V G, Economical 3d Printer by Adopting FDM Technique, International Journal of Mechanical Engineering and Technology.

[4] http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=4

[5] Hideo Kodama, "Automatic method for fabricating a three-dimensional plastic model with photo-hardening polymer," Review of Scientific Instruments, Vol. 52, No. I l, pp 1770-1773, November 1981.

[6] Hideo Kodama, "A Scheme for Three-Dimensional Display by Automatic Fabrication of Three- Dimensional Model," IEICE TRANSACTIONS on Electronics (Japanese Edition), vol. J64-C, No.4, , April 1981

[7] Beck, J.E.; Fritz, B.; Siewiorek, Daniel; Weiss, Lee (1992). "Manufacturing Mechatronics Using Thermal Spray Shape Deposition" (PDF). Proceedings of the 1992 Solid Freeform Fabrication Symposium.

[8] Amon, C. H.; Beuth, J. L.; Weiss, L. E.; Merz, R.; Prinz, F. B. (1998). "Shape Deposition Manufacturing With Microcasting: Processing, Thermal and Mechanical Issues" (PDF). Journal of Manufacturing Science and Engineering 120 (3).

[9] Freedman, David H. "Layer by Layer." Technology Review 115.1 (2012): 50—53. Academic Search Premier. Web. 26 July 2013.

[10] Jason King Book Review: 3D Printing — The Next Industrial Revolution, 3D Printing Direct Digital Manufacturing Pioneers, Headquarters, 27th April 2014.Replicator World, June 2013

[11] Gary Anderson Christopher Barnatt on "The Business of 3D Printing", 10th October 2013.

[12] T. Prabhu. Modern Rapid 3D Printer - A Design Review. International Journal of Mechanical Engineering and Technology, 7(3), 2016, pp. 29–37

[13] Jabbar Qasim Al-Maliki, Alaa Jabbar Qasim Al-Maliki (2015), the Processes and Technologies of 3D Printing, International Journal of Advances in Computer Science and Technology, pp. 161– 165.