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Design and Fabrication of Delta type 3D printer

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Abstract— 3D printing, also known as additive manufacturing (AM), refers to various processes used to synthesize a three-dimensional object. In 3D printing, successive layers of material are formed under computer control to create an object. These objects can be of almost any shape or geometry and are produced from a 3D model or other electronic data source. A 3D printer is a type of industrial robot. Rapid prototyping is a technique used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD/INVENTORY) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology 3D printers capable of outputting in color and multiple materials already exist and will continue to improve to a point where functional products will be able to be output. With effects on energy use, waste reduction, customization, product availability, medicine, art, construction and sciences, 3D printing will change the manufacturing world. This is just like a Cartesian bot.

Index Terms—Cartesian, Additive Manufacturing, 3D printer, computer aided design, delta design, extrusion,

1 INTRODUCTION

As per (3D Printing Industry, 2017) "3D Printing is a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material. It brings a digital object (its CAD representation) into its physical form by adding layer by layer of materials". The most basic, differentiating principle behind 3D printing is that it's an additive manufacturing method and this is often so the key as a result of 3D printing may be a radically totally different producing methodology supported advanced technology that builds up components, additively, in layers at the sub mm scale this is often basically completely different from the other existing traditional manufacturing techniques

There is variety of limitations to traditional manufacturing that has wide been supported human labor and created by hand ideology growing back to the account origins of the French word for manufacturing itself. However, the globe of manufacturing has modified, and automated processes like machining, casting, forming and moulding are all (relatively) new, advanced processes that need machines, computers and mechanism technology. However, these technologies all demand subtracting material from a bigger block whether or not to realize the top product itself or to provide a tool for casting or moulding processes and this is often a heavy limitation at intervals the manufacturing process.

In recent years, 3D printing has gone on the far side being an industrial prototyping and manufacturing method because the technology has become additional accessible to little corporations and even people. Once the domain of big, international companies because of the dimensions and political economy of owning a 3D printer, smaller (less capable) 3D printers will currently be no inheritable for underneath $1000.The most widely 3D printer configuration is the cartesian, meaning that the printing movements happen on the X, Y and Z orthogonal axes. Core XY is one emerging configuration for cartesian printers that presents the extruder nozzle moves on the X and Y axes and the construction bed moves on the Z axis.

2 LITERATURE REVIEW

1) **Pradeep R. Sledge, "This paper describes the design of a 3D printer by reducing its cost to the optimum level". Students, Department of Mechanical Engineering, D.I.E.T., Satara, MS, India**

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.

2) **Reece Arnett, "The RepRap Project Open Source meets 3D printing", Dunedin, New Zealand, 2008.**

This presentation discusses the reasons why 3d printing can be used for, such as printing toys, prototypes, fix broken parts of technology, and build original devices that could be used for various things. Self- replication is very important as it allows cost to go down to make these printers, to fix present machines and create new types of printers. It highlights why open source is important and how building a Reprap can be made easier. He continues to discuss the past, present and future of Reprap. He discusses how making Repraps has become easier with electronics being made by maker bot and other kits that have been put together. The future is to expose the masses to this technology. They have already started creating scaffolding to print things that is more then 45 angles.

3)**Betina Madeira Schmitta, A Comparative Study of Cartesian and Delta 3D Printers on Producing PLA Parts, University of Florida, Brazil, 2017[3]**

The additive manufacturing processes emerged at the end of the last century and became popular by low-cost 3D printers. The most used printers work on a cartesian configuration, but recently were launched delta machines. These 3D printers use a more complex control system due to their trajectories generation but may present some advantages over the cartesian configuration. To increase the knowledge about additive manufacturing, a comparative study with cartesian and delta printers was performed to evaluate the performance on printing a testing part. Three samples were produced in each printer and compared based on surface quality, manufacturing time, mass and dimensional measurement. The printed objects were 3D scanned for comparing the digitized geometry by aligning the point cloud generated to its virtual 3D model. The parts produced in delta printer obtained better surface quality, while cartesian printer provided better dimension to produce the parts were not significant.

4) **P. Girish, B. Sai Sharan, L.B. Bharath Raju, "Design and Manufacturing of a Delta 3D Printer" (IJMETMR, Volume 4, Issue 4 April-2017)**

3D printing, also known as additive manufacturing (AM), refers to various processes used to synthesize a three-dimensional object. In 3D printing, successive layers of material are formed under computer control to create an object. These objects can be of almost any shape or geometry and are produced from a 3D model or other electronic data source. A 3D printer is a type of industrial robot. Rapid prototyping is a technique used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD/INVENTORY) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology 3D printers capable of outputting in color and multiple materials already exist and will continue to improve to a point where functional products will be able to be output. With effects on energy use, waste reduction, customization, product availability, medicine, art, construction and sciences, 3D printing will change the manufacturing world.

3 Process and technologies:

Not all 3D printers use the same technology. There are several ways to print and all those available are additive, differing mainly in the way layers are built to create the final object.

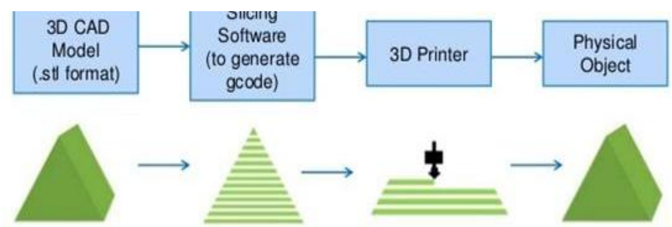

Fig 1: Process flow

Some methods use melting or softening material to produce the layers. Selective laser sintering (SLS) and fused deposition modeling (FDM) are the most common technologies using this way of printing. Another method of printing is when we talk about curing a photo-reactive resin with a UV laser or another similar power source one layer at a time. The most common technology using this method is called stereo lithography (SLA).

To be more precise: since 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing", developed a set of standards that classify the Additive Manufacturing processes into 7 categories according to Standard Terminology for Additive Manufacturing Technologies.

Below you'll find a short explanation of all of seven processes for 3d printing:

Vat Photopolymerization

A 3D printer based on the Vat Photopolymerization method has a container filled with photopolymer resin which is then hardened with UV light source [6].

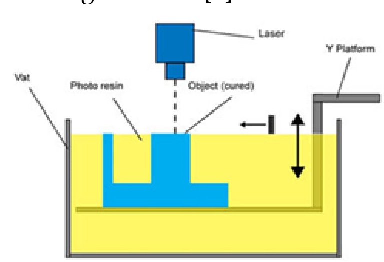

Fig 2: Stereolithography technoque

After the pattern has been traced, the SLA" s elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm (0.002″ to 0.006″). Then, a resin-filled blade sweep across the cross section of the part, re-coating it with fresh material. On this new liquid surface, the subsequent layer pattern is traced, joining the previous layer. The complete three dimensional object is formed by this project. Stereolithography requires the use of supporting structures which serve to attach the part to the elevator platform and to hold the object because it floats in the basin filled with liquid resin. These are removed manually after the object is finished.

Material Extrusion
The most commonly used technology in this process is fused deposition modeling (FDM)

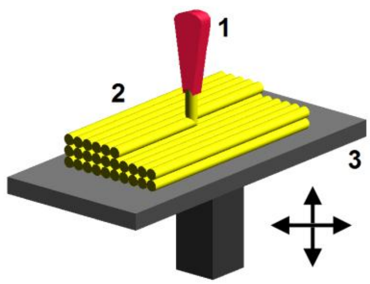

Fig 3: Fused deposition modeling

Fused deposition modeling (FDM), a method of rapid prototyping: 1 – nozzle ejecting molten material (plastic), 2 – deposited material (modeled part), 3 – controlled movable table. Image source: Wikipedia, made by user Zurek's under CC Attribution-Share Alike 4.0 International license.

The FDM technology works using a plastic filament or metal wire which is unwound from a coil and supplying material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer-aided manufacturing (CAM) software package.

Applications of 3D Printing
Applications include rapid prototyping, architectural scale models & moquette's, healthcare (Delta 3d printed prosthetics and printing with human tissue) and entertainment (e.g. film props).

3D printing industry
The worldwide 3D printing industry is expected to grow from $3.07B in revenue in 2013 to $12.8B by 2018, and exceed $21B in worldwide revenue by 2020.
As it evolves, 3D printing technology is destined to transform almost every major industry and change the way we live, work, and play in the future.

Medical industry
The outlook for medical use of 3D printing is evolving at an extremely rapid pace as specialists are beginning to utilize 3D printing in more advanced ways. Patients around the world are experiencing improved quality of care through 3D printed implants and prosthetics never before seen.

Bio-printing
As of the early two-thousands 3D printing technology has been studied by biotech firms and academia for possible use in tissue engineering applications where organs and body parts are built using inkjet techniques.

Aerospace & aviation industries
The growth in utilization of 3D printing in the aerospace and aviation industries can, for a large part, be derived from the developments in the metal additive manufacturing sector.

NASA for instance prints combustion chamber liners using selective laser melting and as of march 2015 the FAA cleared GE Aviation's first 3D printed jet engine part to fly; a LASER sintered housing for a compressor inlet temperature sensor.

Automotive industry
Although the automotive industry was among the earliest adopters of 3D printing it has for decades relegated 3d printing technology to low volume prototyping applications.

The expectations are that 3D printing in the automotive industry will generate a combined $1.1 billion dollars by 2019
.

Industrial printing
In the last couple of years, the term 3D printing has become more known and the technology has reached a broader public. Still, most people haven't even heard of the term while the technology has been in use for decades. Especially manufacturers have long used these printers in their design process to create prototypes for traditional manufacturing and research purposes. Using 3D printers for these purposes is called rapid prototyping.

Personal printing
Personal 3D printing or domestic 3D printing is mainly for hobbyists and enthusiasts and really started growing in 2011. Because of rapid development within this new market printers are getting cheaper and cheaper, with prices typically in the range of $250 – $2,500. This put 3D printers into more and more hands.

4 WORKING COMPONENTS OF DELTA 3D PRINTER:

EXTRUSION
Extrusion in 3-D printing using material extrusion involves a cold end and a hot end. The cold end is part of an extruder system that pulls and feed the material from the spool, and pushes it towards the hot end. The cold end is mostly gear- or roller-based supplying torque to the material and controlling the feed rate by means of stepper motor. Thus, controlling the process rate in result, The hot end is the active part which also hosts the liquefier of the 3D printer that melts the filament. It allows the molten plastic to exit from the small nozzle to form a thin and tacky bead of plastic that will adhere to the material

it is laid on. Hot end consists of heating chamber and nozzle. The hole in the tip (nozzle) has a diameter of between 0.3 mm and 1.0 mm. Different types of nozzles and heating methods are used depending upon the material to be printed.

PROCESS OF EXTRUSION

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 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.

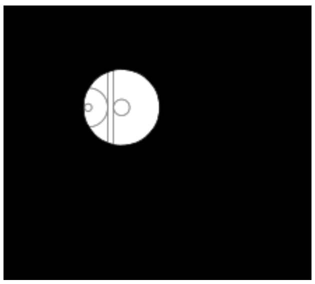

Fig 4: Extruder

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 roads which solidify 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.

HOT ENDS

You want to make sure the voltage of the heating cartridge matches other systems on your printer; most are 12V, but 24V is common too. There is no real advantage of one voltage over the other; it just depends on the components you use.

Filament size is dictated by what you want to print. 1.75mm is the most common these days, but many people still prefer to use 3mm. Make sure your hot end matches the filament you intend to use, a 3mm hot end will not work with 1.75mm filament.The most common size nozzle is .4 mm, which is a good medium between the speed of .5 mm nozzles and the detail of .35 mm nozzles. Larger and smaller nozzles exist, however most people stay within the practical .35 to .5 mm range.

EXTRUDER

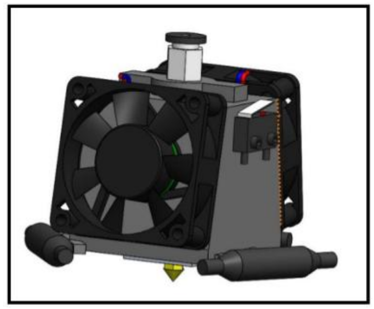

Fig 5: Extruder assembly

The E3D V6 is the latest version of the popular E3D all-metal hot end. The all-metal claim is a bit false, though, as the E3D does come with a PTFE tube that is inserted into the hot end for thinner (1.75mm) filaments. When the PTFE tube is not used, the E3D can reach 300C with ease, and print with just about any filament on the market, just like the Hexagon. The
PTFE Liner never enters the really hot section of theE3D nozzle, so a meltdown is not a concern if used properly.

Pros

- High temperature allows for printing of any material
- All-metal design
- Easy to change nozzles

Cons

- PTFE liner tube improves smaller filament performance but limits max temperature
- Needs active cooling fan to prevent melting extruder body and printer jams.

Typically paired with Any J-head compatible extruder body

Stepper Motor:

A stepper motor is one kind of electric motor used in the robotics industry. Stepper motors move a known interval for each pulse of power. These pulses of power are provided by a stepper motor driver and are referred to as a step. As each step moves the motor a known distance it makes them handy devices for repeatable positioning.

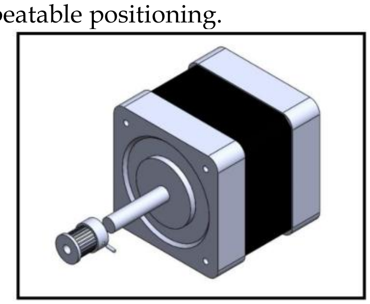

Fig 6: Stepper Motor

Properties:

Step angle

Stepper motors have a step angle. A full 360° circle divided by the step angle gives the number of steps per revolution. For example, 1.8° per full step is a common step size rating, equivalent to200 steps per revolution. Most stepper motors used for a Mendel have a step angle of 1.8 degrees. It is sometimes possible to use motors with larger step angles, however for printing to be accurate, they will need to be geared down to reduce the angle moved per step, which may lead to a slower maximum speed.

Micro stepping

A stepper motor always has a fixed number of steps. Micro stepping is a way of increasing the number of steps by sending a sine/cosine waveform to the coils inside the stepper motor. In most cases, micro stepping allows stepper motors to run smoother and more accurately.

If your motors are near to mechanical limitations and you have high friction or dynamics, micro steps don't give you much more accuracy over half-stepping. When your motors are 'overpowered' and/or you don't have much friction, then micro stepping can give you much higher accuracy over half-stepping. You can transfer the higher positioning accuracy to moving accuracy too.

Bipolar:

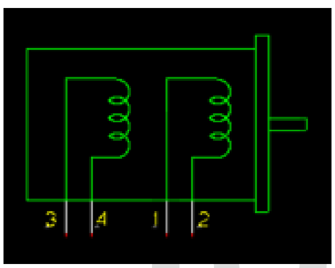

Fig 7: Bipolar

Bipolar refers to the internals of the motor, and each type has a different stepper driver circuit board to control them. In theory a RepRap could use a unipolar motor, but in practice most are bipolar. They are also the type of motors we are using in the RepRap Project's Mendel and Darwin designs.

Bipolar motors are the strongest type of stepper motor. You identify them by counting the leads - there should be four or eight. They have two coils inside, and stepping the motor round is achieved by energizing the coils and changing the direction of the current within those coils.

Holding torque

The Mendel officially requires approximately 13.7 N·cm torque (19.4 ozf·in) of holding torque (or more) for each of the X, Y and Z axis motors to avoid issues, although one stepper with less has been used successfully (see below). Recent designs for extruders (Extruder Controller) almost exclusively require stepper motors as well, but no torque requirements have been given in those designs. If in doubt, higher is better.

Size

The physical size of stepper motors are usually described via a US-based NEMA standard, which describes the bolt-up pattern and shaft diameter. In addition to the NEMA size rating, stepper motors are also rated by the depth of the motor in mm. typically, the power of a motor is proportional to the physical size of the motor.

NEMA:

Referring to the frame size of the motor as standardized by the US National Electrical Manufacturers Association in its Publication of ICS 16-2001, it specifies the 'face' size of the motor but not its length. For example a NEMA 23 stepper has a face of 2.3 x 2.3 inches with screw holes to match. Note: just because a motor is bigger does not mean it is more powerful in terms of torque. It is perfectly possible for a NEMA 14 to 'out pull' a NEMA 17 or a NEMA 23. Based upon the NEMA 17 specification (from what I can find) the mounting holes are spaced 31 mm (1.22 inch) apart along the edge of the motor. This should help if you are using second-hand/salvaged parts [7].

Shaft

Any part that goes on a stepper motor shaft expects the shaft to be roughly Ø 5 mm. If the shaft is a different size, you will need to make allowances for this in the (plastic) parts you obtain/make.

Wiring

Steppers motors come in several wiring configurations. It is fairly common to find 4, 6 and 8 wires, and these works fine with the standard RepRap electronics.

Stepper motors with 5 wires exist but won't work with the standard RepRap electronics, because the 5th wire connects to both coil centres. See stepper wiring for more details.

Heat

Most of the motors specs give the current for two coils that will give an 80 °C rise, i.e. they can run at 100 °C! When using them on plastic brackets you need to under-run them to keep the brackets from melting. With PLA's glass transition temperature between 60-65 °C, you have to seriously under-run them! Fortunately temperature rise is proportional to power, which is in turn proportional to the square of current (P=I2R), but torque is directly proportional so you can keep temperature under control without losing too much torque. For example, running a stepper at 70% of the rated current would result 70% of the torque and 49% (0.72=0.49) of the power dissipation and thermal rise.

Power and current

All recent stepper controllers use a current-limiting design. Because of this, the resistance (ohms, Ω) of the coils doesn't matter, as long as it is low enough for the current to rise fast enough for the current-limiting design to come into play. If the resistance is too high (i.e. 24 V steppers) the current simply doesn't raise enough. For this reason, stepper motors rated for 3-5 V and 1-1.5 A are generally recommended, as these motors will perform near their peak torque with a current-limiting stepper controller (such as a Palolo A4988).

Designs which use a separate "extruder controller board" sometimes use H-bridges (which are designed for running a DC motor) instead of a proper current limiting stepper controller. On these boards, you need to be careful not to turn the current (PWM) too high, especially with low-ohm (low voltage) motors. You run the risk of overheating both the stepper motor and the H-bridge chip.

POWER SUPPLY:

12v DC 30 amp power supply
POWER-230W/110W

- 200x200mm PCB bed heater (12V/10A/1.2 ohms) = 120W
- Hot end heater = 12V 40W
- 5 stepper motors, each run at up to 1.2A @ 4V peak per phase = 5 * 4 * 1.2 = 24W, times 2 to allow (conservatively) for driver losses and back emf during movement = 48W
- Electronics, about 100mA @ 12V (assuming a linear regulator) = 1.2W
- LCD display, servos etc. say 5W
- Two 12V fans @ 150mA = 3.6W

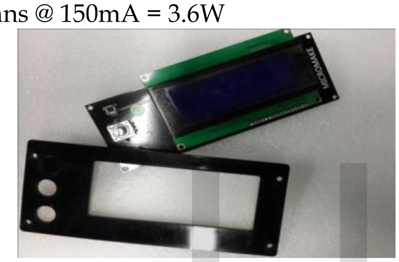

Fig 8: LCD Display

MOTHER BOARD

MICROMAKE DIY is a feature rich all-in-one electronics solution for Riprap and other CNC devices. It features an onboard ATmega2560. Its five motor outputs are powered by compatible stepper drivers.

The board features a developer friendly expansion port supporting giving access the same as Ramps1.4. MICROMAKE DIY is designed to be flexible in the user's power source availability, allowing any power supply from 12V-24V.

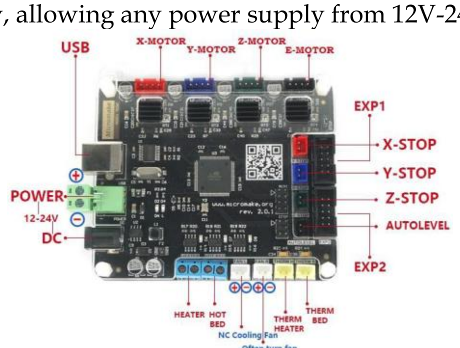

Fig 9: Mother Board

X,Y,Z DRIVING AXIS

Basic Mechanics

Most desktop 3D printers are designed around Cartesian geometry, just like their milling machine kin. In fact, a CNC mill can be fitted with a "hot end" and extruder to create a 3D printer. This is still a popular design and construction. The framework, shown in the drawing below, supports the X, Y, Z positional mechanics and provides sufficient rigidity for the task of laying down melted plastic filament.

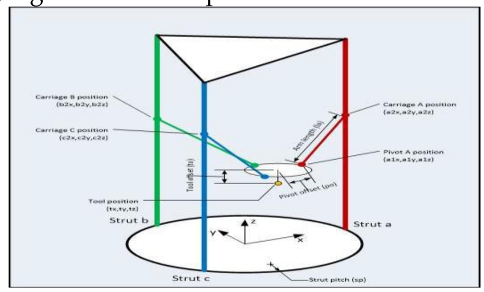

Fig 10: Line diagram of delta frame

These mechanics will be familiar to CNC mill or router operators. Because there is very little mass to move, small NEMA 17 stepper motors and simple timing belts provide the motion control for the X,Y and Z axes. Desktop inkjet printers also use small steppers and timing belts to achieve their remarkable positional accuracy and these work quite well for 3D printers too. Close scrutiny of the drawing above reveals that the Z axis is different – it uses screws to move along Z. Typically a low cost 1/4-20 threaded rod is used for this application. This results in much lower feed rates in Z as compared to X and Y but this is not normally an issue since movement along Z is incremental and one layer at a time from Z=0 (at the print table surface) to +Z as it moves up.
.

switches. The reasons to use mechanical switches as end stoppers
are as follows

- Switches are the cheapest endstop in most cases.
- Simple switches can be used on x y and z axis.
- You could even make your own contact switch from a few pieces of metal.

5 CAD DESIGN:

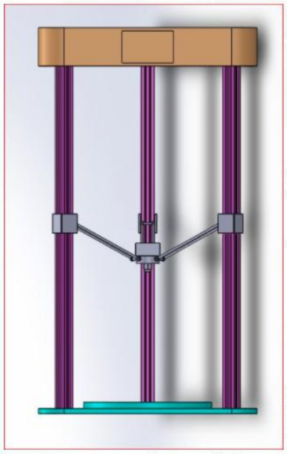

Fig 11: Side view of model

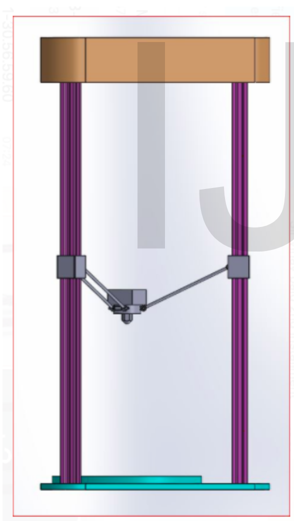

Fig 12: Manuvering of Arms

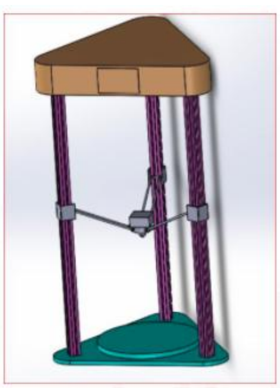

Fig 13: 3D view of model

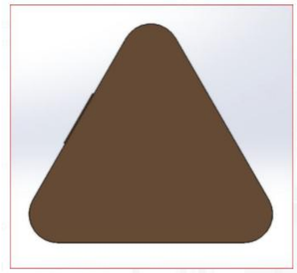

Fig 14: Triangular over head

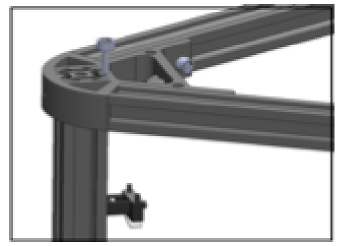

Fig 15: End stoppers

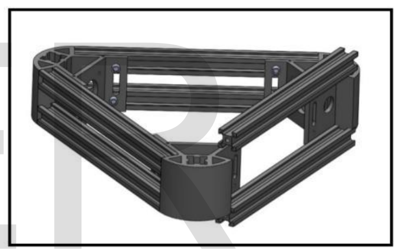

Fig 16: Plate

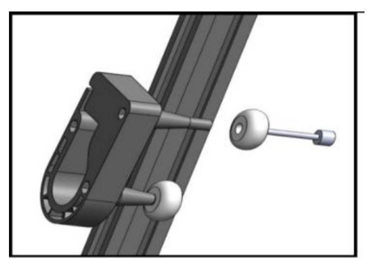

Fig 17: Bearings

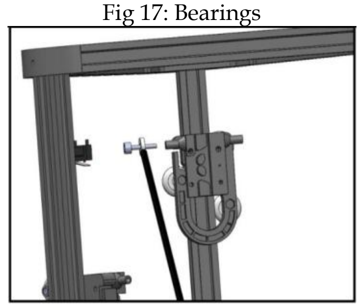

Fig 18: Arms

Fig 19: Semi Assembled Delta 3D-printer

COST ANALYSIS
Cost of electronic components
= 10,400 INR
Motherboard –3000
LCD Display –800
Stepper motors -2000
Base – 1700
Hot end – 1000
Extruder – 500
End stoppers – 300
Power supply - 1000
Cost of Mechanical components =
4,900 INR
Sheet metal (250*19kg" s)-
Bearings – 900
MS shaft plain & threaded-1000
Cost of filament (Qty-1kg" s)
= 2,000 INR
Miscellaneous cost
= 3,176 INR
Belt dives – 400
Workshop costs – 1876
Stationary cost – 400
Tools and screws - 500
Total cost = 20,,476 INR
*DELTA 3D printer of same specifications averagely
costs 85,000 INR

6 CONCLUSION

It is generally believed that 3D printing will be a revolutionary force in manufacturing and prototyping, whether positive or negative. Many Multinational companies have already been using the technology to produce intricate components in various fields.

As3D printers become more affordable, they will inevitably be used for local, small scale manufacturing largely eliminating supply chain for many types of product. There will be major challenges for the conventional manufacturing industry to adapt to these changes in technology.

The outlook for medical use of 3D printing is evolving at an extremely rapid pace as specialists are beginning to utilize 3D printing in more advanced ways. 3D printing of liver or kidney tissues is better than transplantation of organs. This could be a breakthrough in medical history.

3D printers capable of outputting in colour and multiple materials already exist and will continue to improve to a point where functional products will be able to be output. With effects on energy use, waste reduction, customization, product availability, medicine, art, construction and sciences, 3D printing will change the manufacturing world.

In this delta type 3D printer we can print the object without using the hot bed. Which is main difference with the existing delta 3D printer as well as cost also low and the filaments used are PLA (WOOD,GLASS, etc.)

REFERENCES

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