Design and Development of 3D Delta Printer for Ceramic Materials in PED

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Abstract: At present, 3D printing is considered as a new phenomenon of the 21st century. 3D printing is an additive manufacturing technology which can create a physical model by placing the layers of material one above the other It is a fast and efficient technology that is slowly going to replace the conventional manufacturing technologies The current trend is the continuous development of 3D printing technology in the form of different raw materials for the betterment of the technology. Designing and development of new parts specially designed 3D printers and devices that lead to progress in modeling in several areas of industry and home appliance.

Our aim in this project is to manufacture the ceramic 3D printer for the prototype model which will be quite easy to replace the some plastic 3D printed parts in the current condition. It will be eco-friendly material for the environment while making this 3D printer we are also checking the all parameters such as low cost manufacturing, simple and stable design & program coding of algorithms. We will be using CATIA V5 software for the CAD modeling.

Keywords: 3D Printing, Ceramic, prototype, Marlin Firmware, CAD,

1. Introduction

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 is an additive manufacturing process. And this is indeed the key because 3D printing is a radically different manufacturing method based on advanced technology that builds up parts, additively, in layers at the sub mm scale. This is fundamentally different from any other existing traditional manufacturing techniques. There are a number of limitations to traditional manufacturing, which has widely been based on human labour and made by hand ideology rooting back to the etymological origins of the French word for manufacturing itself. However, the world of manufacturing has changed, and automated processes such as machining, casting, forming and moulding are all (relatively) new, complex processes that require machines, computers and robot technology. However, these technologies all demand subtracting material from a larger block whether to achieve the end product itself or to produce a tool for casting or moulding processes and this is a serious limitation within the overall manufacturing process.

In recent years, 3D printing has gone beyond being an industrial prototyping and manufacturing process as the technology has become more accessible to small companies and even individuals. Once the domain of huge, multi-national corporations due to the scale and economics of owning a 3D printer, smaller (less capable) 3D printers can now be acquired for under $1000.

This has opened up the technology to a much wider audience, and as the exponential adoption rate continues apace on all fronts, more and more systems, materials, applications, services and ancillaries are emerging.

2. Problem Statement

Now a day's 3D printers are making their way to the educational institutions, prototyping, production & manufacturing industry areas, medical institutions and even at homes. There are many 3D printers in the market, but they are based on plastic filament process. Here the company wants to introduce another raw material so as to create more awareness about 3D printing technology. So the new chosen raw material is Ceramic. The project will ensure a user friendly 3D printer that will produce ceramic prototypes, sculptures and a like objects along with these ensuring critical parameters such as strength of 3D printed objects, programming for 3D printer and cost are the basic challenges.

3. Types of 3D Printing Process

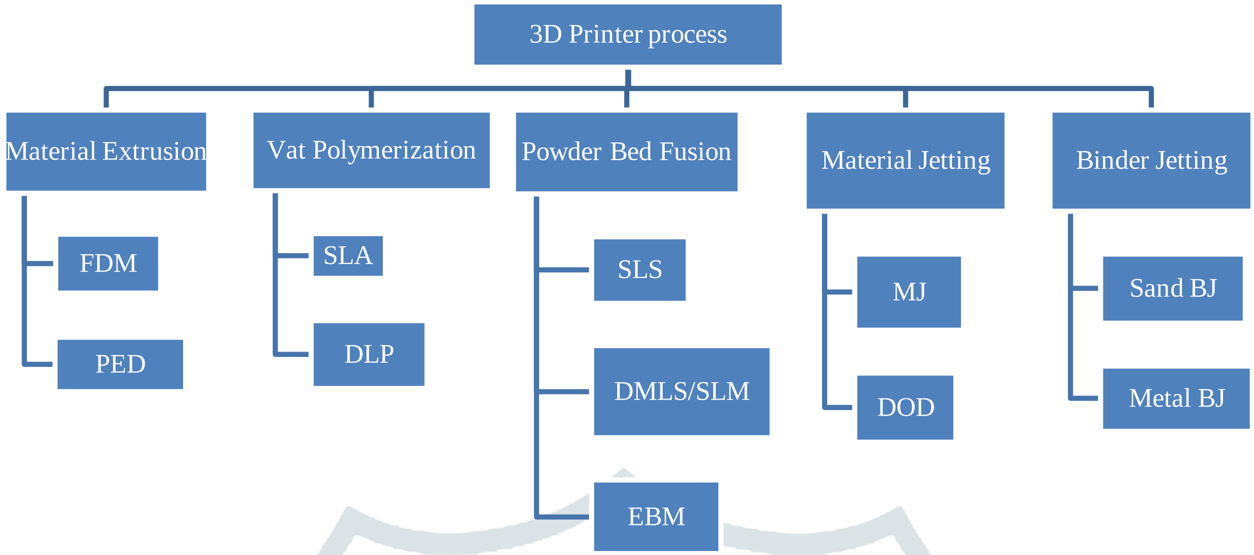

Fig.1 Tree diagram of 3D Printing Process.

- Fused deposition Modeling (FDM)
- Paste Extrusion Deposition (PED)
- Stereolithography (SLA)
- Digital Light Processing (DLP)
- Selective Laser Sintering (SLS)
- Direct Metal Laser Sintering (DMLS)
- Selective Laser Melting (SLM)
- Electronic Beam Melting (EBM)
- Material Jetting (MJ)
- Drop on Demand (DOD)
- Binder Jetting (BJ)

4. Design & material selection in Delta Printer for PED

Fused Deposition of Ceramics (FDC) is a rapid prototyping technique which is a modification of an older technique known as Fused Deposition Modeling (FDM). FDM has become the most common AM technique for use in commercial off-the-shelf instruments, largely due to its simple operation principle and its low start up and operating costs. FDC is simply FDM which uses a filament containing a moderate concentration of ceramic particles (20 - 45 vol%). Once the printing is complete, the polymer is burnt out and sintering can proceed. With careful control of the printing conditions and post processing steps, near full density has been achieved for ceramics. The main drawbacks of FDC are the need for support structures for many spanning, overhanging and all floating features, the poor part resolution and the large volume of polymer in the green part which can require extremely slow burn-out schedules and limited densification.

a) Base Table

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 200Ø x150 mm. So the diameter of the table is taken as 200mm. The material used for the table is aluminum since it is corrosion resistant and light in weight.

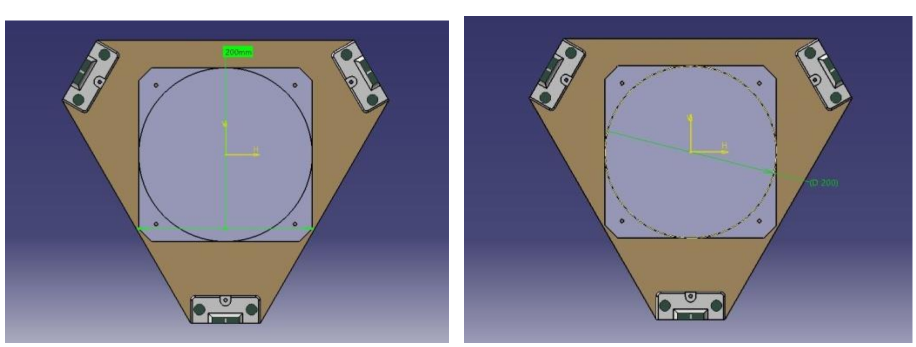

Fig.2 base table dimensions from top view.

b) Frame Plates

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, and each pillar contain 2 Chrome rod of 12mm diameter so we have decided the shape of the frame plate to be triangular. Each side of the triangle is taken to be 296mm, and the corners are filleted with a radius of 5mm**.** The material used for making these plates is acrylic/wood instead of steel as steel is costlier than acrylic/wood. As our main objective to reduce the cost so we have used this acrylic/wood.

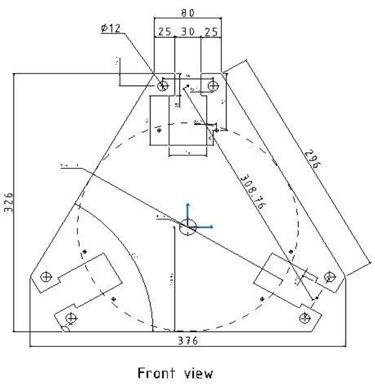

Fig.3 detailing of frame plate

c) Arm Length

The center distance between two Chrome rods is come to be 308.76mm. And the length of the arm is taken as 80% of this distance.

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

L= 308.76x (80/100)

L= 247 ≈ 245mm

d) Chrome rod

Total length of the solid rod is given by-

L=W+B+N+C++P+E+W

W= wood thickness
B= thickness of bed
N= nozzle setup
C= carbon rod height
G= gap between carbon rod end and end stop surface
P= part height
E= end stop setup

L=18+20+100+170+44+150+18+18

=538mm

Since we have decided the maximum size of the object to print is 150mm, 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 150mm. The material used for the pillar rod is steel to reduce the cost of the frame. With the 12mm diameter of the rod

e) 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= (16 x 2) =32mm

PD= 538mm
BCD= 15mm

Excess belt used for clamping= 100mm

$$\text{Length of belt (L)} = [PC + (PD \times 2) - BCD]$$
$$= [38 + ((538 \times 2) + 100) - 15]$$
$$= 1199mm \sim 1200mm$$

The material used for the belt (GT2) is nylon composite since it has higher strength and timing belt is used for the precise motion of the extruder.

f) Motor Selection

m= total mass (Kg)
a= acceleration (m/s2)
d=diameter of geared toothed pulley (cm)
T=torque (N-cm)
Acceleration is taken as 10000 mm/s2 or 10m/s2 as per the marlin file configuration. Diameter of the pulley is measured from the top of the tooth and comes to be 15 mm.

$$\text{Total mass on the motor pulley} = \text{mass of extruder} + \text{mass of carbon rods}$$
$$m = 1.2 + 0.5$$
$$m = 1.7Kg$$
$$\text{Force acting on pulley} = m \times a$$
$$= 1.7 \times 10$$
$$= 17\ N$$
$$\text{Torque required} = F \times d/2$$
$$= 17 \times 1.5/2$$
$$= 12.75N\text{-}cm$$

Most of the NEMA 17 motors used, have 53.93Ncm (5.5Kgcm) or more, so around 4x as much as calculated. So we have selected the NEMA 17 with holding torque 53.93Ncm along with 1.8° step angle.

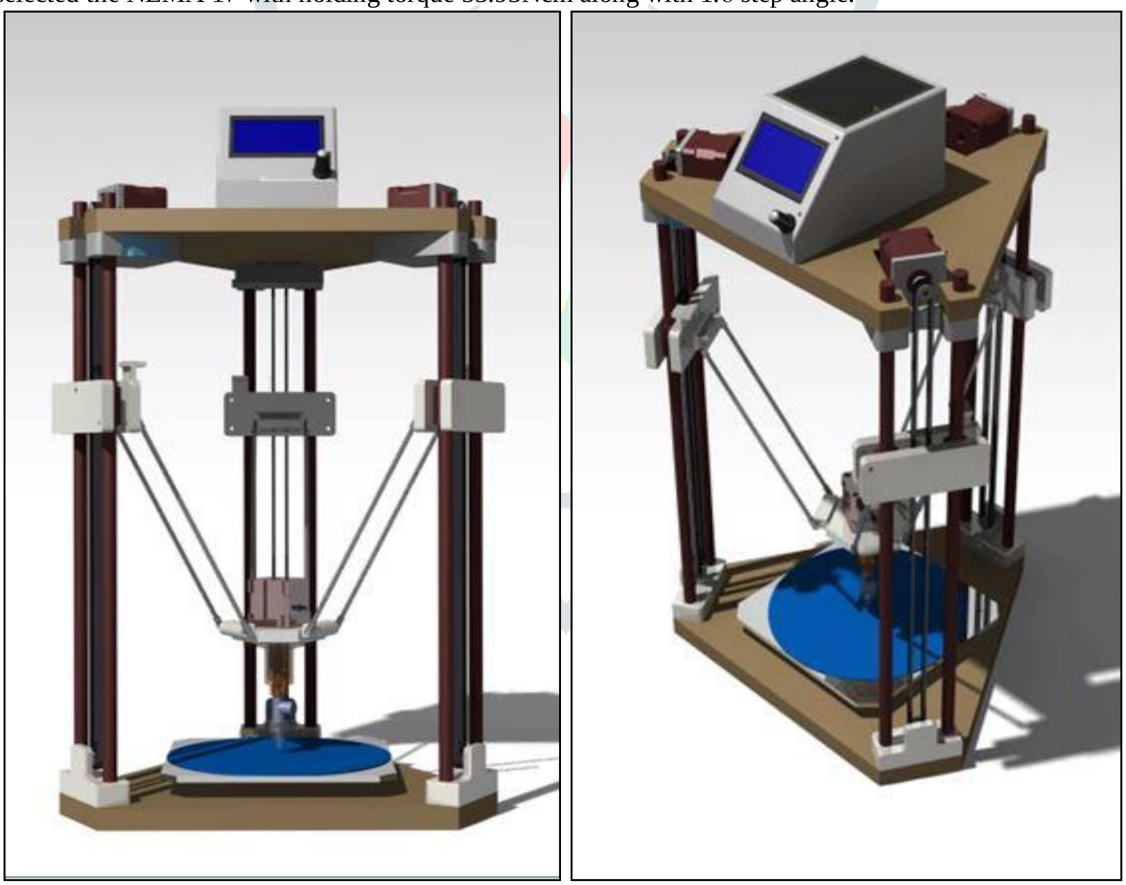

Fig.3 Delta 3D Printer views

Below table shows the bill of material and cost required for the 3D ceramic Printer

Bill of Material			
Sr. No.	Name	QTY	Price (Rupees)
1	NEMA 17 motor	4	1150 X 4 =4600
2	Chrome rod	6	390 (per meter) = 1287
3	Ball slider	6	95 X 6 = 570
4	Screw bar	6	200
5	Pulley with thread	6	200
6	Mechanical endstop	3	86 X 3 = 258
7	GT2 belt	3	348
8	Switched-Mode Power Supply Board	1	1300
9	Adjustable studs	4	60 X 4 = 240
10	Screw bar joint	12	92
11	LCD Screen (Arduino base)	1	3699
12	Mega 2560 microcontroller (Arduino base)	1	
13	Wire cable of endstop (3 pin)	3	With endstops
14	Wire cable of motor (4 pin)	4	With motors
15	8mm flexible plastic pipe	1	89
16	T Joint	1	47
17	Motor support (3D Printed)	3	390 X 3 =155
18	Pulley support (3D Printed)	3	290 X 3 =870
19	Ball slider support (3D Printed)	3	355 X 3 =1065
20	Push Joint Female	1	48
21	Nozzle motor support (3D Printed)	1	280
22	Flexible shaft coupling	1	105
23	Drive screw of nozzle	1	40
24	Nozzle screw support (3D Printed)	1	30
25	Nozzle (3D Printed)	1	10
26	M3 nut & bolt	30	150
27	M4 nut & bolt	30	200
28	Material storage tank	1	700
29	Mounting of tank (3D Printed)	2	250
30	Push Joint Male	1	48
31	Casing part (3D Printed)	1	1000
32	Wood base	2	100
33	Ceramic materials	1	200
Total			Rs.18181 /-

Table No.1 Bill of Material

5. Controlling

Marlin Firmware runs on the 3D printer’s main board, managing all the real-time activities of the machine. It coordinates the heaters, steppers, sensors, lights, LCD display, buttons, and everything else involved in the 3D printing process. The control-language for Marlin is a derivative of G-code. G-code commands tell a machine to do simple things like “set heater 1 to 180°,” or “move to XY at speed F.” To print a model with Marlin, it must be converted to G-code using a program called a “slicer.” Since every printer is different, you won’t find G-code files for download; you’ll need to slice them yourself. As Marlin receives movement commands it adds them to a movement queue to be executed in the order received. The “stepper interrupt” processes the queue, converting linear movements into precisely-timed electronic pulses to the stepper motors. Even at modest speeds Marlin needs to generate thousands of stepper pulses every second. Heaters and sensors are managed in a second interrupt that executes at much slower speed, while the main loop handles command processing, updating the display, and controller events. For safety reasons, Marlin will actually reboot if the CPU gets too overloaded to read the sensors. Marlin can be controlled entirely from a host or in standalone mode from an SD Card. Even without an LCD controller, a standalone SD print can still be initiated from a host, so your computer can be untethered from the printer.

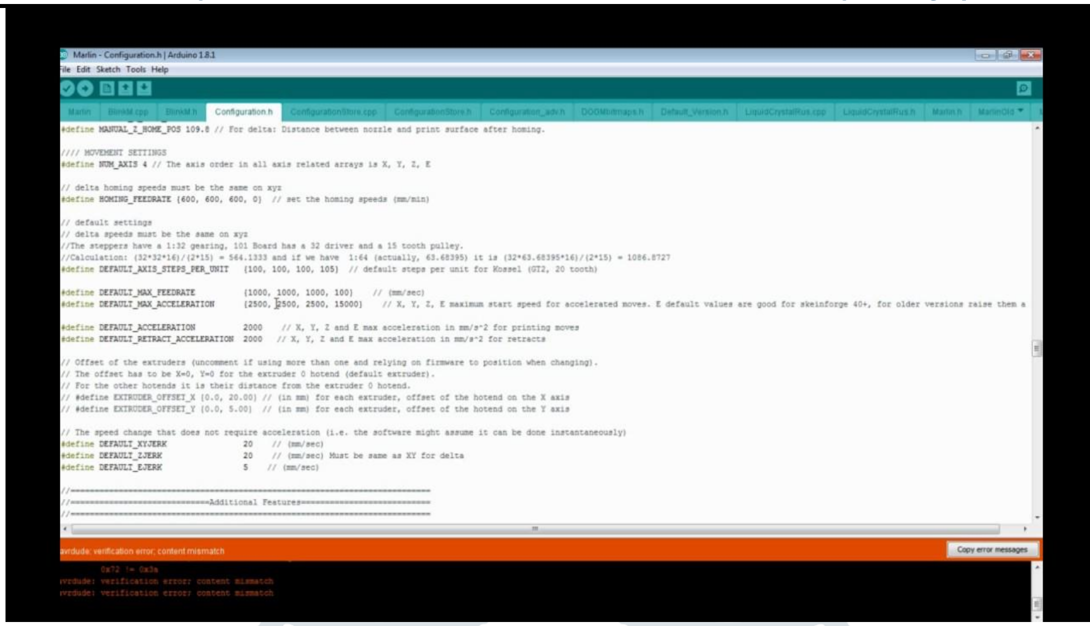

Fig.4 Marlin configurations

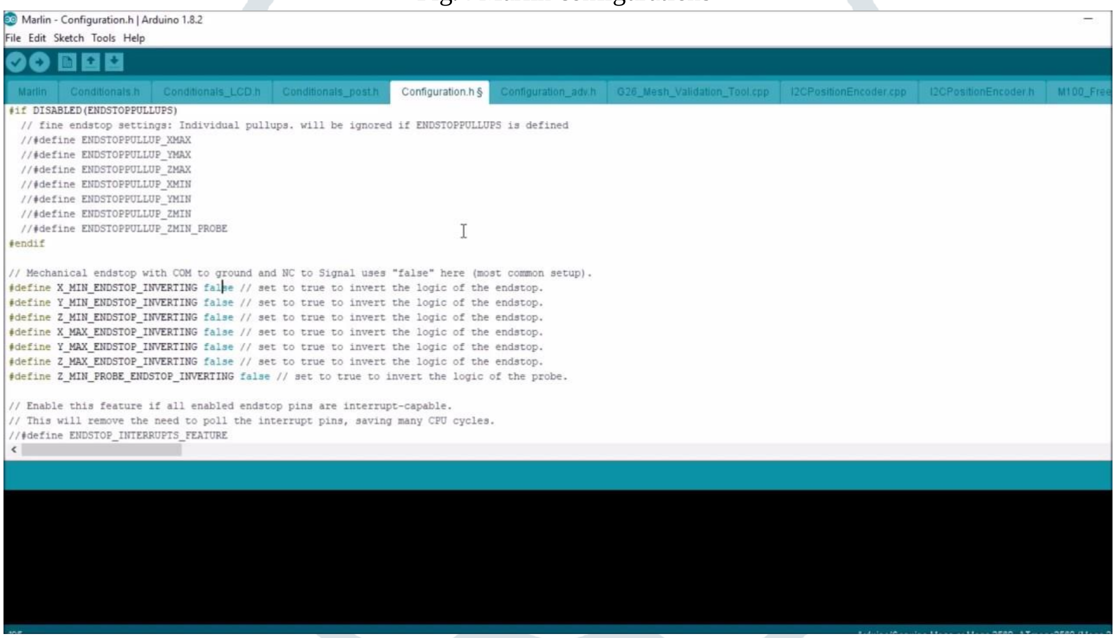

Fig.5 Marlin endstop configuration

While Marlin only prints G-code, most slicers only slice STL files.
Whatever you use for your CAD toolchain, as long you can export a solid model, a slicer can "slice" it into G-code, and Marlin firmware will do its best to print the final result.
Before Marlin can dream of printing, first you'll need a 3D model. You can either download models or make your own with one of many free CAD programs, such as FreeCAD, OpenSCAD, Tinkercad, Autodesk Fusion 360, SketchUp, etc.

6. CONCLUSION

The aim of this paper is to reduce the overall cost of the ceramic Delta 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 Delta 3D printer and ceramic material that reduce the overall cost of the additive manufacturing machine and eco-friendly material for the nature, replacing the plastic parts with the ceramic clay materials in the many application product part.

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