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Design and Fabrication of Delta 3D Printer and its Experimentation

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Abstract – 3d printing is a process of developing a three-dimensional solid object from a software design. 3d Printing is an additive manufacturing process which is growing rapidly now days as it has the potential to alter the manufacturing industry. Any type of complex part can be developed using a 3d printer which makes this technology more superior and accurate than traditional machines. This research mainly highlights design and fabrication of a low-cost delta 3d printer, besides this the testing result of standard samples printed using 3d printer are also shown graphically so in order to get optimum operational parameters which are desirable for good quality and better surface finish of printed parts. At last, a comparison is also provided graphically between the fabricated delta printer and a readily available printer.

***Key Words*: FDM, 3D printing, Fabrication, PLA**

1. INTRODUCTION

After the first three industrial revolutions, the 21st century started the next industrial revolution. Industry 4.0 introduces, what has been called the 'smart manufacturing' process. The essential components or framework of Industry 4.0 comprise: Big data, Model Simulation, Cloud Technology, Augmented Reality, 3D Printers / Additive Manufacturing, Industrial Internet of Things (IIoT), Artificial Intelligence, Autonomous Robots and Cyber security. 3D printers are a vital part of Industry 4.0. Various 3D printing technologies are employed all over the world and for different purposes and fields such as Industry, Automotive, Healthcare, Environment, etc.

3D printing is also called additive manufacturing and it is a process of making three dimensional objects from a CAD file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created.

Fused deposition modeling (FDM) also known as fused filament fabrication (FFF) is a 3D printing process that uses a continuous filament of a thermoplastic material. Filament is fed from a large spool to a hot end through extruder mechanism, and the melted material gets deposited on a bed to form a product. Overall, FDM is the most common process used in 3d printers in different sectors.

2. LITERATURE STUDY

1)Design and fabrication of delta type 3d printer, school of Mechanical engineering, REVA university, Bengaluru.

3d printers are available in various configurations, but Cartesian and delta configurations are most commonly used one in industries. This paper also discusses the design and fabrication of a delta FDM printer. 3d printer has wide application in the field of aerospace, biomedical, automotive and many others. In order to make a product one has to first make a 3d model of the object in modeling software and then the 3d model is passed to the slicing software after converting into STL extension so that the tool path can be generated and the product can be printed. Post processing is also done on printed parts to get better appearance and surface finishing. A 3d printer is made of a variety of parts, this paper has briefly explained the functions of all the main parts which are essential for building a 3d printer, and besides this the processes that the parts will undergo are also mentioned in it. At last, the designing section shows the various views of the proposed delta 3d printer along with a bill of material.

2) Investigation of delta robot 3d printer for a good quality of printing, Dept. of industrial design, Ming Chi University of technology, New Taipei city

3d printing is one of the most versatile and revolutionary techniques to create 3d objects with unique structure and diverse properties. The growth of open source 3d printers has increased by a great amount. Kossel Mini, Rostock and Prusa i3 are the most commonly used open-source printers. A delta printer can easily be created at low cost. However, the quality of the printed parts is dependent on a series of calibrations. The calibrations include defining the dimensions of frame, configuring firmware and setting the building parameters. So, this paper summarized how an open source 3d printer can be calibrated so that it can function appropriately and as per the requirement. By proper calibration the printing quality, surface finishing and accuracy can be increased greatly and the chances of failure can be reduced to the minimum amount.

3) Design and development of a Delta 3d printer using salvaged E-waste materials, Dept. of mechanical engineering, university of mines and technology, Tarkwa, Ghana

In this paper a Delta configuration 3d printer has been created using printed parts and salvaged E- waste materials. The delta printer has three similar towers. Each tower is made up of a square tube and a carriage that runs up and down the column. The printer achieves its motion through the movements of delta arms whose one end is connected to the extruder mechanism and other to the carriage which moves up and down vertically on a linear rail with the help of stepper motors, belt and pulley. This paper shows how the steps count of a stepper motor can be calculated, in addition to this it also summarized the calculation for the total weight to be moved by motors during 3d printing process through which the stresses and the deflection occurring in the parts can be found. For accuracy and speed, NEMA 17 stepper motor was used to drive the carriages. The functional details of all the parts used are also provided in the paper. This Delta printer is programmed with marlin firmware. It is an open-source firmware which is used to tell the circuit board about the physical hardware connected with it. It works as an interface between the hardware and software. The marlin firmware makes it possible to choose between various electronics used in making a printer to enable good communication between software and hardware.

3. COMPONENTS USED

1) End stops: - There are two types of End stops available in the market: -

1. Mechanical End stops
2. Optical End stops

The one which we have used in the 3D printer is a mechanical End stop. It is kind of a switch used to signal by making a click noise when the axis reaches end of its guide. They are located at the top side of 3 axes and are connected to the Main circuit.

FIG (1)

2) Nema 17 Stepper Motor: - It is a 3-phase motor. There are two types of stepper motor

1. Normal stepper motor with step angle of (15 ° or 30 °)
2. Hybrid stepper motor with step angle of (1.8 °or 0.9 °)

Here we have used hybrid stepper motor of 1.8 ° step angle. In this more torque is produced with lower speed thus increases the efficiency. Nema 17 stepper motors are commonly used in 3D printer and CNC mills.

FIG (2)

3) Pulleys and Belts: - The GT2 belts are designed specifically for linear motion. They use a rounded tooth profile, with 2mm pitch, that guarantees that the belt tooth fits smoothly and accurately in the pulley groove, so when you reverse the pulley direction, there is no room for the belt to move in the groove. The pulley is with 20 teeth on its outer bore. Both of these components are important to get desired steps count of each axis to get good print.

4) 3D printed parts: - 3D printed parts are used as shown in figure (3) and (4) which are made up of PLA material for the Build plate support and at the top and bottom corners of each pillar to get more rigidity so that more stability can be obtain at the effector while printing at higher speed up to 100mm/s.

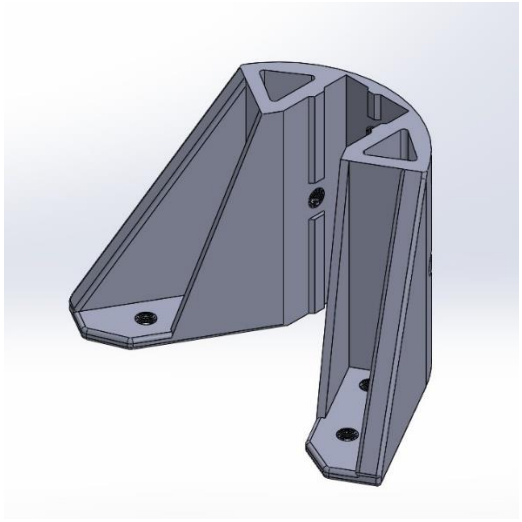


FIG (3)

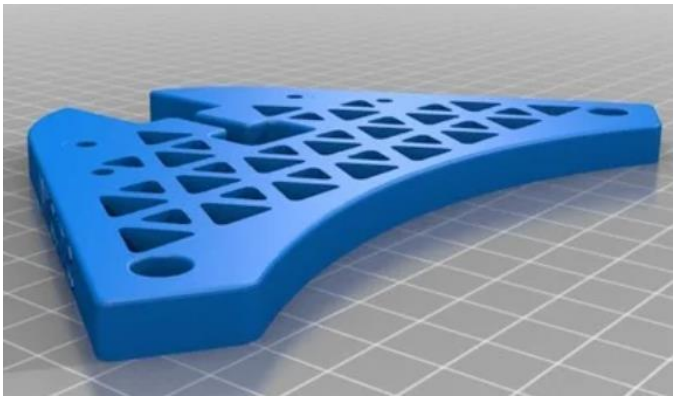


FIG (4)

5) A4988 Stepper motor drivers: - It can control both speed and spinning direction of a bipolar stepper motor like NEMA 17 with just two pins. The A4988 stepper motor driver has output drive capacity up to 35V and +2 or -2 A and it enables us to control one bipolar stepper motor at up to 2A output current per coil. The driver has a translator built in for easy operation.

6) Motherboard: -The electronics board is used to load the firmware, which contains the programming necessary for the printer to work. It is a small microcontroller platform which utilizes several components that are responsible for reading the g-codes and translating them into signals to control stepper motors. Here, an Arduino Mega 2560 circuit is used.

7) Connecting Rods: - also called delta arms which connect effector with carriages on linear guides of all 3 axes. The function of it is to move extruder which is on effector to print the desired shaped product. It is shown in figure (5).

FIG (5)

8) Extruding Mechanism: -It is used to feed the material through the PTFE pipe to the hot end. The component here used is MK8 Bowden type extruding mechanism. It is shown in figure (6).

FIG (6)

4. RESULT AND QUALITY: -

Here is a comparison between the Delta 3D printer made by us which is named as INDUS BOT is compared with one of well-known and professional 3d printer ZORTRAX M200 model Cartesian type. A rectangular stripe was designed as per ASTM standard with the dimensions as shown in the table(1.1). A total 3 stripes from each were made and their print dimensions were measured using vernier caliper. As shown in the table (1.1), overall, the dimensional inaccuracy of the Indus Bot was quite large as compared to the Zortrax M200. However, the Indus bot takes less printing time to prepare all 3 stripes than that by Zortrax 3D printer.

Talking about the print quality, the stripes were printed at the speed of 40mm/s in both the printers with 40%, 70% and 100% infill density.

To check the print quality the first printed part by both the 3d printer were captured as shown in fig(7) and fig(8).

	CAD MODEL (mm)		INDUS BOT						ZORTRAX M200			
		1	2	3	x̄	ERROR		1	2	3	x̄	ERROR
LENGTH	128	128.98	127.8	127.74	128.2	0.2		127.84	127.78	127.9	127.84	-0.16
BREATH	12	12.4	12.14	12.46	12.33	0.33		11.96	12	12.1	12.02	0.02
THICKNESS	3	3.1	3.12	3.06	3.1	0.1		3.04	3.08	3.12	3.08	0.08
BUILT TIME(MIN.)	51	62	70					60	65	73		
INFILL DENSITY (%)	40	70	100					40	70	100		

TABLE (1.1)

FIG (7)

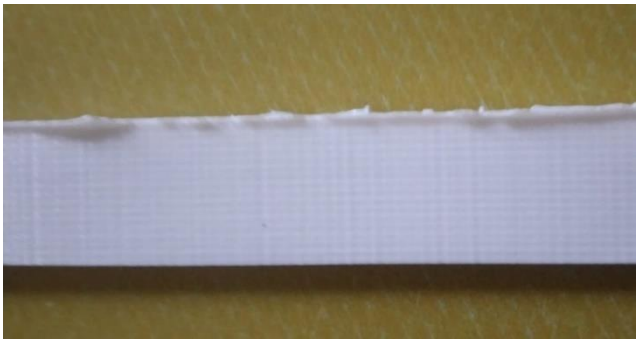


FIG (8)

No doubt from the printed parts that Zortrax printer has a better surface finish with smooth and shined surface compared to that of Indus Bot as shown in figure (7) and (8). The print produce on the Indus Bot creates a layer shift on the edges and on the surface the layer formation was easily seen with naked eyes. So, it requires some post processing for getting a better surface finish.

5. EXPERIMENTAL TESTING: -

An UTM testing was done for an I-section sample printed from the Indus Bot and Zortrax M200. To find the part which gives highest strength. The figure of the I-section is shown below.

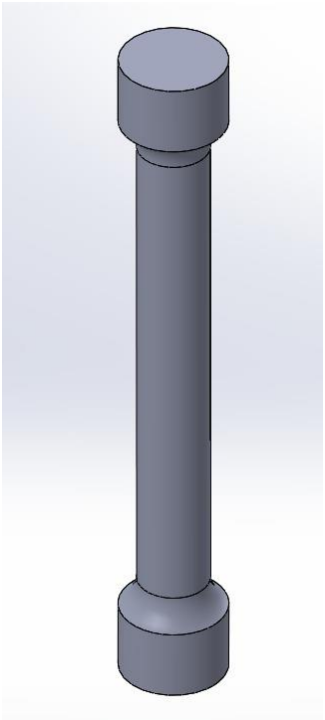
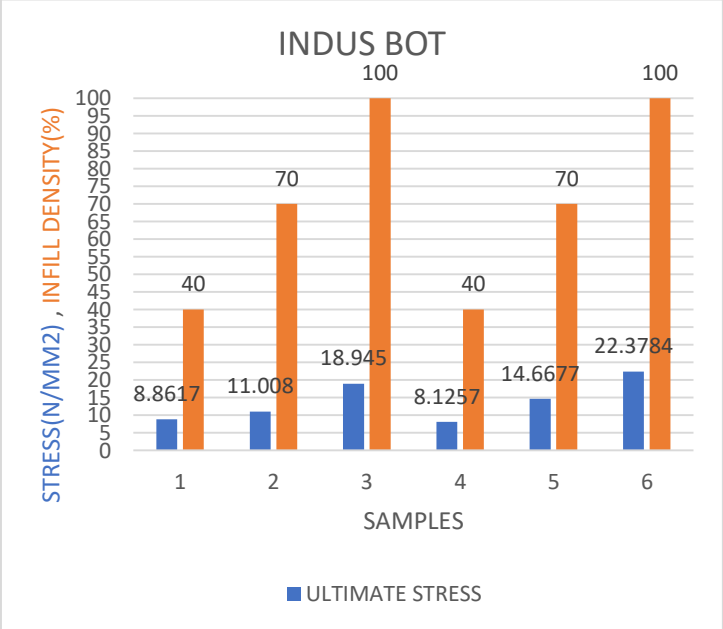


FIG (9)

The table (1.2) below gives the obtained ultimate stress of 6 sample prints prepared from Indus Bot. The given data is graphical presented below as in graph (2.1).

NO. OF SAMPLES	MAXIMUM LOAD(N)	UTIMATE STRESS(N/MM2)
1	696	8.8617
2	864	11.008
3	1488	18.945
4	638.2	8.1257
5	1152	14.6677
6	1757.6	22.3784

TABLE (1.2)

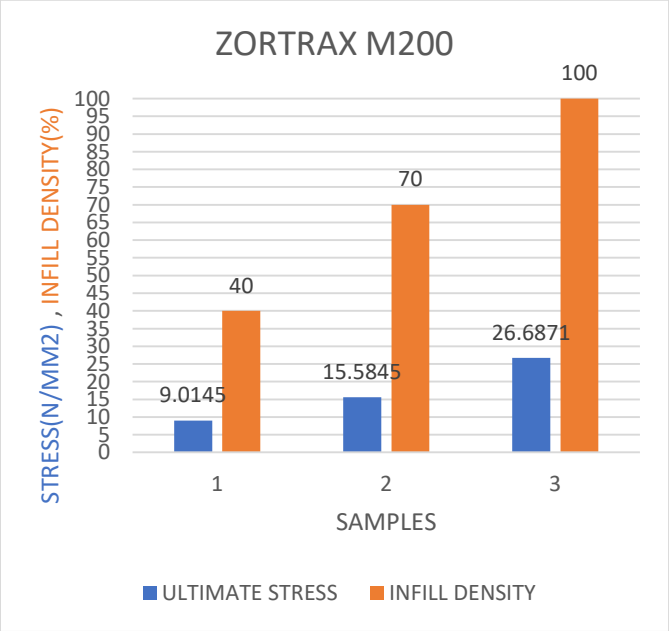


GRAPH (2.1)

Similar testing on UTM was done for parts printed by Zortrax M200 and its details are shown in table (1.3) and it is represented graphically as shown in graph (2.2).

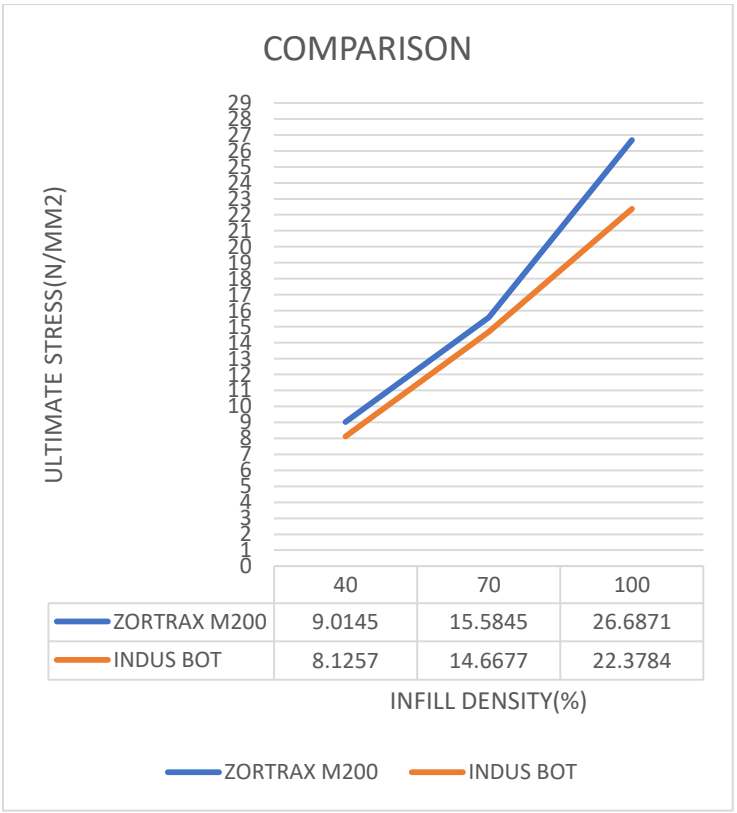
NO. OF SAMPLES	MAXIMUM LOAD(N)	UTIMATE STRESS(N/MM2)
1	708	9.0145
2	1224	15.5845
3	2096	26.6871

TABLE (1.3)



GRAPH (2.2)

From above two testing's, a comparison between both the 3D printers was made to find the printer which prints a part of highest ultimate strength. For this, 3 print samples of I-section were taken from each printer having similar parameters. And from the graph (2.3) generated below it is clear



GRAPH (2.3)

that both printers with infill density parameter of 100% will produce their highest ultimate strength sample print of I-section. However, the print by Zortrax M200 produces a highest strength print of that of 26.6871 N/MM2.

6. SPECIFICATIONS: -

INDUS BOT DELTA 3D PRINTER

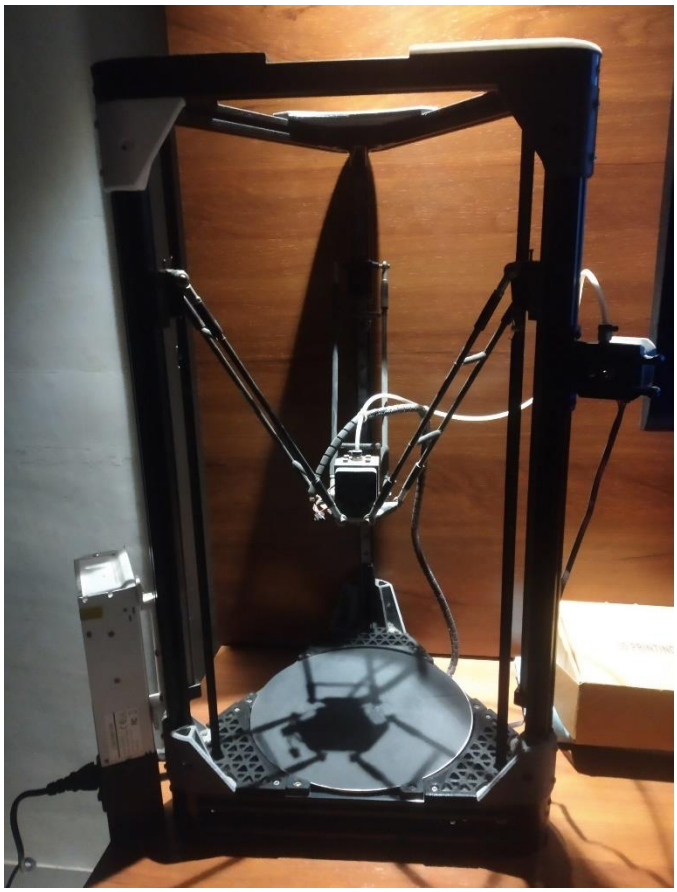


FIG (10)

EXTRUDER	E3D V6 Brass nozzle o.4mm dia.
EXTRUDER TEMPERATURE	Up to 285°C
PRINTING AREA	200*280
BED PLATE	Circular(wooden)
BED TEMPERATURE	Up to 100°C
FIRMWARE	Marlin 2.0x
SLICING SOFTWARE (OPEN SOURCED)	Ultimaker Cura
PRINTABLE FILAMENTS	PLA, ABS, PETG, PEET, Wood (Composite).

TABLE (1.4)

7. CONCLUSIONS: -

Based on the comparison study of two printers Indus Bot (Delta) and Zortrax M200(cartesian), the M200 3D printer gives nearly exact dimensional accuracy than that of Indus Bot 3D printer. Regarding the print quality, Zortrax M200 being a computer 3D printer has the better surface finish quality than that of DIY Indus Bot 3D printer. However, As seen from the comparison table, the DIY Indus Bot takes lesser time in printing than that of Zortrax M200. The Zortrax M200 has a built volume of 200*180 and costing of 1190$ while that of Indus Bot has a built volume of 200*280 and costing of 330$.

8. REFERENCES: -

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