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Design and Fabrication of 3D Printer for Analyzing 3D Printing Materials

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Abstract- Digital Fabrication technology also known as 3D Printing or additive manufacturing creates physical objects by adding successive layers of material. The main objective of this paper is to design and fabrication of 3D printer and analysis of different printing materials with respect to different parameters such as 3D printer speed and accuracy of printing material. The fundamental idea behind 3D printing is to increase the printer's speed in comparison to a standard 3D printer by using the Fused Deposition Modeling process. Problem highlighted in literature that the operating speed of 3D printers tends to decrease over time due to exposure to high temperatures and slow cooling of the polymer material deposited on the heat bed. In this paper the design and fabrication of 3D printer is discussed in which installation of fan on the extruder ensuring the decrease in operational time and improving extruder speed up to 100mm/sec. The lightweight aluminum plate heat bed also reduces operating time by moving the heat bed Faster. The use of tempered glass on heat bed which improves accuracy in its physical strength and heat resistance. Numerous industries, including the automotive, architectural, educational, medical, business, and consumer sectors, are impacted by 3D printing.

Keywords- 3D Printing, Printing Material and Fused Deposition Modelling

I. INTRODUCTION

Desktop fabrication is the term used to describe 3D printing. It is a quick prototyping method that turns a 3D concept into a tangible product. A CAD model is utilized by a 3D printing device to expedite the prototyping process. When creating something from its 3D model, a structure is used. Prior to being sent to the 3D printer the 3D design is saved in STL format. A variety of materials including composites PLA and ABS can be used with it. One quickly evolving and economically viable method used for quick prototyping is 3D printing. Layer by layer the 3D printer creates an actual object by printing the CAD design. The inkjet desktop printers that produce multiple deposit jets and printing material layer by layer from CAD 3D data are the source of the 3D printing process. Living a more varied and speedier life is made possible by 3D printing which makes life easier and faster to create things with different qualities [1]. 3D printing majorly dealing with the process of Rapid Prototyping & Additive Manufacturing process plays vital role in it. But major obstacle in to this is speed of rapid prototyping machine. Additive Manufacturing used as a real, scalable manufacturing process to generate fully functional final components in high-tech materials for low batch high-value manufacturing [2]. Nowadays, rapid prototyping has a wide range of applications in various fields of human activity, research, engineering, medical industry, military, construction, architecture, fashion, education, the computer industry and many others. Similar to previous technologies like photocopying three-dimensional (3D) printing can have an impact on information transfer. This lists resources for learning about 3D printing its technology, required apps and software. Without wasting time or resources businesses can also use 3D printing to extract and innovate new ideologies and different design replicas. Therefore, 3D printing is one of emerging areas in design and manufacturing enabling reliability of product design and production [3]

2D printing techniques have dominated the visual world of printed fonts for more than a century. Simple to read and comprehend but terribly outsourced when it comes to mapping actual and tangible models. Every 3D model cannot simply be rendered and displayed on a 2D workstation. Only image reproduction is worth mentioning for comprehensive perception. This ushered in the era of the much-needed idea of 3D printing. The sole purpose of splitting the 3D printer was to prepare 3D patterns directly on the printer bed. This is an efficient production method as many companies are adopting this type of method for their production operations. Rapid prototyping and additive manufacturing are two processes in which 3D printing plays a crucial role. However, a significant barrier to this is the rapid prototyping machine's speed because Printing the part takes a few hours to many days [4]. This paper primary objective is to increase the rapid prototyping machine's speed. The technology is not different rather, it's how it's used and scaled. Quick Prototyping used to create batch-of-one components for proof of concept or non-structural, non-functional demo pieces [5]. Using high-tech materials additive manufacturing can produce fully functional final components in small batches for high-value manufacturing [3]. The most repeated file type that 3D printers can read is stereo lithography (STL). Therefore, in contrast to material extracted from a stock during traditional machining. 3D printing sometimes referred to as additive manufacturing uses a computer-aided design (CAD) model to build a three-dimensional object by layering on material. In order to construct a 3-dimensional object layers of material are generated under computer control in a process known as additive manufacturing (AM), or 3D printing. Almost any form or geometry can be achieved with objects they are often produced using digital model data from an Additive Manufacturing File (AMF) or another electronic data source such as a 3D model. [6].

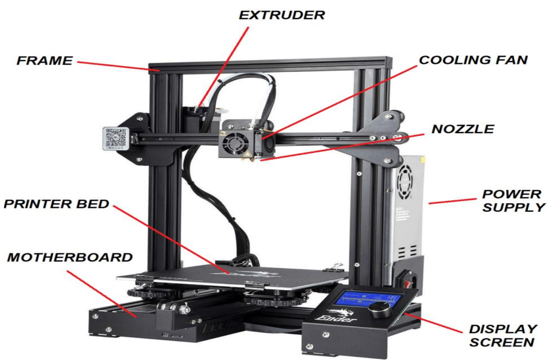

Fig.1 Schematic Daigram of 3D printer.

II. MATERIALS AND METHODS

2.1 Fabrication of 3D Printer

There are many parts that used for fabrication of 3D Printer few of them important parts are discussed with their required Specifications

2.1.1 Frame

- Size: 440 x 410 x 465mm / 17.3 x 16.1 x 18.3 inches (Aluminum)
- Printing Size: 220 x 220 x 250mm / 8.6 x 8.6 x 9.8 inches
- 40×40 aluminum extrusion for the Y-axis base.

Fig.2 3D Printer Frame

2.1.2 Print Bed

- Heated bed temperature: 110℃
- Max Hotbed Temperature: 110 ℃
- Bed levelling: Manual
- Max. print speed: 100 mm/

Fig.3 Print bed

2.1.3 Stepper Motor

Stepper Motor used in 3D Printer description is given in table 01

Table 1: Stepper Motor Description

S. No.	Item	Description
01	Voltage	12V DC
02	Motor Length	1.54 inches
03	Operating Temperature	-10 to 40 °C
04	Step Angle	1.8 deg.
05	Current	1.2A at 4V
06	No. of Phases	04
07	200 steps per revolution	1.8 degrees

Fig. 4 Stepper motor

2.1.4 Extruder

Heated filaments are fed onto the bed by the extruder. When printing items, this is a crucial component. First, the filament is heated in the extruder. The heating causes the filament to melt and deposit on the print bed. An essential component of an extruder is the Nozzle, which is often referred to as the extruder's tip. Melted filament is deposited onto the print bed through the nozzle. The range of sizes is 0.25 mm to 0.75 mm. The most typical nozzle size is 0.5 mm.

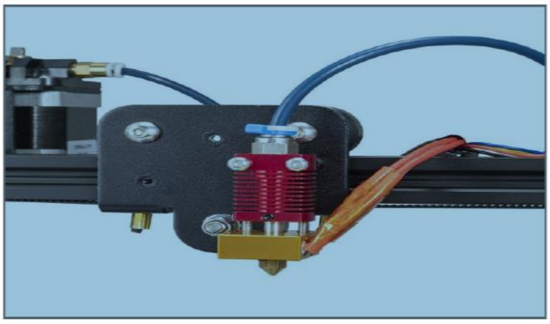

Fig 5 Extruder

2.2. CAD Models of 3D Printer

CAD models of different parts of 3D printer were designed on solid works.

2.2.1 Stepper Motor

The stepper motor is used to precise positioning with a motor and CAD model of stepper motor is given in fig. 10

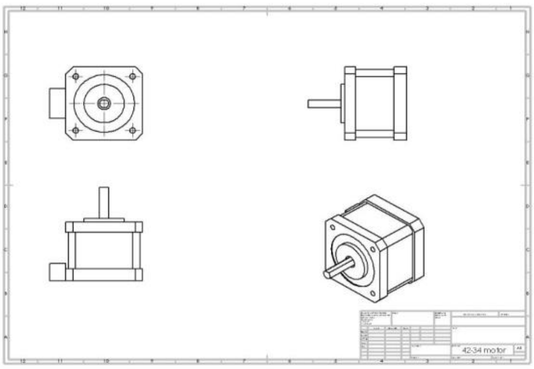

Fig. 6 CAD model of Stepper motor

2.2.2 Print Bed

A print bed is the surface of 3d printer where a print lays down the material that make up a 3D print

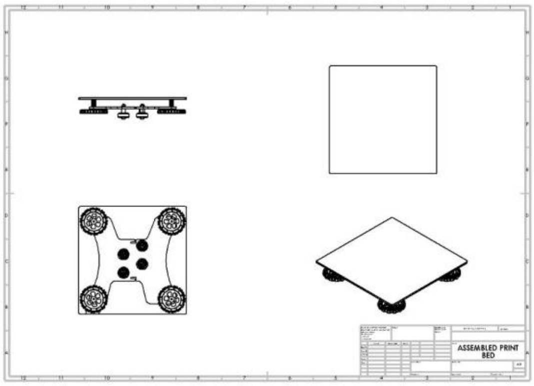

Fig. 7 Printing head

2.2.3 Frame

Frame is used for supporting the components of all 3D printer.

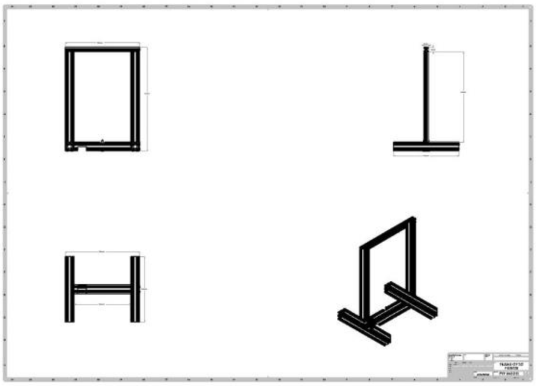

Fig.8 Frame

2.3.4 Extruder

The extruder is the part responsible for drawing in, melting, and pushing out the filament

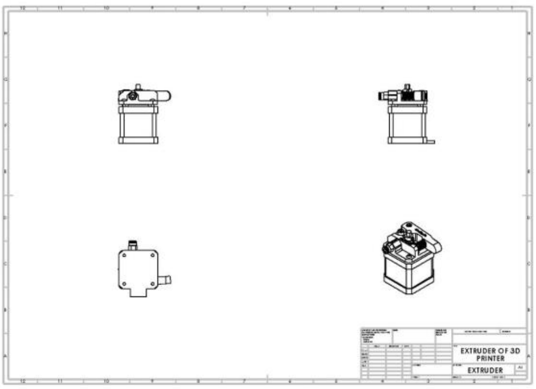

Fig. 9 Extruder

2.3.5 Executed Model

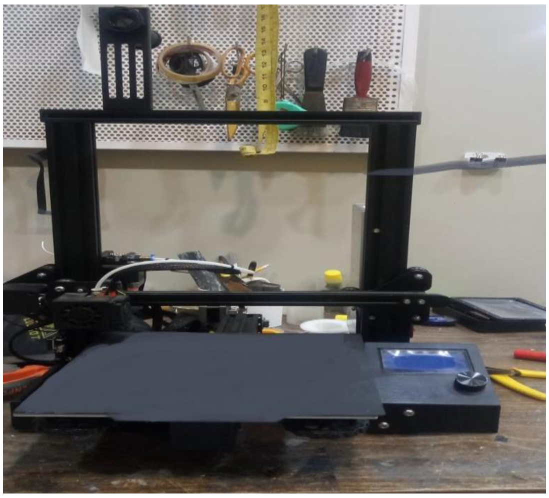

Fig. 10 Executed 3D Printer

III. RESULTS AND DISCUSSION

Different materials Polylactic Acid (PLA), Polyethylene Terephthalate Glycol (PET-G), & Acrylonitrile Butadiene Styrene (ABS) were printed and materials analyzed on the basis of object accuracy, layer thickness such as 0.28, 0.2, 0.16 and 0.12 mm and printing speed. During printing it is noted that as the layer thicknesses decreases the accuracy of printed part increases. Further different materials namely Polylactic acid (PLA), polyethylene terephthalate glycol (PET-G), & Acrylonitrile Butadiene Styrene (ABS) analysis were discussed one by one.

3.1 Analysis of Polylactic Acid (PLA)

Polylactic acid PLA thermoplastic filament material used to print four rectangular parts of 50% infill density with different layer thicknesses, As the layer thickness decreases the number of printing layer increases which successively increases the accuracy of the printed part. For each printed part temperature of filament and bed temperature is set to 220^{o} C and 70^{o} C respectively. Polylactic acid (PLA) is a shiny and smoother material which is more environmental friendly and there are no harmful fumes during printing.

Fig.11 Polylactic Acid (PLA) Printed objects in different Qualities

3.2 Analysis of Polyethylene Terephthalate Glycol (PET-G)

Polyethylene Terephthalate Glycol (PET-G) thermoplastic filament material were used to print four rectangular parts of 50% infill density with different layer thicknesses, As the layer thickness decreases the number of printing layer increases which successively increases the accuracy of the printed part. During printing the melting temperature of filament and bed temperature is set to 240^{o} C and 80^{o} C respectively for each printed part.

Polyethylene Terephthalate Glycol (PET-G) has a minor accuracy variation as compare to Polylactic Acid (PLA) the highest accuracy achieved in Polyethylene Terephthalate Glycol (PET-G) is 99.8% in super quality (0.12mm layer thickness). It has higher heat resistance, Flexibility, and glossy finish.

Fig. 12 Polyethylene Terephthalate Glycol (PET-G) Printed objects in different Qualities

3.3 Analysis of Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile Butadiene Styrene (ABS) thermoplastic filament material were used to print four rectangular parts of 50% infill density with different layer thicknesses, As the layer thickness decreases the number of printing layer increases which successively increases the accuracy of the printed part. During printing the melting temperature of filament and bed temperature is set to 250^{o} C and 90^{o} C respectively for each printed part.

The warping distortion of Acrylonitrile Butadiene Styrene (ABS) material is greatest along the height axis, and shape inaccuracies are caused by heat shrinkage in the rectangular samples. The better printing of this material could be done by concealing the printer under acrylic cover

Fig. 13 Acrylonitrile Butadiene Styrene (ABS) printed objects in different qualities

3.4 Result Analysis

During the printing process nozzle diameter, printing speed and different layer thicknesses were set at 0.4 mm, 100 mm/s, and Low (0.28mm), Standard (0.20mm), Dynamic (0.16mm) and Super (0.12mm) respectively. It is noted that as the layer thickness decreases the quality of object increases which in turn increases the accuracy of printed part 50% infill density parts fabricated by a FDM 3D printer using different types of thermoplastic filament materials namely Polylactic Acid (PLA), Polyethylene Terephthalate Glycol (PET-G), & Acrylonitrile Butadiene Styrene (ABS). Geometrical accuracy was measured by using a Vernier caliper gauge and calculation of the deviation relative to the original STL file format. Figure 16, 17 and 18 shows the dimensional accuracy of printed parts. There are variations in the dimensional precision between the actual values of 40 mm Length (L), 40 mm Width (W), and 15 mm Height (H) and the parts that were 3D printed using Fused Deposition Modelling (FDM). While Acrylonitrile Butadiene Styrene (ABS) thermoplastic filament material has significant surface roughness, waviness, and primary behavior. Polylactic acid (PLA) thermoplastic filament material demonstrates superior surface behavior and was determined to be more accurate. Both Polylactic acid (PLA) and polyethylene terephthalate glycol (PET-G) shows good surface performance. The Accuracy and Percentage Error is calculated through formula given below:

$$\text{Accuracy} = \frac{\textit{Printed Object Dimensions}}{\textit{CAD Model Dimensions}} \times 100$$

$$\text{Percentage Error} = \frac{\textit{Printed Object Dimensions} - \textit{CAD Model Dimnesions}}{\textit{CAD Model Dimensions}} \times 100$$

Results analysis of dimensional accuracy of each material with different layer thickness at constant speed discussed in Table no:01.

Table 2: Results of different Materials

Quality	Layer Thickness (mm)	No: of Printing Layers	Weight (Grams)	Temp (◦C)	Time (Mint)	Speed (mm/s)	CAD Model Dimensions (mm)	Printed Object Dimensions (mm)	Accuracy (%)	Percentage Error
Polylactic Acid (PLA)										
Low	0.28	54	15	205-225	49	100	L=40 W=40 H=15	L=39.8 W=40 H=14.4	95.53	-4.47
Standard	0.2	75	13	205-225	64	100	L=40 W=40 H=15	L=39.7 W=39.8 H=14.8	97.43	-2.56
Dynamic	0.16	74	12	205-225	101	100	L=40 W=40 H=15	L=39.95 W=39.95 H=14.8	98.42	-1.58
Super	0.12	125	11	205-225	120	100	L=40 W=40 H=15	L=40 W=40 H=14.9	99.33	-0.67
Polyethylene Terephthalate Glycol (PET-G)										
Low	0.28	54	15	220-260	54	100	L=40 W=40 H=15	L=39.4 W=39.4 H=14.5	93.78	-6.22
Standard	0.2	75	14	220-260	70	100	L=40 W=40 H=15	L=39.6 W=39.8 H=14.5	95.22	-4.78
Dynamic	0.16	74	13	220-260	75	100	L=40 W=40 H=15	L=39.8 W=40 H=14.7	97.51	-2.49
Super	0.12	125	19	220-260	114	100	L=40 W=40 H=15	L=39.9 W=39.95 H=14.8	98.29	-1.70
Acrylonitrile Butadiene Styrene (ABS)										
Low	0.28	54	13	220-260	75	100	L=40 W=40 H=15	L=39 W=39.4 H=14.2	90.91	-9.08
Standard	0.2	75	12	220-260	65	100	L=40 W=40 H=15	L=39.2 W=39.1 H=14.5	92.60	-7.39
Dynamic	0.16	83	11	220-260	71	100	L=40 W=40 H=15	L=39.4 W=39.5 H=14.6	94.67	-5.32
Super	0.12	125	11	220-260	112	100	L=40 W=40 H=15	L=39.7 W=39.5 H=14.6	95.40	-4.60

IV. CONCLUSION

The key benefits of 3D printing are its capacity to manufacture complex structures with minimum waste, mass customization, and design freedom. Comprehensive review of 3D printing methods and materials. Fused Deposition Modelling (FDM) is a widely utilized 3D printing technology because of its ease of use, affordability, and quick processing speed. The main aim of this paper is to design and fabricate a 3D printer and analysis of dimensional accuracy of 3D printed parts. Mostly the operating speed of 3D printers tends to decrease over time due to exposure to high temperatures and slow cooling of the polymer material deposited on the heated bed, shortening the polymer cooling time will lead to reduction in future execution time. In this paper Fused Deposition Modelling (FDM) type of 3D printer were fabricated which improves extruder speed up to 100mm/sec and installation of fan on the extruder ensuring the decrease in operational time and the use of a light-weighted heat bed with an aluminum plate allowed the bed to move quickly. And the tempered glass placed on heat bed Which improves accuracy in its physical strength and heat resistance. Parts created in 3D design software can be successfully loaded into printing software, however the final result has some dimension variance because of as layer thickness of filament material decreases accuracy and percentage error of printed material improved as compared to the specifications provided during the design phase.

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