Design and Fabrication of DLP 3D Printer

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Abstract Digital light processing (DLP) 3D printing is an additive manufacturing (AM) process which is used to produce parts via photopolymerization process in which resin is cured by UV light. Vat photopolymerization is a form of AM. It has a liquid bath of a polymeric resin which is cured layer by layer through precise control with help of stepper motor and projection of a light source of DLP projector. Printing time, layer thickness, and lumens of the projector play an important role in the printing process. A series of specimens was designed, printed, and tested. Total printing time, layer thickness, and layer exposure time were analyzed. We used 365 nm wavelength photopolymer resin, BENQ MP515 projector having 2500 ANSI lumens. This paper shows the design and fabrication of DLP 3D printer with low cost and good accuracy.

Keywords 3D printing · Additive manufacturing · Digital light processing (DLP) · Vat photopolymerization

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1 Introduction

There are various types of 3D printing. All types have their own sets of process and applications. They all have their various principles and advantages. Table 1 shows the different types of rapid prototyping. Additive manufacturing (AM) is the manufacturing process by which three-dimensional (3D) parts are produced using an additive approach [3]. Vat photopolymerization is a form of AM. Vat polymerization 3D printing uses a liquid photopolymer resin which is solidified under the light source [3]. There are two main technologies in vat polymerization: DLP and SLA. Basically, both use the resin but the major difference between them is the light source which cured the resin [1]. In order to understand DLP, first look at the process of its forerunner SLA. In DLP, the light source is a digital light projector screen which blinks the layer of part all at once. Therefore, all points of layer cured simultaneously, and the printing speed is increased and at the same time printing time is decreased [2]. On the other hand, SLA takes more time than DLP because it uses a point-to-point method to cure [6, 7]. Also, the accuracy of the part made by DLP is seen better than SLA. DLP 3D printer uses in dental, jewelry, art and other sectors which require high detailing and finish.

This paper is organized as follows: first basic introduction of vat polymerization, second its methodology, and next its machine building. Finally, we present testing, analysis, and conclusion.

1.1 Working Principle

3D printing is any of the various processes in which material is joined or solidified under computer control to create a 3D object [1]. DLP 3D printing uses light to solidify a liquid photopolymer (Fig. 1).

By changing the pattern of the light and incrementing the vertical position of the workpiece, the desired geometry is built up layer by layer. In this process, once the 3D model is sent to the printer, a vat of liquid polymer is exposed to light from a DLP projector under safelight conditions. The DLP projector displays the image of the 3D model onto the liquid polymer. The exposed liquid polymer hardens, the build plate moves down, and the liquid polymer is once more exposed to light. The process is repeated until the 3D model is complete, and the vat is drained of liquid, revealing the solidified model [5].

1.2 Methodology

For making any object in DLP,

Table 1 Comparative summary of rapid prototyping (3D printing) techniques [4]

Types of 3D printing technology	Fused deposition modeling	Stereolithography, digital light processing	Selective laser sintering	Material jetting, drop on demand	Direct metal laser sintering; electobeam melting
Materials	Thermoplastic filament	Photopolymer resin	Thermoplastic Powder	Photopolymer Resin	Metal Powder
Dimensional accuracy	±0.5 mm (lower limit ± 0.5 mm)	±0.5 mm (Lower limit ± 0.5 mm)	±0.3 mm (Lower limit ± 0.3 mm)	±0.1 mm	±0.1 mm
Applications	– Electrical housings; form and fit tastings; – jigs and fixtures; investment casting patterns	– Injection mold-like polymer prototypes; – jewelry (Investment Casting); dental applications; hearing aids	Functional parts; complex ducting (Hollow Designs); low run part production	Full color product prototypes; injection mold-like prototypes; low run injection molds	Functional metal parts (Aerospace and Automotive); medical; dental

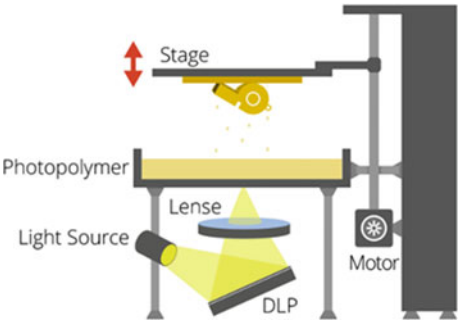

Fig. 1 Working of DLP 3D printer (*Source* www.think3d.in) [4]

(1) Create 3D design of an object in CAD software, (2) convert into .stl file, (3) creation workshop, (4) print, (5) 3D object, and (6) post-process.

2 Machine Building

2.1 Design of the Frame with Dimensions

The detailed design set-up is as shown in Fig. 2.

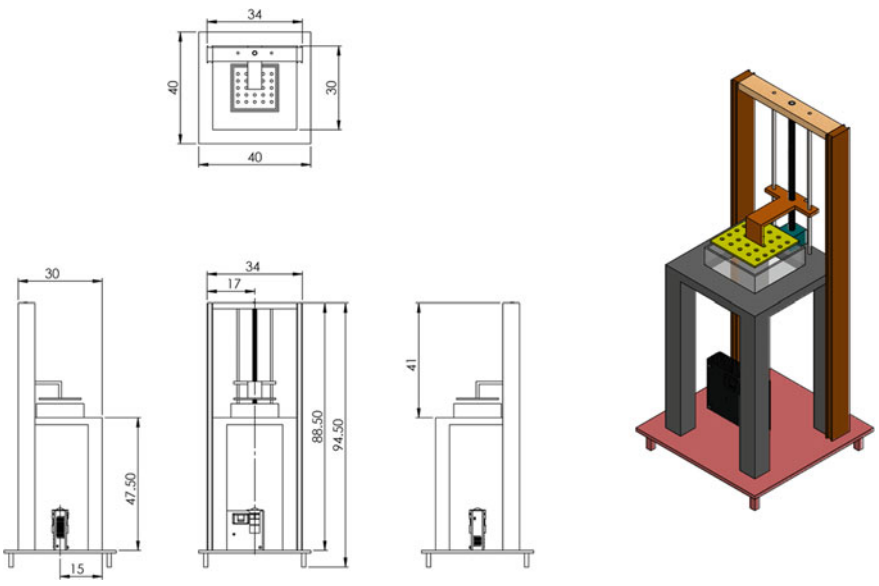

Fig. 2 Detailed design

2.2 Materials and Equipment

See Table 2.

Table 2 Material and equipment used in machine building

S. No.	Material & equipment	Specification	Qty. (Q)	Price (P)	TOTAL (Q*P) RS.
1	Projector	Model: BENQMP515 Resolution: 800*600 Lumens: 2500 Display type: DLP Throw ratio: 1.86:1–2.04:1	1	20,000	20,000
2	Resin	Company: Drop Shape Color: Orange Weight: 250 gm Wavelength: 365–405 Nm		4000	4000
3	Electronic components	(i) Nema17 Stepper Motor: 200 steps per mm Max. speed- 600–800 rpm (ii) Arduino Mega 2560 (iii) Motor drive circuit (iv) Power supply 12 V 20A	–	4323	4323
4	Aluminum frame	Aluminum from scrap	–	1000	100
5	Linear bearing	For 8 mm rod	2	250	500
6	SS Rod	8 mm	2	120	240
7	M8 Lead screw (300 mm)	Screw diameter: 8 mm Length: 300 mm Pitch: 1.25 mm Material: Stainless steel- lead screw, brass- nut	1	200	200
8	Flange nut		2	150	300
9	Flexible coupling		1	150	150
10	Vat and build plate	Vat crystal glass build plate aluminum	1	480	480
12	Bearing	8 mm	1	120	120
14	labor cost		–	450	450
GRAND TOTAL		30,863 INR			

2.3 Fabrication

First, we made our aluminum frame section from the scrap. The frame section looked good. We put stepper motor with an attached lead screw with the support of bearing on the top (Fig. 3).

But later on, we found from the above setup not up to the mark because it could not hold the weight of the build plate properly, and at the time of curing process, it could not have smooth movement. So, we changed that setup and used a linear channel for better up-down movement as in Fig. 4-i. We see the one channel which is held vertically to support, we put 3 mm glass at the bottom and stick vat on it, and we tested this setup but again we found the same problem which we found before. And also, we found that resin took more time to cure because of too much thickness of glass sheet and vat. So now, we put two channels facing each other and attached build plate and bearing on top (Fig. 4-ii). The vertical movement now seemed good. Then we attached plywood and cut it from the center as we stick our crystal glass vat with help of Araldite glue. Another remarkable point is that first, we used PCB board as our build plate. But the problem is that the layers would not stick to it properly. We also used Bakelite, SS plate, but the problem was not solved. Then we used an aluminum plate as our build plate; it is light in weight and also resin layer stick to it properly.

After the testing, the movement was good at earlier, but because of error in channel alignment and lack of support at the bottom later, we found some defaults. Therefore, we decided to change the setup. We used linear guild with two SS rods, and this time we gave support from the side all from down to up. Also, we put bearing at the top for proper lead screw movement. After testing, we found better results with smooth vertical movement. Here is the final setup which is given below in Fig. 4-iii. Also, at the time of the curing process, the build plate sticks to the vat after each layer, and sometimes layers of component stick to vat and affect the

Fig. 3 Frame section and initial design setup

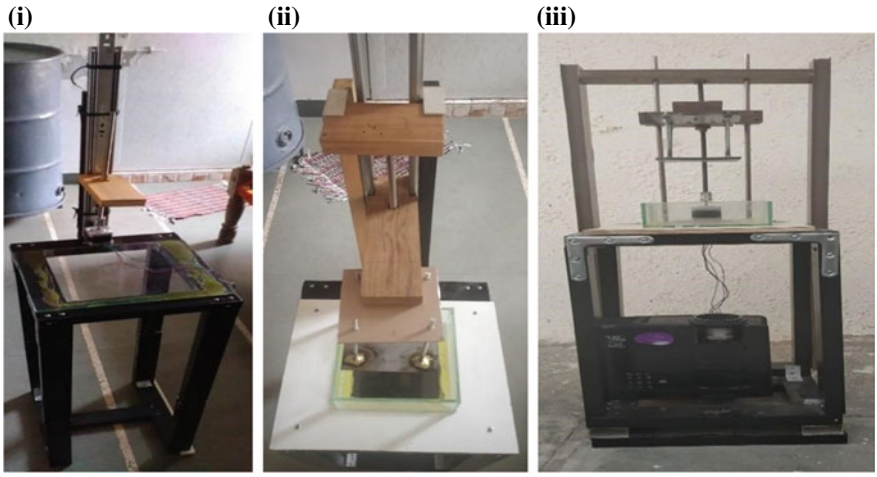

Fig. 4 **i** Channel used for better movement. **ii** Fixed bearing at top of lead screw for stability of build plate. **iii** Used linear bearing and steel road for smooth movement and better stability

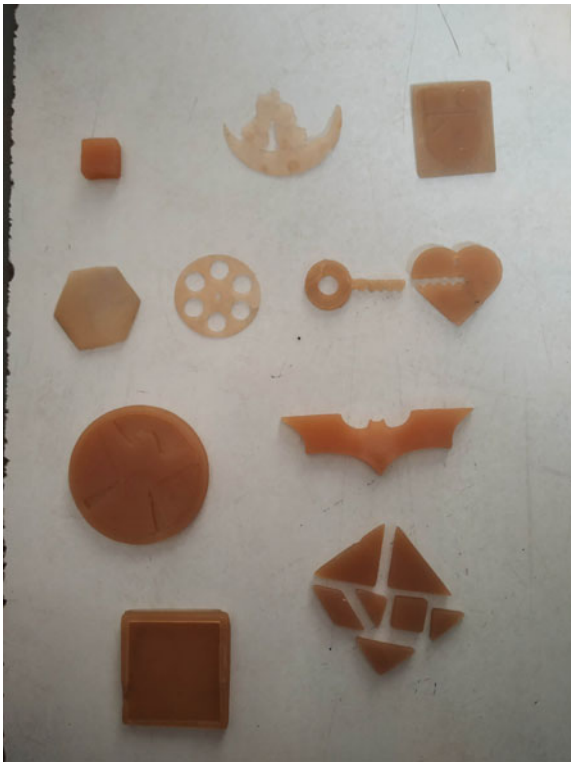

Fig. 5 Finished components made by our DLP 3D printer

accuracy of the finished product. So, we used non-stick material acrylic film on the vat. After using non-stick film, the layers would not stick to vat. Later on, we removed the color wheel from the projector for a better throw of UV light.

3 Results and Discussion

3.1 Testing and Analysis

After our 3D printer being complete in fabrication, we then do testing and analysis. We focused on printing time and accuracy and thickness of each layer of components that we made. We concluded the results of layer thickness and exposure time. We conclude that the cost of our DLP 3D printer is low compared to others in the market. Also, we got great accuracy with minimum printing time. Also, another aspect that we found is that if we removed UV filter from the projector, then our curing time will be decreased (Tables 3 and 4; Fig. 5).

3.2 Environmental Parameters

There are some environmental parameters that one should aware of before using the printer. The room temperature should be maintained at about 25–28 °C. And also, if printing process is done in the darkroom, then it would be easy for the resin to cure. Because if the resin exposes to the sunlight for a longer duration, then it may start to cure automatically at certain extent and this could affect the printing process.

4 Conclusion

From this paper, we conclude that after removing UV filter, the curing time is decreased by around 60%. Also, if we decreased cross-sectional area of projection or if your component is having a complex structure, then it is necessary to increase exposure time. Another point is that the thickness of vat should be minimum; otherwise, build plate will stick to the vat and also resin will take more time to cure. Therefore, with a minimum thickness of vat you do not need to use any non-stick

Table 3 Testing and analysis

No.	Layer thickness (mm)	Layer exposure (seconds)		First three-layer exposure (seconds)	
		Before	After	Before	After
1	0.05	50	20–25	100	55–60
2	0.1	80	35–40	130	70–100
3	0.15	100–110	50–60	160	85–120

Table 4 Comparison of cost estimation [1, 8–10]

Comparison	Micro protojet [8]	Formlabs from 2 [9]	B9Creation B9core550 [1]	Rapidshape S30 [10]	Our DLP printer
Built volume XY resolution	65 × 36 × 1 20 mm	145 × 145 × 175 mm	104 × 75 × 203 mm	50 × 31 × 80 mm	100 × 100 × 200 mm
Light source	LED projector	UV laser	LED projector	LED projector	DLP projector
Resolution (μ)	60	140	55	50	140
Resin per Kg.	150$	300$	150$	800$	114$
Cost	4995$	5500$	10,000$	20,000$	460$

film. If DLP projector has an adjustable resolution, it will affect your exposure times. If your distance between projector and vat is minimum, then curing time is increased. And also, from this research paper, we can conclude that DLP technology can replace the SLA technology with its great speed. And it can also replace FDM in many areas of work. Also, this research paper shows how to make DLP 3D printer at a low cost with good accuracy. Also, we conclude that DLP 3D printer has less maintenance with great reliability and consistency.

5 Future Scope

There is no doubt about the future of DLP 3D printer, because of its better capabilities than SLA in many industries. Also, in future, there might be a solution of having components with different color. This could be possible with the conveyor which has continued flow of various colored resin vat. For Example: firstly a build plate dip in red colored resin vat, after it being cured the red resin vat moves and blue colored resin vat comes and again the same process can repeat with other colors. There might be a problem to control the flow of vats. However, DLP technology has a great future scope.

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