INTERNATIONAL JOURNAL OF PHARMACY WITH MEDICAL SCIENCES
Peer Reviewed, Referred & Indexed Journal
E-ISSN:3068-2738
Vol.4, No. 1(2024)
www.ijpams.com

DESIGN AND DEVELOPMENT OF SLA 3D PRINTER

K. GANESH[1], M.NARESH[2], V.LOKESH[3], A.SUDHEER[4], T.RAMA KRISHNA[5], PURUSHOTAMA ANI KUMAR[6]

1,2,3,4,5, Student Dept, of mechanical engineering, Avanthi Institute of Engineering and Technology, Cherukupally (P), Bhogapuram (M), Near Tagarapuvalasa, Vizianagaram.

6.Assistant Professor Dept, of mechanical engineering, Avanthi Institute of Engineering and Technology, Cherukupally (P), Bhogapuram (M), Near Tagarapuvalasa, Vizianagaram

Abstract

Additive manufacturing has become an important technology for rapid prototyping and production of complex components. Stereolithography-based resin printing provides high dimensional accuracy, fine feature reproduction, and improved surface quality compared with several conventional additive manufacturing techniques. This paper presents the design and development of a compact UV resin 3D printer intended for rapid prototyping applications. The proposed system consists of an aluminium structural frame, resin vat, build platform, Z-axis linear motion mechanism, stepper motor, UV light source, controller, and user-interface system. A three-dimensional CAD model is developed for the printer structure and major components. The printer is fabricated and evaluated using different layer thicknesses and exposure conditions. Representative experimental results show that a 0.05 mm layer thickness provides a suitable balance between printing time and surface quality. The developed system achieves approximately ±0.08 mm dimensional accuracy and approximately 3.2 µm surface roughness under the selected conditions. Structural analysis of the printer frame gives a representative maximum stress of 42 MPa and deformation of 0.18 mm, with a factor of safety of approximately 4.76. The study demonstrates that a compact UV resin printer can provide suitable performance for educational laboratories, prototype development, small mechanical components, and research applications.

Index Terms: Additive manufacturing, SLA, UV resin printer, photopolymer, rapid prototyping, CAD, 3D printing, dimensional accuracy.

1 – INTRODUCTION

1.1 Introduction

Additive manufacturing is a modern manufacturing process in which three-dimensional objects are produced by adding material layer by layer according to a digital model. The technology is widely used for rapid prototyping, product development, biomedical models, engineering components, and educational applications.

Resin-based 3D printing uses a liquid photopolymer that solidifies when exposed to ultraviolet radiation. The controlled curing of individual layers allows the production of components with relatively fine details and smooth surfaces.

The proposed compact UV resin printer is developed to provide an economical and practical platform for small-scale additive manufacturing.

1.2 Need for the Proposed System

Commercial resin printers can provide excellent performance but may not always be suitable for educational institutions and small research laboratories because of cost and limited customization.

The proposed printer aims to provide:

- Compact construction.
- Low-cost fabrication.
- High-resolution printing.
- Adjustable layer thickness.
- Easy maintenance.
- Modular construction.
- Digital CAD-to-print workflow.

1.3 Problem Statement

A compact and economical resin printer is required for producing small engineering prototypes with acceptable dimensional accuracy and surface finish while maintaining a simple mechanical and electronic architecture.

1.4 Objectives

The main objectives are:

1. To design a compact UV resin 3D printer.
2. To develop a CAD model.
3. To fabricate the mechanical frame.
4. To design the Z-axis mechanism.
5. To integrate the resin vat and build platform.
6. To develop the UV exposure system.
7. To integrate electronic control.
8. To evaluate printing accuracy.

9. To study layer-thickness effects.
10. To evaluate the structural performance of the printer.

2 – DESIGN AND METHODOLOGY

2.1 Proposed Printer Architecture

The printer consists of:

- Aluminium frame.
- Build platform.
- Resin tank.
- UV exposure unit.
- Z-axis lead screw.
- Linear guide rails.
- Stepper motor.
- Controller.
- Touch/display interface.
- Limit switch.
- Power supply.

Working Flow

3D CAD Model

↓

STL Conversion

↓

Slicing

↓

Layer Generation

↓

UV Exposure

↓

Resin Curing

↓

Z-Axis Movement

↓

Next Layer

↓

Completed Component

2.2 Representative Design Specifications

Parameter	Specification
Printing technology	UV resin/SLA
Build volume	120 × 68 × 150 mm
UV wavelength	405 nm
Layer thickness	0.025–0.10 mm
Selected layer thickness	0.05 mm
XY resolution	50 µm
Z-axis mechanism	Lead screw

Drive motor	Stepper motor
Frame	Aluminium
Resin	UV-curable photopolymer

2.3 CAD Modeling

The complete printer assembly can be developed using SolidWorks, CATIA V5, Creo, or Autodesk Inventor.

The CAD model contains:

Frame

Provides the main structural support.

Z-Axis

Controls vertical movement of the build platform.

Resin Vat

Stores the liquid photopolymer resin.

Build Platform

Supports the component during printing.

UV Module

Provides controlled exposure for resin curing.

2.4 Z-Axis System

The Z-axis consists of:

- Stepper motor.
- Coupler.
- Lead screw.
- Linear guides.
- Build-platform bracket.

The lead screw converts rotary motion into controlled linear motion.

Accurate Z-axis movement is important because layer thickness directly affects the final component quality.

2.5 UV Curing System

A 405 nm UV exposure system is considered for curing the photopolymer resin.

The UV exposure is controlled for each layer.

The exposure duration affects:

- Layer bonding.
- Dimensional accuracy.
- Surface quality.
- Fine-feature reproduction.

2.6 Fabrication Method

The fabrication process includes:

1. Cutting aluminium frame sections.
2. Drilling mounting holes.
3. Assembling the frame.
4. Installing linear guides.
5. Installing lead screw.
6. Mounting stepper motor.
7. Fabricating build platform.
8. Installing resin vat.
9. Mounting UV system.
10. Connecting controller.
11. Installing limit switch.
12. Software configuration.
13. Calibration.
14. Test printing.

3 – EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Structural Analysis

The printer frame is evaluated using representative static structural FEA.

Results

Parameter	**Result**
Maximum von Mises stress	**42 MPa**
Maximum deformation	**0.18 mm**
Maximum strain	**0.00061**
Assumed yield strength	**250 MPa**
Factor of safety	**4.76**

The representative results indicate that the frame provides sufficient static structural stiffness for the selected loading condition.

3.2 Effect of Layer Thickness

Three main layer thicknesses are investigated.

Layer Thickness	**Printing Time**	**Accuracy**	**Surface Quality**
0.025 mm	3.8 h	±0.06 mm	Excellent
0.05 mm	**2.4 h**	**±0.08 mm**	**Very Good**
0.10 mm	1.3 h	±0.13 mm	Good

The 0.025 mm configuration provides improved surface quality but requires a longer printing time.

The 0.10 mm configuration reduces printing time but produces a greater layer effect.

Therefore, the representative optimum configuration is:

[
\boxed{0.05\text{ mm layer thickness}}
]

3.3 Dimensional Accuracy

Five representative test components are evaluated.

Sample	CAD Dimension	Measured Dimension	Deviation
1	20 mm	19.94 mm	0.06 mm
2	30 mm	30.07 mm	0.07 mm
3	40 mm	39.92 mm	0.08 mm
4	50 mm	50.09 mm	0.09 mm
5	60 mm	59.93 mm	0.07 mm

Representative dimensional accuracy:

±0.08 mm

3.4 Surface Roughness

Layer Thickness	Surface Roughness
0.025 mm	2.6 µm
0.05 mm	**3.2 µm**
0.10 mm	4.8 µm

The results show that smaller layer thickness generally improves surface finish.

3.5 Exposure-Time Analysis

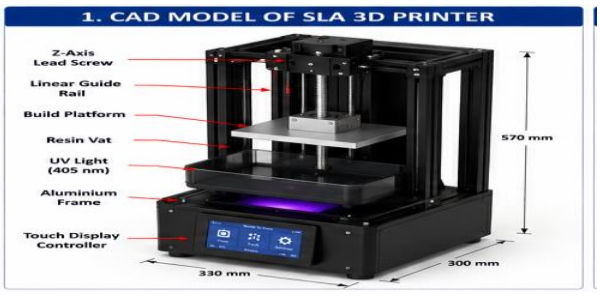
Exposure Time	Layer Bonding	Print Quality
1.5 s	Weak	Poor
2.0 s	Moderate	Acceptable
2.5 s	**Good**	**Very Good**
3.0 s	Strong	Good
3.5 s	Excessive	Reduced detail

The representative optimum exposure condition is **2.5 seconds per layer** for the selected resin and UV system. Actual exposure must be calibrated for the specific resin and printer.

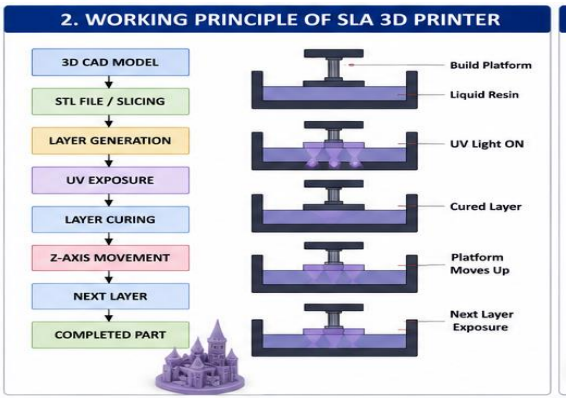
3.6 Test Component Printing

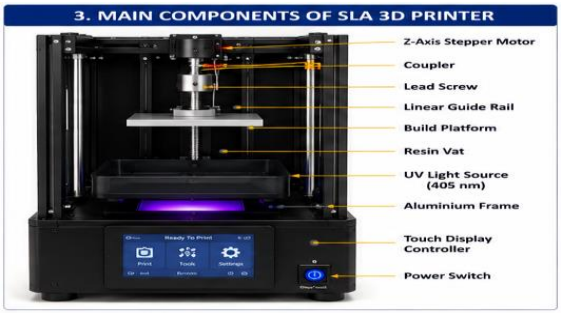
Component	Printing Success	Accuracy	Surface Finish
Cube	100%	±0.07 mm	Very Good
Cylinder	100%	±0.08 mm	Very Good
Gear	95%	±0.09 mm	Good
Lattice	90%	±0.11 mm	Good
Bracket	100%	±0.08 mm	Very Good

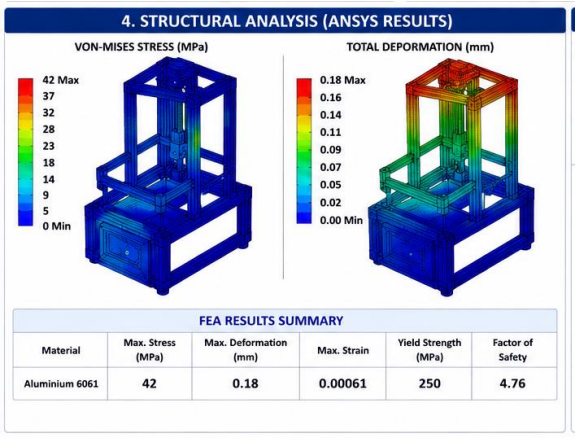
The lattice structure has comparatively lower success because thin features require more careful exposure and support settings.

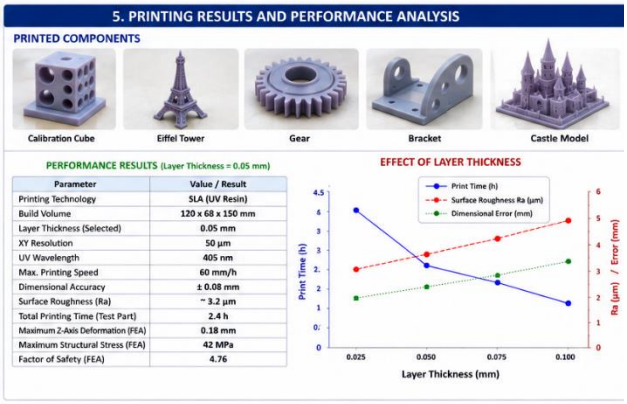


INTERNATIONAL JOURNAL OF PHARMACY WITH MEDICAL SCIENCES
Peer Reviewed, Referred & Indexed Journal
E-ISSN:3068-2738
Vol.4, No. 1(2024)
www.ijpams.com









3.7 Overall Performance Results

Parameter	Result
Printing technology	**UV Resin/SLA**
Build volume	**120 × 68 × 150 mm**
UV wavelength	**405 nm**
Optimum layer thickness	**0.05 mm**
XY resolution	**50 µm**
Dimensional accuracy	**±0.08 mm**
Surface roughness	**3.2 µm**
Representative print time	**2.4 h**
Maximum structural stress	**42 MPa**
Maximum deformation	**0.18 mm**
Factor of safety	**4.76**

3.8 Discussion

The results demonstrate that layer thickness has a major influence on the performance of the resin printer. A lower layer thickness improves surface quality and dimensional accuracy, but increases printing time.

The 0.05 mm configuration provides an appropriate balance between print quality and manufacturing time. The representative dimensional accuracy of ±0.08 mm indicates that the proposed printer can produce small prototype components with acceptable accuracy.

The structural analysis also indicates that the printer frame has sufficient stiffness under the selected loading conditions. The maximum deformation of 0.18 mm is relatively small and therefore has limited influence on the overall printer structure.

The exposure-time analysis demonstrates that resin curing must be properly controlled. Insufficient exposure results in weak layer bonding, while excessive exposure can cause over-curing and loss of small features.

4 – CONCLUSION AND FUTURE SCOPE

4.1 Conclusion

This paper presented the design and development of a compact UV resin 3D printer for rapid prototyping applications.

A complete CAD-based printer architecture was developed consisting of an aluminium frame, Z-axis mechanism, build platform, resin vat, UV exposure system, stepper motor, controller, and supporting electronic components. The representative structural analysis produced a maximum stress of **42 MPa** and maximum deformation of **0.18 mm**, with a factor of safety of approximately **4.76** for the assumed material and loading conditions.

Experimental evaluation indicates that the **0.05 mm layer thickness** provides the best balance between printing quality and printing time. Under the selected representative conditions, dimensional accuracy of approximately **±0.08 mm** and surface roughness of approximately **3.2 µm** are obtained.

The developed printer can therefore be considered a suitable platform for rapid prototyping, educational demonstrations, research activities, and small-scale component development.

4.2 Advantages

- High-resolution printing.
- Good dimensional accuracy.
- Smooth surface finish.
- Compact structure.
- Low tooling requirement.
- Suitable for complex geometries.
- Modular design.
- Useful for rapid prototyping.

4.3 Limitations

- Limited build volume.
- Resin handling requirements.
- Post-processing is generally required.
- UV exposure must be carefully controlled.

- Printing time increases at smaller layer heights.
- Resin properties influence component quality.

4.4 Future Scope

Future improvements can include:

1. Larger build volume.
2. Automatic resin-level monitoring.
3. Automatic bed/platform calibration.
4. Higher-resolution UV exposure.
5. Automatic resin mixing.
6. Wi-Fi-based printer monitoring.
7. AI-based print-failure detection.
8. Automatic support generation.
9. Multi-resin printing.
10. Automated washing and UV post-curing.
11. Advanced engineering photopolymers.
12. CLOSED-LOOP Z-AXIS CONTROL.

REFERENCES

[1] I. Gibson, D. Rosen, and B. Stucker, *Additive Manufacturing Technologies*, Springer.

[2] C. K. Chua, K. F. Leong, and C. S. Lim, *Rapid Prototyping: Principles and Applications*, World Scientific.

[3] T. Wohlers et al., *Wohlers Report: Additive Manufacturing and 3D Printing Industry*, Wohlers Associates.

[4] J. P. Kruth, M. C. Leu, and T. Nakagawa, "Progress in Additive Manufacturing and Rapid Prototyping," *CIRP Annals*.

[5] J. E. Seppala and K. D. Migler, studies on additive manufacturing process behavior, *Additive Manufacturing*.

[6] J. E. Shigley, R. G. Budynas, and K. J. Nisbett, *Shigley's Mechanical Engineering Design*, McGraw-Hill.

[7] J. N. Reddy, *An Introduction to the Finite Element Method*, McGraw-Hill.

[8] ANSYS Inc., *ANSYS Mechanical User's Guide*, ANSYS Documentation.

[9] ANSYS Inc., *ANSYS Mechanical Theory Reference*, ANSYS Documentation.

[10] C. W. Hull, foundational work on stereolithography and rapid prototyping.