MECHANICAL ENGINEERING DEPARTMENT

SIR BHAVSINHJI POLYTECHNIC INSTITUTE, BHAVNAGAR

CODE: 3361910 COURSES: PROJECT-II

PROJECT TITLE

Development, testing and benchmarking of 3D Printer

Sr. No.	Name	Enrollment No.
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2.	MAKWANA VAIBHAV R	206490319127
3.	RADADIYA MAYUR B	206490319012
4.	CHHAPRU HARSH J	206490319050
5.	MORI NIKHIL R	206490319104

NAME OF GUIDE

D.B. UPADHYAY SIR
LECTURER IN MECH. ENGG.

SIR BHAVSINHJI POLYTECHNIC INSTITUTE,
BHAVNAGAR

CERTIFICATE

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This is to certify that the following team/group members of Mechanical Engg. Dept MECHANICAL Division & Batch A, B have completed project work as per GTU, Ahmedabad syllabus.

Sr. No.	Name	Enrollment No.	Student sign
1	VAGHELA DHARMIK M	206490319038	
2	MAKWANA VAIBHAV R	206490319127	
3	RADADIYA MAYUR B	206490319012	
4	CHHAPRU HARSH J	206490319050	
5	MORI NIKHIL R	206490319104	

Sign. of Project Guide **Sign. of HOD/Principal**

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to everyone who has contributed to the successful completion of this 3D printer project.

First and foremost, we would like to thank our project guide **D.B. Upadhyay Sir**, for providing us with guidance and support throughout the project. His expertise and insights were invaluable in helping us overcome the challenges we faced.

We would also like to thank our colleagues who contributed their time, effort, and ideas in various stages of the project. Their input helped us improve the printer's design and functionality.

We extend our appreciation to our H.O.D. **A.A. Lohiya Sir** and our principal **Dr. A.S. Pandya Sir**, for providing us with the necessary resources and facilities to complete this project.

All of us also specially thank our guide **D.B. Upadhyay Sir** for giving us knowledge in addition to moral support. He guided us in the right direction in making our project.

Finally, we would like to thank our families and loved ones, whose unwavering support and encouragement kept us motivated throughout the project.

Once again, we thank everyone who has contributed to this project, directly or indirectly.

ABSTRACT

This report provides a comprehensive overview of the design, development, and implementation of a 3D printer that employs fused deposition modeling (FDM) technology. The primary objective of this project was to produce a cost-effective and dependable 3D printer that could be used for prototyping and small-scale production. Additionally, the printer was intended to be utilized in a college setting to introduce students to the FDM technology and 3D printing processes.

The printer was designed using computer-aided design (CAD) software and was constructed using readily available components, such as a microcontroller, stepper motors, and a heated bed. The software was also specifically developed to allow users to upload 3D models and divide them into layers that could be printed. A range of materials, including ABS and PLA, were tested on the printer, and the outcomes were compared to those of commercially available 3D printers. In order to measure the accuracy of the printer, we selected an industrial component impeller and benchmarked it against a commercially available printer by analyzing the quality, weight, time, and energy usage.

Finally, the report concludes with suggestions for enhancing the printer's design and features in the future.

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MECHANICAL ENGINEERING DEPARTMENT

SIR BHAVSINHJI POLYTECHNIC INSTITUTE, BHAVNAGAR

SUBJECT CODE: 3361910 SUBJECT NAME: PROJECT-II

PROJECT TITLE: 3D PRINTER DESIGN USING FUSED DEPOSITION MODELING (FDM) TECHNIQUE

T- Table

a b – Subtopic

1. Introduction to project

The history of printing starts from the duplication of images using stamps followed by the flatbed printing process in the 18th century. In mid of the 19th-century color printing called Chromolithography became very popular. A revolution occurred when the print workings, specifically a 2D printer was used as a peripheral device, which made a persistent human-readable representation of the graphics a text on paper. After some years the concept of the 3D printer starts evolving, a new way to look at past printing technologies.

Our report emphasizes the design and development of a low-cost 3D printer. The 3D printer is the concept to make or print objects layer by layer and thus making it so-called "Three dimensional". Nowadays 3D printer available is of higher costs that are due to the printing technology used and the material used in the 3D printer, so this project sparks upon making the 3D printer low cost by using scrap materials and designing a frame for the 3D printer.

The main aim of this project is to make the 3D printer available to the common man making this equipment easy to operate and automate working once the command and specific design are given to this device. So operating time will automatically decrease as it can handle the task without any human intervention. This project deals with or in other words, targets the people who have cost as a main strain and thus makes a 3D printer useful in school laboratories, making imitation jewelry for women, automobile industries, making prototype material in industries, etc.

1a Cartesian Configuration

Cartesian 3D printers are pretty much named after the coordinate system the X Y and Z axis which is used to determine where and how to move in three dimensions and the Cartesian 3D printers have a heated bed that moves only in the Z axis. The extruder sits on the X-axis and Y-axis, where it can move in four directions on a gantry. This is the principle that can be seen in action on the models from Ultimaker and MakerBot. With the Printrbot Simple instead of moving the print head purely in XY space, one of the axes is changed by moving the print bed itself. This is a very easy and simple design, and therefore it will be easier to maintain, but at the sacrifice of printing speed.

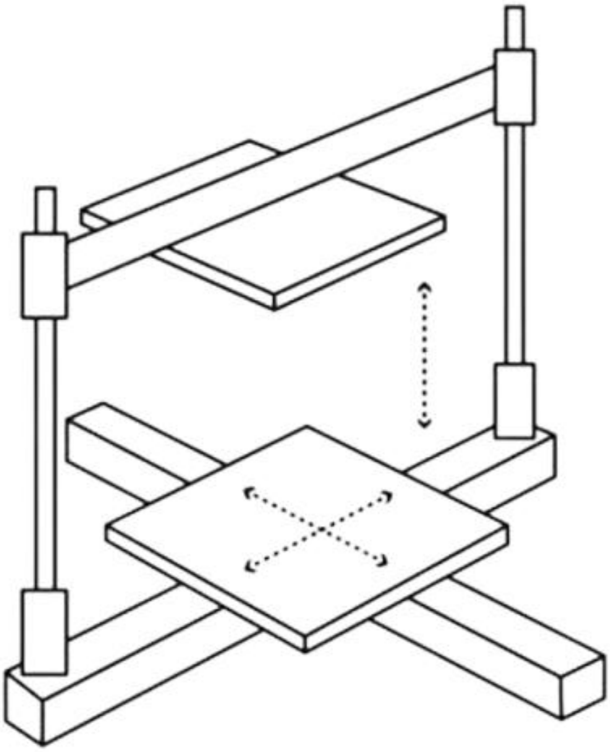

Fig. 1 Cartesian Configuration

1b Software Used for Printing (Ultimaker Cura)

The world's most advanced 3D printer software. Cura is Eco-friendly to face the slicing software so many users do not know how to realize what it is doing. Just load the cad model into the software, and select the quality that should be printed by pressing the print option in the software. It is as easy as traditional 2D printing. Essentially that is all Cura is print software can get a digital file from any computer to the 3D printer in any format. so that the 3D printing can understand itself for printing. Cura can be available free for you to download, but it is also open source. It is the standard software for 3D slicers worldwide. If you compare Cura to other 3D slicing software, it seems very simple in Cura there are many features available for slicing when compare to other software with limited options and adjustments. But Cura's has more complex settings are there if you need them; it has just been designed very neatly and user-friendly. Cura is developed by 3D printer manufacturer Ultimaker and, as everyone is known from their hardware, they are perfectionists. In the Cura software are almost all those settings and options that can be seen in most of the other slicing software. We can change the setting according to what we want to print by changing a few quality and speed options, then in Cura, it is all carefully laid out and ready to go. We are only going to assume that you have switched to the printer and loaded the filament. From that point, it can help to guide operations in the ways of Cura 3D and get started with 3D printing. Cura which can be creates a seamless integration between hardware, software, and materials for the best 3D printing experience around it support different file formats such as STL, 3MF, AND OBJ. we are using our 3D printer in STL file format because the model is completely designed from solid works and the file format is in STL. Every model we design for print must be translated by cura into instructions your Ultimaker will understand. The first thing you will need is a 3D model just make sure the export file is in STL file format so that cura understands it. within moments, cura slices your models ready for print. You can do any changes required for a 3D printer using the printer setting.

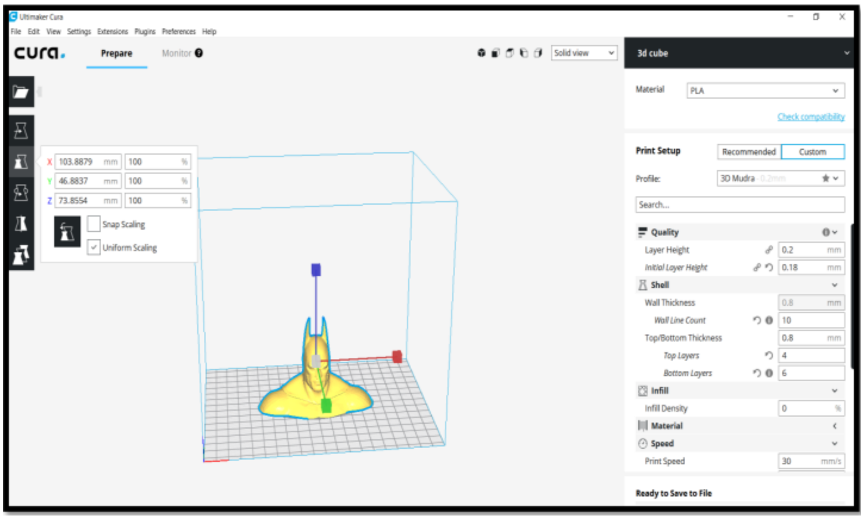

Fig. 2 Cura

Table 1 Work allocation matrix

Sr. no.	SHORT DESCRIPTION OF THE ACTIVITY	Responsible person name	Planned date	Actual date
1	Preparation of assembly & detail drawing in auto CAD.	CNS CHJ	10/12/2022	10/1/2023
2	Preparation of bill of the material sheet with make or buy decision.	DMV MVR	1/1/2023	15/1/2023
3	Preparation of estimation sheet of project.	RMB MNR	10/1/2023	18/1/2023
4	Row Material purchase activity for model manufacturing.	DMV MVR CNS	20/1/2023	22/1/2023
5	Readymade part purchase activity for project model.	DMV RMB MNR	25/1/2023	28/1/2023
6	Which Manufacturing process to be used	MVR CHJ	2/2/2023	7/2/2023
7	Startup of manufacturing activity and preparation of physical model.	DMV RMB	20/2/2023	4/3/2023
8	Project fund management and accounting activity.	DMV	10/3/2023	10/3/2023
9	Project actual cost calculation including all Row Material cost, Readymade part cost, manufacturing process cost, transportation cost, testing & inspection cost, documentation cost, etc.	CNS MNR MVR CHJ RMB DMV	20/3/2023	27/3/2023
10	Project report preparation, editing, and final printing.	DMV CHJ MVR	1/4/2023	9/4/2023

2. Project estimated cost calculation.

a. Raw Material Cost	1500/-
b. Bought out Part Cost	10000/-
c. Manufacturing Process Cost	500/-
d. Transportation Cost	1500/-
e. Inspection, Testing, Documentation Cost	1500/-
f. Overhead Cost	1500/-

Total Cost (Estimated)	16500/-

3. (a) Project detail drawings

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DETAIL DRAWING

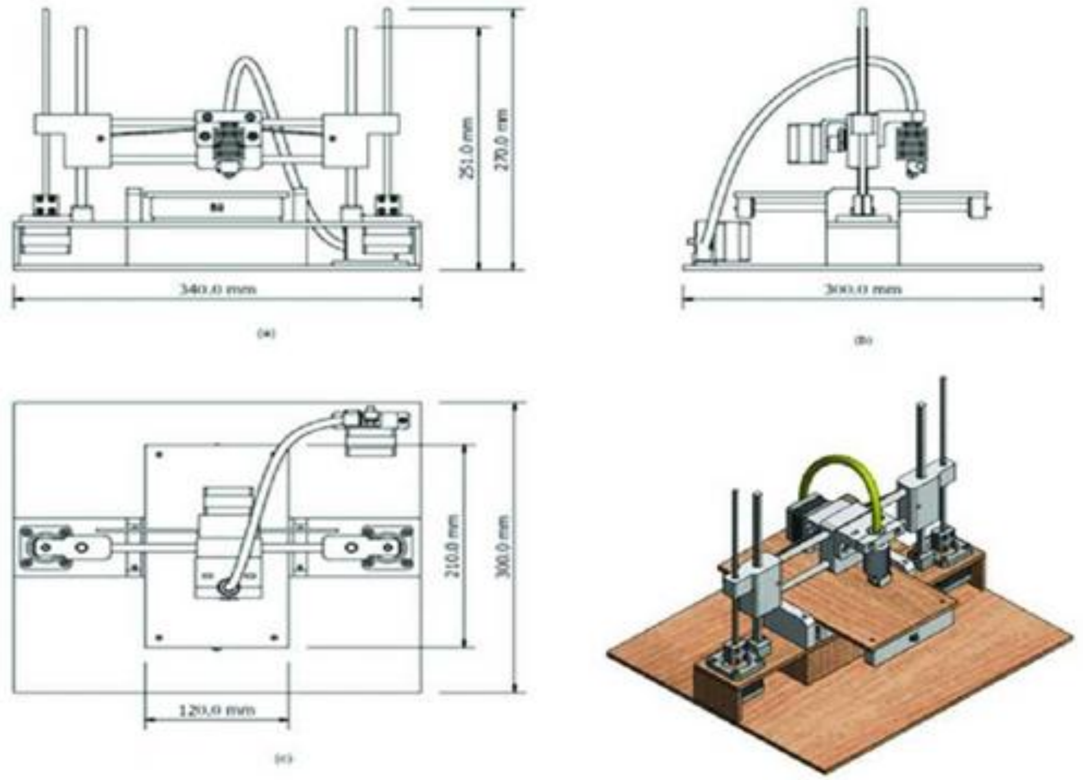

Fig 3. Detailed Drawing of 3D printer

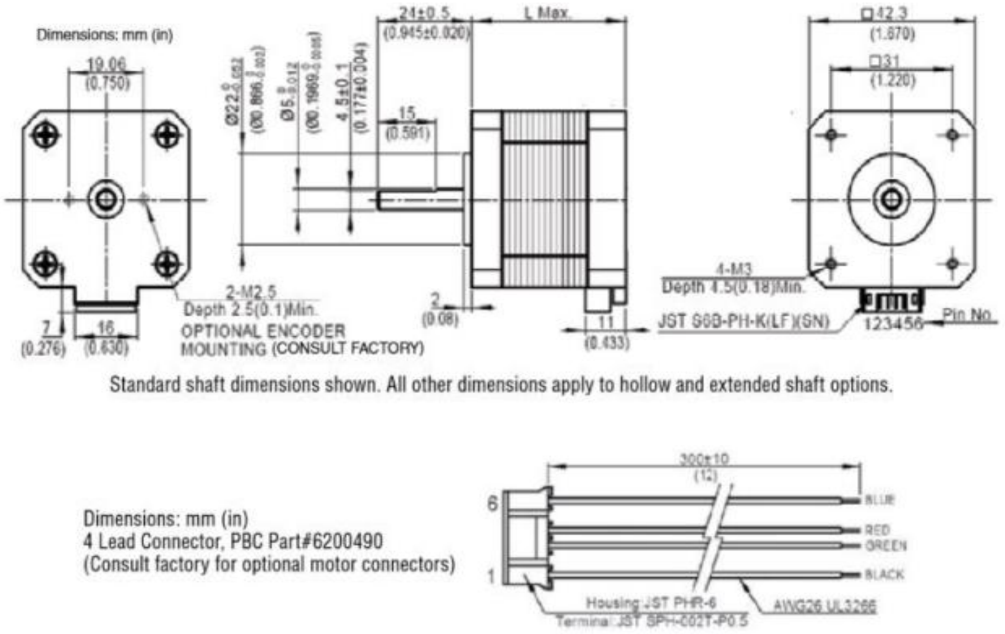

Fig 4. Detailed Drawing of extruder

(b) Assembly drawings

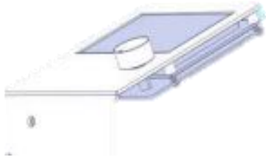

Fig 5. Display Screen

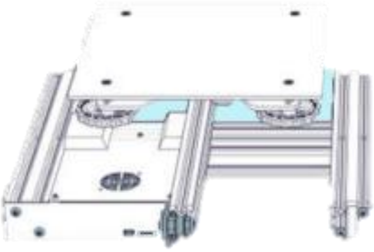

Fig 6. Bed

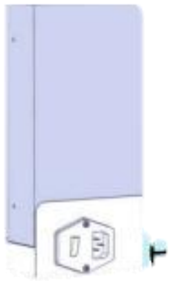

Fig 7. Power Supply

Fig 8. End Support

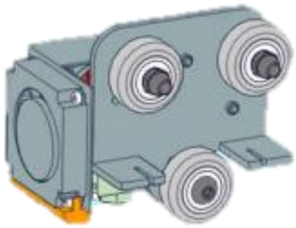

Fig 9. Nozzle Section

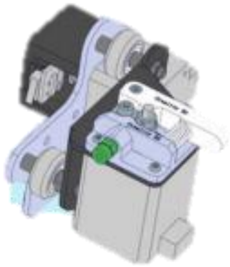

Fig 10. Extruder

Fig 11. Stepper Drive

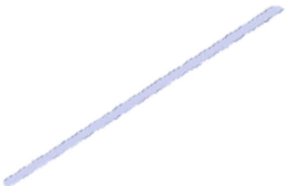

Fig 12. Lead Screw

Fig 13. Aluminum Frame

Fig 14. Power Cord

Fig 15. Timing Belt

Table no. 2 Bill of material with make or Buy decision

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Mechanical Engineering Department

BILL OF MATERIAL

Sr. No.	Part Name	Qty	Cost/Piece	Total Cost	Make/Buy
1	**Stepper Motor**	3	350	1050	Buy
2	**Arduino Maga**	1	1100	1100	Buy
3	**RAMPS 1.4 Shield**	1	300	300	Buy
4	**Stepper Drive A4988**	4	70	280	Buy
5	**E3D Hot End**	1	750	750	Buy
6	**LCD Display (128x64)**	1	250	250	Buy
7	**Heat Bed MK3**	1	750	750	Buy
8	**240watt Power Supply**	1	1350	1350	Buy
9	**PLA Filament (white)**	1kg	900	900	Buy
10	**MK8 Extruder Kit (Nozzle Included 0.5mm)**	1	850	850	Buy
11	**GT2 Timing Belt**	1	190	190	Buy
12	**GT2 Pulley 2m**	2	95	190	Buy
13	**SC8UU Bearings (8mm)**	1	270	270	Buy
14	**8mm Smooth Rods (1000mm)**	2	450	900	Buy
15	**Smooth Rod Holder(8mm)**	1	300	300	Buy
16	**Stepper Motor Mount**	1	250	250	Buy
17	**Threaded Rod (Dia. 10mm, Length 250mm, MS)**	1	320	320	Buy
18	**Angle Brackets (20mm)**	10	60	600	Buy
19	**M3 Screw**	10	4	40	Buy
20	**M3 Nuts**	20	3	60	Buy
21	**Acrylic Sheet (3mm)**	1	220	220	Buy
22	**Aluminum Channel for Frame**	2Kg	380	760	Buy
23	**End Stops (70cm Cable)**	6	60	360	Buy
24	**Stepper Motor Driver with Heat Sink**	5	40	200	Buy
25	**Couplers (8mm)**	5	50	250	Buy
26	**Other Expenses**			1340	
27	**Total**			**13800/-**	

Table no. 3 Specification of bought-out parts.

No. of Memory Sticks	1
Product Dimensions	22x22x25cm, 6.7Kg
Materials	PLA, ABS, TPU, etc.
Material System	Open Material System
Build Volume	220x220x250
Slicing	Ultimaker Cura
Extruder	Single
Feeder System	Direct
Print Bed Details	Heated Bed
Connectivity	SD Card, Mini USB
Nozzle Diameter	0.4mm
Filament Diameter	1.75mm
Print Speed Min.	30mm/sec
Print Speed Max.	180mm/sec
Printing Method	Fused Deposition Modeling
Power Supply	240 Watt
File Type	STL, G-Code
Average Power Consumption	0.125 KWh

4. Flow process chart for assembly of the project

The following flow chart shows the methodology used by us in the construction of a 3D printer. The first step is to select one of the additive manufacturing processes among many processes. Then an appropriate mechanism is selected for X, Y, and Z axis movements, considering various factors such as cost of fabrication, simplicity of design, synchronization, accuracy, etc. Once the mechanism is selected the next step is the integration of electronics and software then the machine is designed and fabricated. The last step is the synchronization of mechanical, electrical, and software elements of the machine.

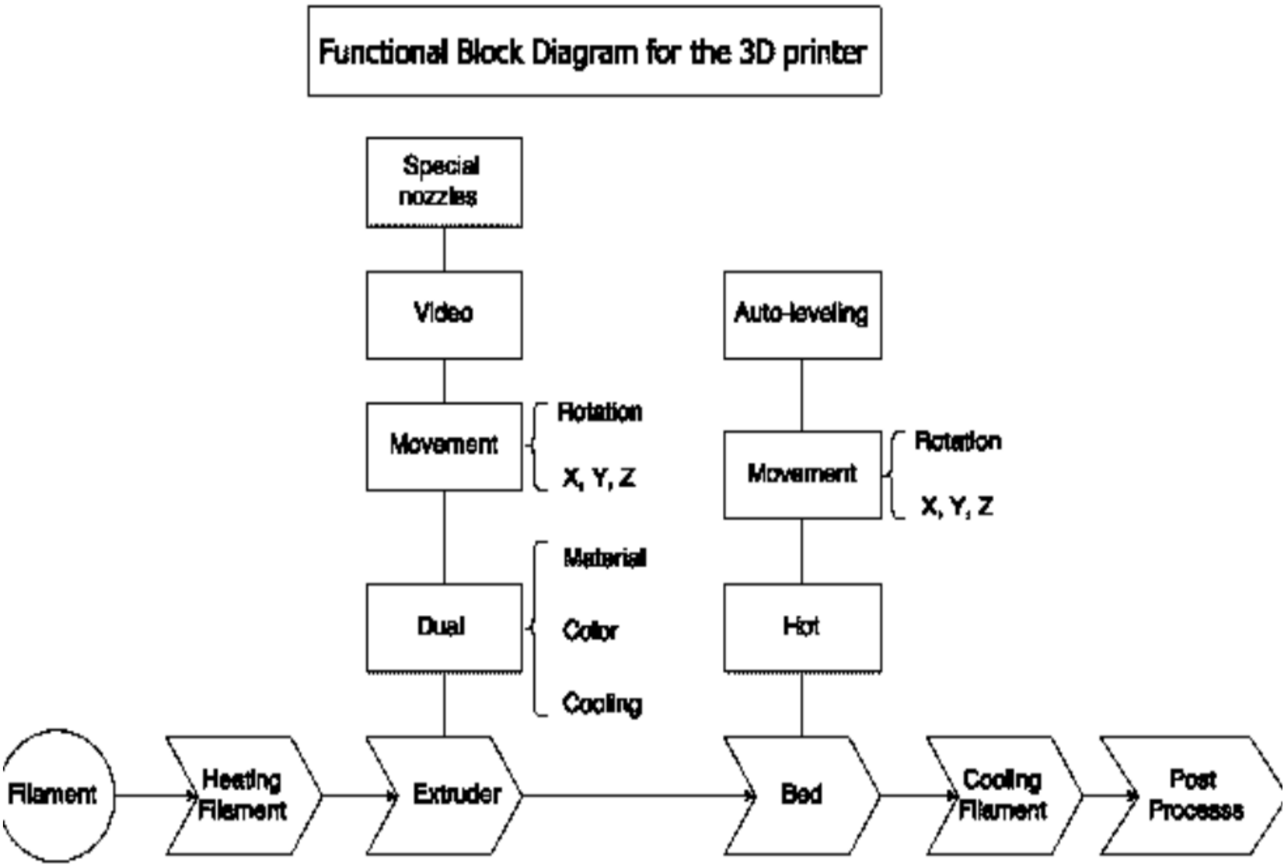

Fig 16. Flow Process Chart

5. Final dimension of the project model

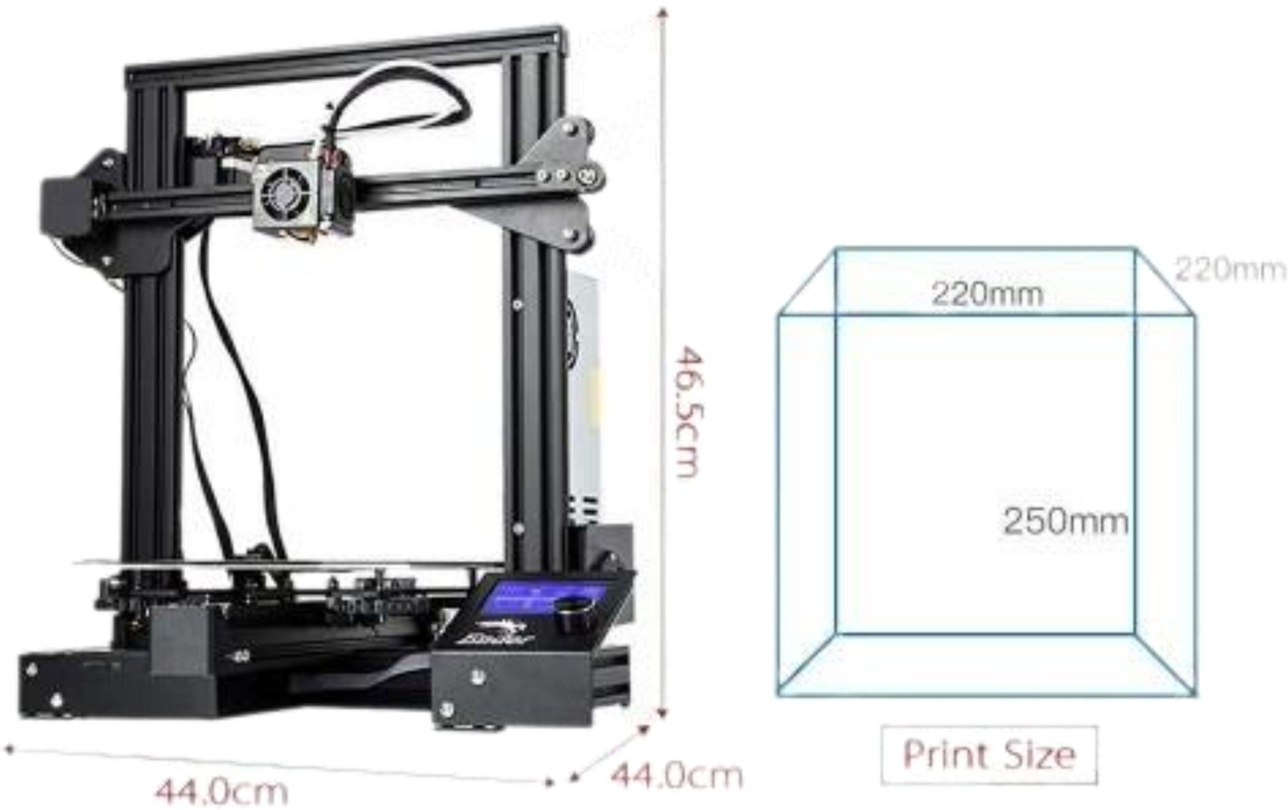

Fig 17. Dimensions of 3D Printer

6. Inspection and testing process used.

❖ Trial and Error Method

<u>Testing Model</u> – Impeller

<u>CAD Model</u> –

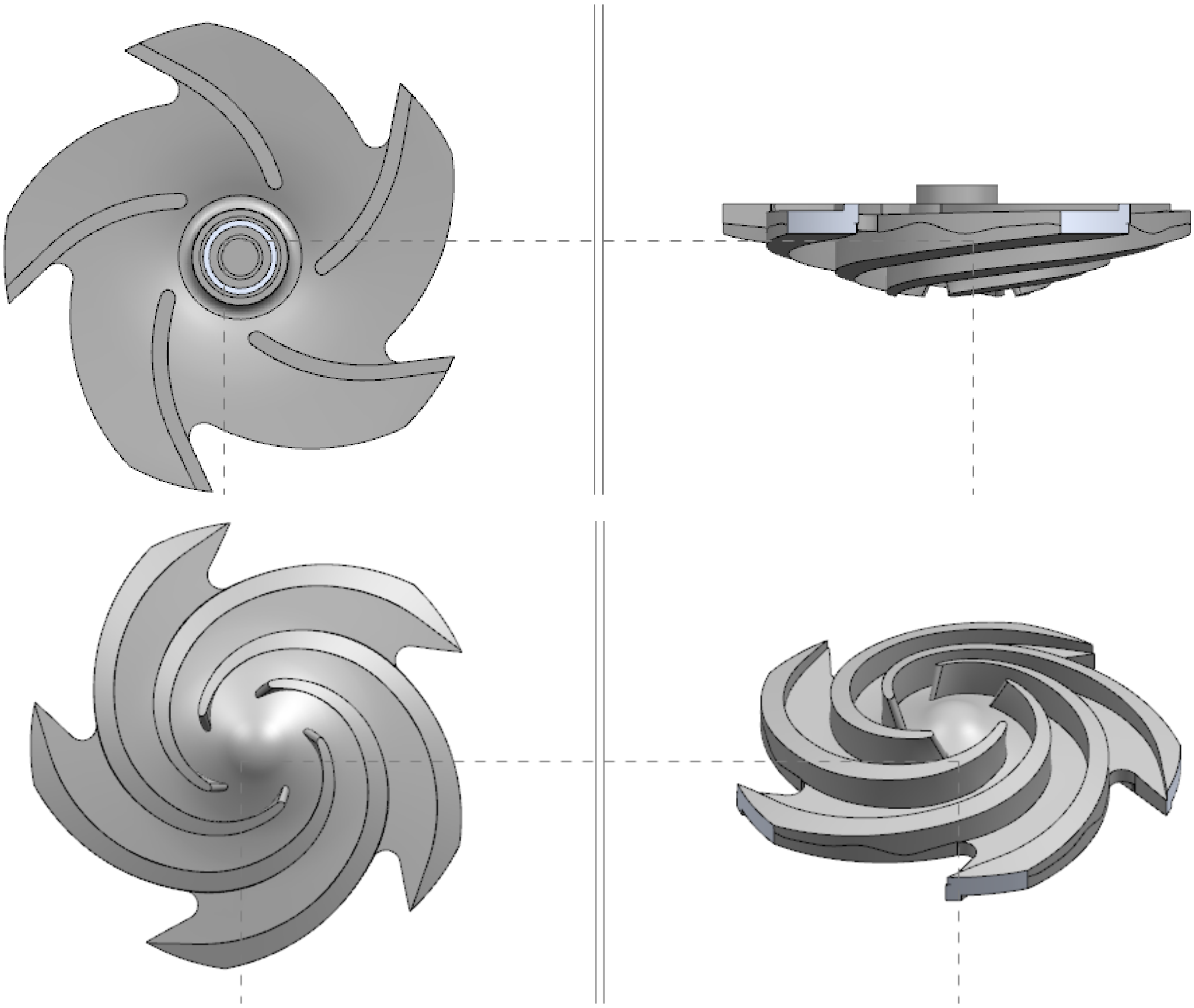

Fig 18. Impeller CAD Model in NX Software

CAD Model Dimensions –

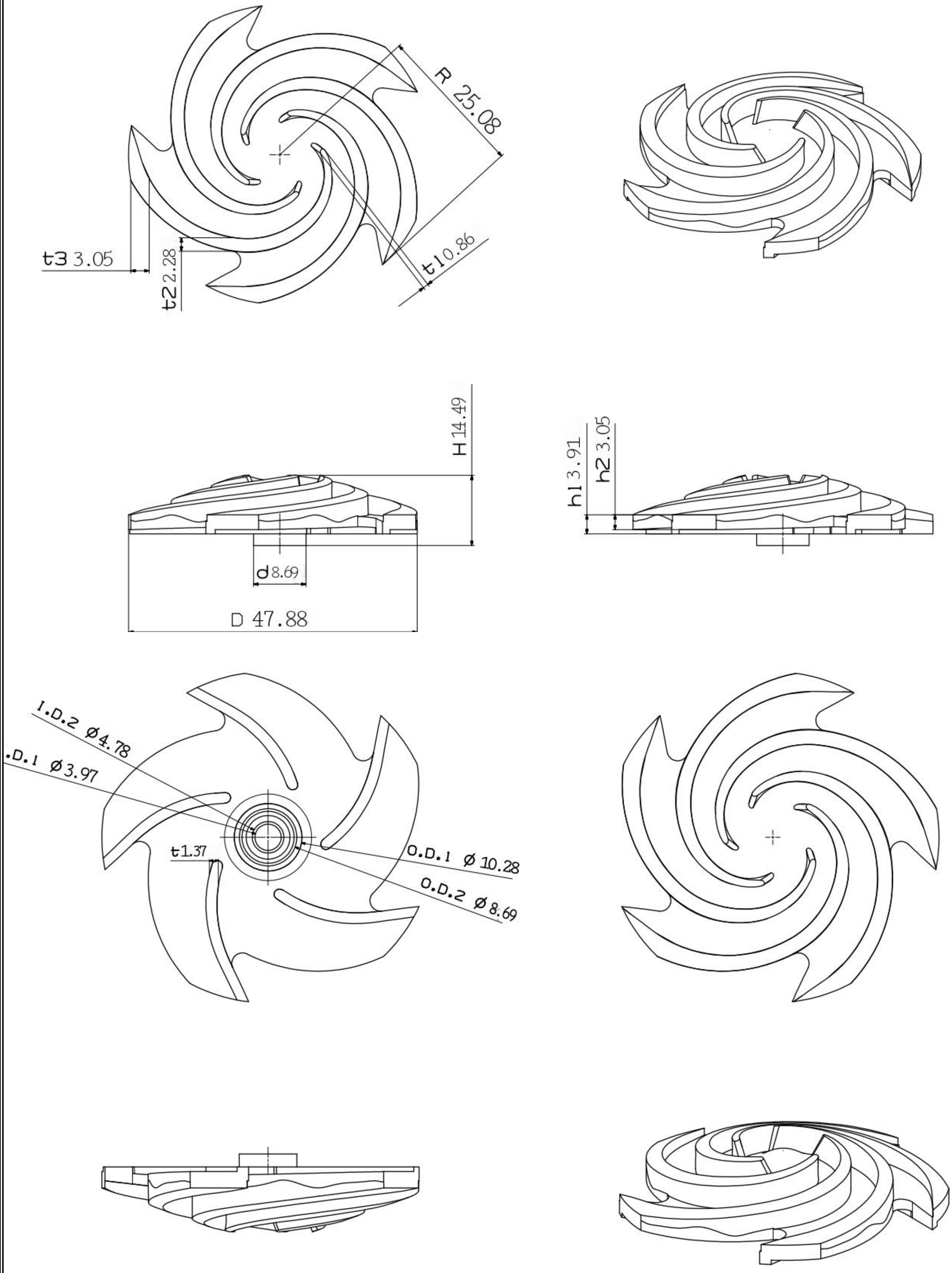

Fig 19. CAD Model Dimensions

Test no. 1 -

Machine used: - Project 3D Printer

Slicer: - Ultimaker Cura

Material: - PLA white

Impeller CAD Model: -

Model in Slicer (Cura): -

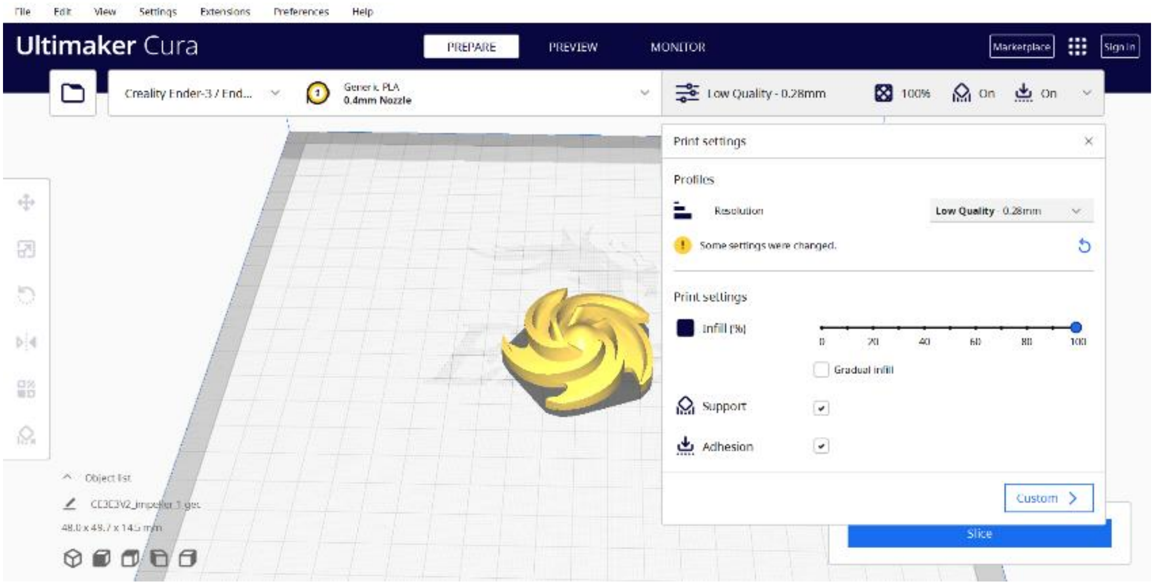

Fig 20. Cura Settings

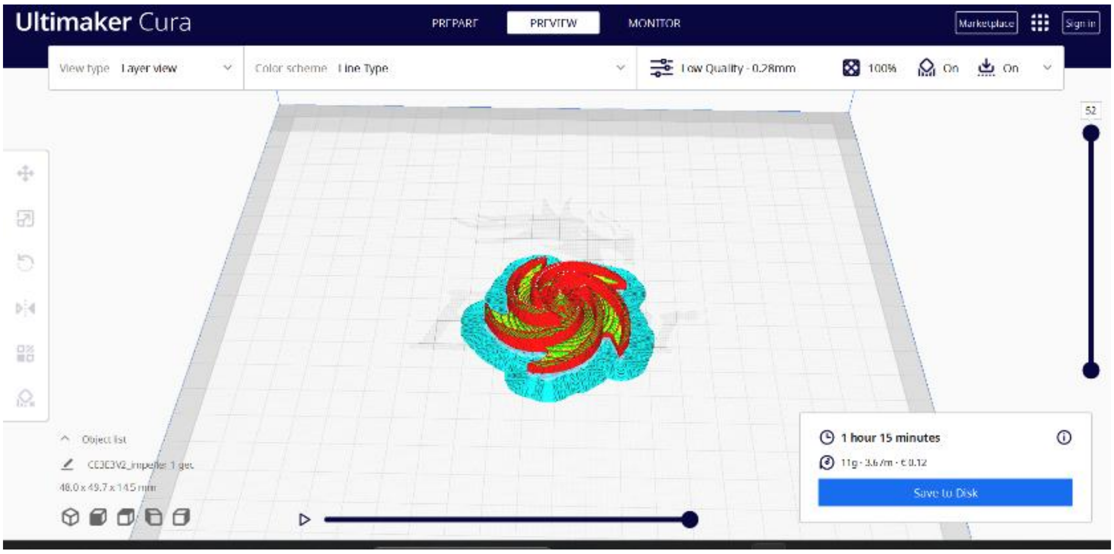

Fig 21. Model in STL Form

Data: -

Software Estimated Time	1 hour 16 minutes
Actual Time	1 hour 12 minutes
Time for Surface Finishing	45 minutes
Estimated Dimensions (E.D.)	48.0 x 49.7 x 14.5 mm
Actual Dimensions (A.D.)	47.52 x 49.51 x 13.60 mm
Difference (E.D. – A.D.)	0.2 to 0.5 mm
Total Time	1 hour 57 minutes
Estimated Total Weight (ETW)	11 grams
Actual Impeller Weight	7.2 grams
Actual Support Weight	1.8 grams
Actual Total Weight (ATW)	9 grams
Uncounted Material (Evaporated = ETW-ATW)	11-9 = 2 gram
Weight After Surface Finishing	7.4 grams
Power Consumption	0.125 KWh

Phases: -

Name of Phases	**Time**	**Energy**
CAD Modelling	1 hour 20 min	0.392 kWh
Preprocessing	10 min	0.075 kWh
Preheating	2.5 min	0.004 kWh
Printing	1 hour 15 min	0.125 kWh
Postprocessing	35 min	0 kWh
Total Time	**3 hour 23 min**	

Actual Model Photos: -

Fig 22. Weight of Support

Fig 23. Weight of the Model

Testing no. 2 -

Machine used: - Project 3D Printer

Slicer: - Ultimaker Cura

Material: - PLA RED (2-year-old)

Model in Slicer (Cura): -

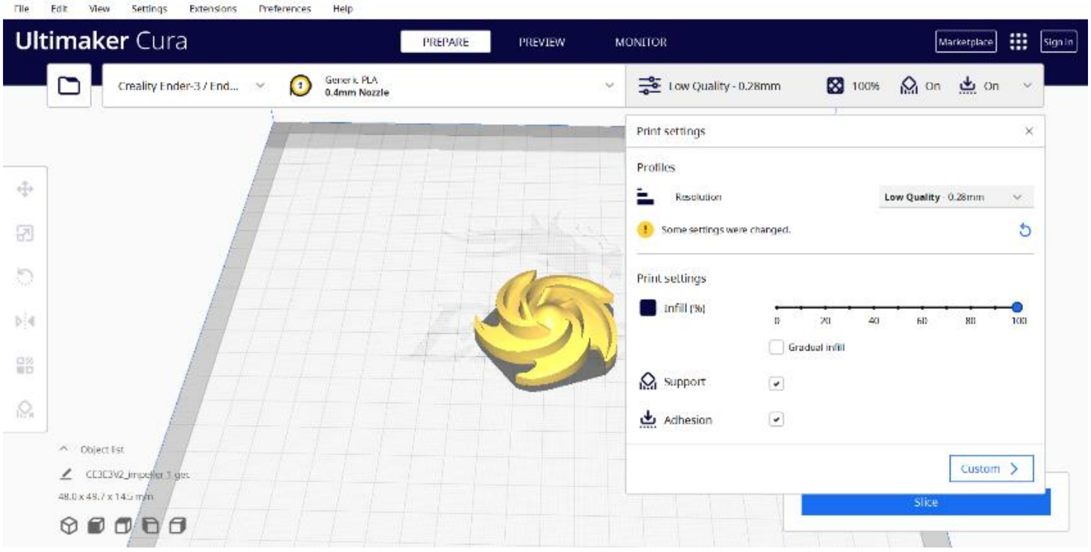

Fig 24. Cura Settings

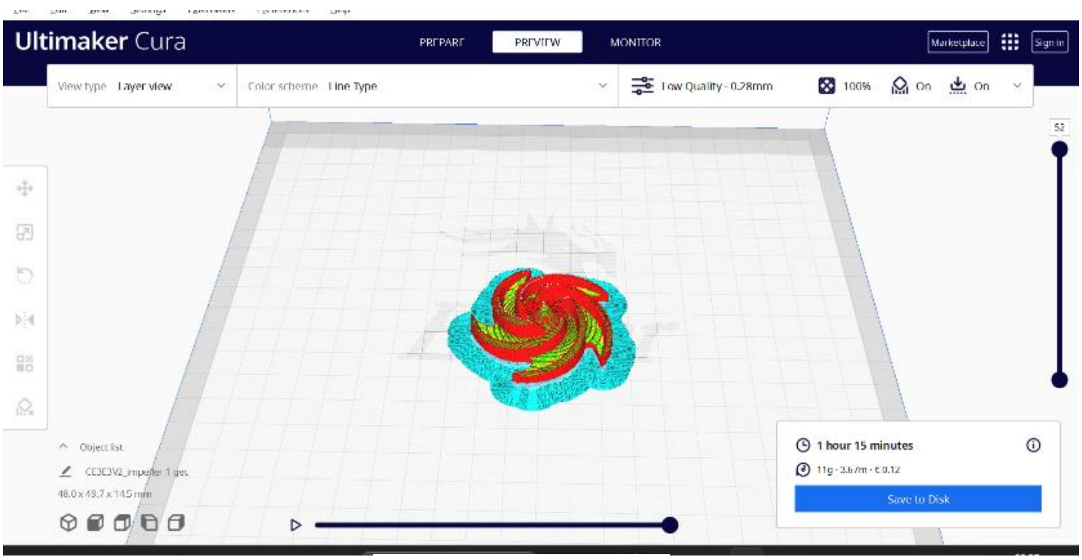

Fig 25. Model in STL Form

Data: -

Software Estimated Time	1 hour 16 minutes
Actual Time	1 hour 13 minutes
Time for Surface Finishing	45 minutes
Total Time	1 hour 58 minutes
Software Estimated Dimensions (E.D.)	48.0 x 49.7 x 14.5 mm
Actual Dimensions (A.D.)	47.52 x 49.51 x 13.60 mm
Difference (E.D. – A.D.)	0.2 to 0.5 mm
Estimated Total Weight (ETW)	11 grams
Actual Impeller Weight	7.8 grams
Actual Support Weight	1.8 grams
Actual Total Weight (ATW)	9.6 grams
Unaccounted Material (Evaporated= ETW-ATW)	11-9.6 = 1.4 gram
Weight After Postprocessing	7.4 grams
Power Consumption	0.125 KWh

Phases: -

Name of Phases	Time	Energy
CAD Modelling	1 hour 20 min	0.392 kWh
Preprocessing	10 min	0.075 kWh
Preheating	2.5 min	0.004 kWh
Printing	1 hour 15 min	0.125 kWh
Postprocessing	35 min	0 kWh
Total Time	3 hour 23 min	

Actual Model Photos: -

Fig 26. Weight of Support

Fig 27. Weight of the Model

Fig 28. Weight of leftover material

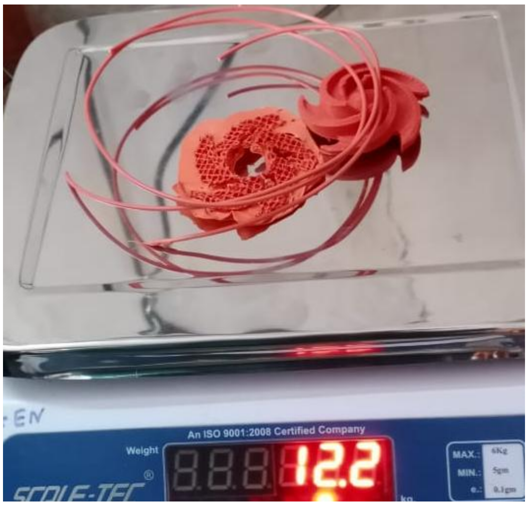

Fig 29. Weight of leftover material + Weight of support and model

Fig 30. Weight of material

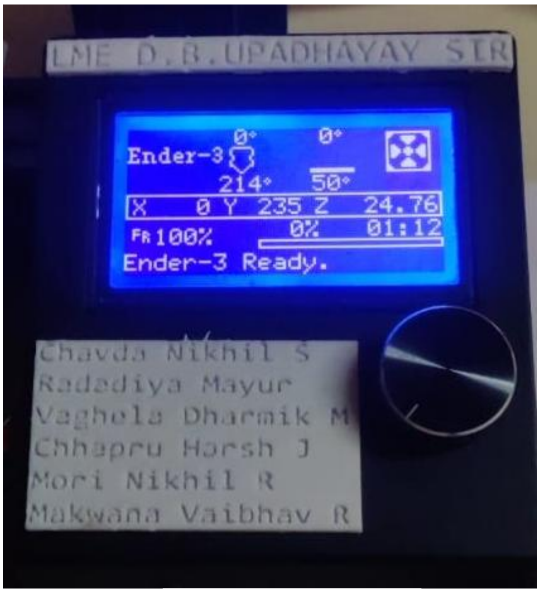

Fig 31. Display screen

Testing no. 3 -

Machine used: - 3D Cubic 4.5 Printer

Slicer: - Simplify 3D

Material: - PLA white

Data: -

Software Estimated Time	37 minutes
Actual Time	35 minutes
Time for Surface Finishing	45 minutes
Total Time	1 hour 15 minutes
Software Estimated Dimensions (E.D.)	48.0 x 49.7 x 14.5 mm
Actual Dimensions (A.D.)	47.72 x 49.59 x 14.10 mm
Difference (E.D. – A.D.)	0.2 to 0.5 mm
Estimated Total Weight (ETW)	10 grams
Actual Impeller Weight	7.5 grams
Actual Support Weight	1.8 grams
Actual Total Weight (ATW)	9.3 grams
Unaccounted Material (Evaporated= ETW-ATW)	10-9.3 = 0.7 gram
Weight After Postprocessing	7.4 grams
Power Consumption	0.125 KWh

Model in Slicer (Simplify 3D): -

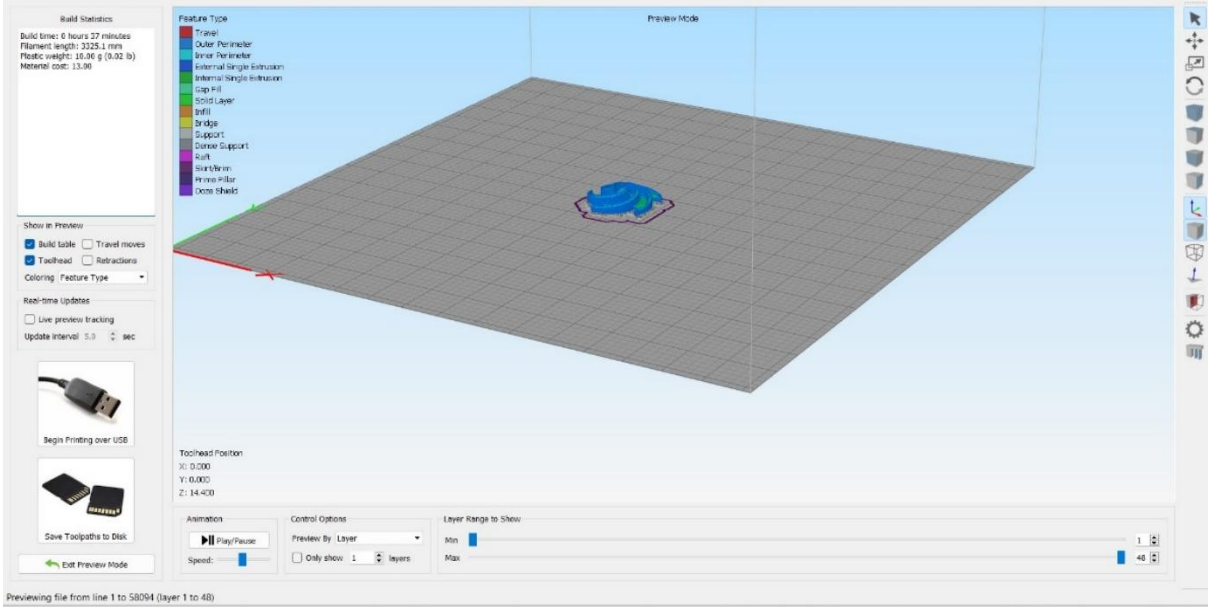

Fig 32. Simplify 3D Settings

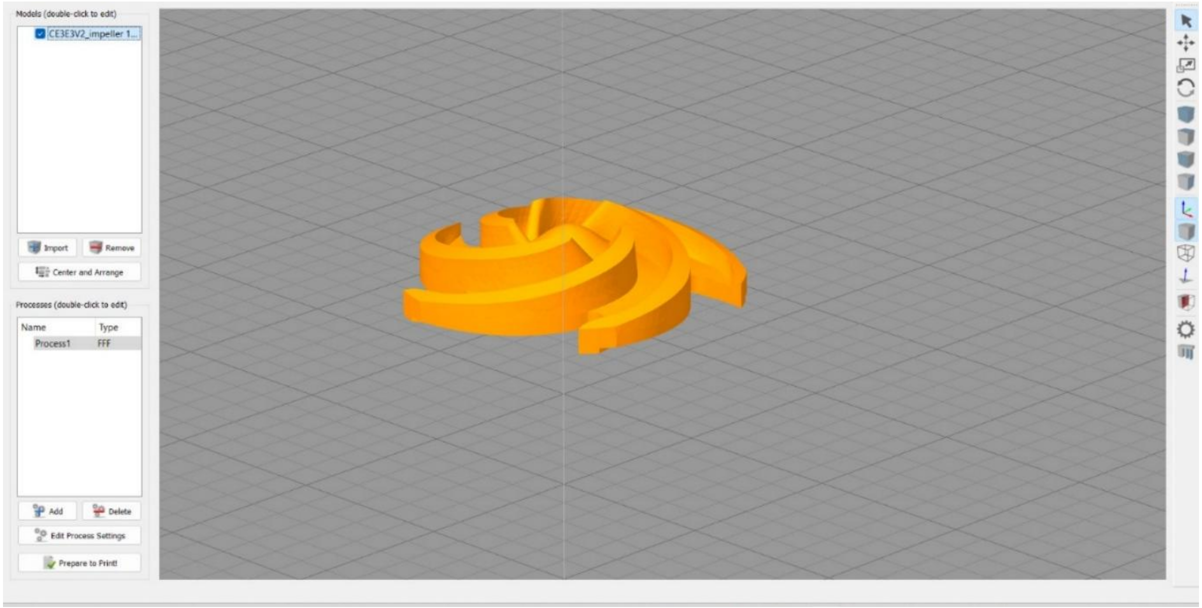

Fig 33. Model in STL Form

Quick Specifications of this printer: -

Advanced extended 3D Printer

Technology	FDM/FFF, Regulatory Compliance CE, ROHS
Build Size (W x D x H)	370mm x 390mm x 450mm
Slicer Software	Rize 2XC Slicer, 3DWOX Slicer
Materials	PLA, ABS, Composite, Nylon, Carbon Fiber Flexible, PCTPE, PVA, TPU, HIPS, PETG, P.C, WOOD
Filament Diameter	1.75 MM
Smart Features	Color Touch Screen, Onboard Storage
Connectivity	SD Card, USB, speed
Convenience Features	Auto Bed Levelling, Auto Nozzle Cleaning, Internal LED lights, Full Auto Levelling

Actual Model Photos: -

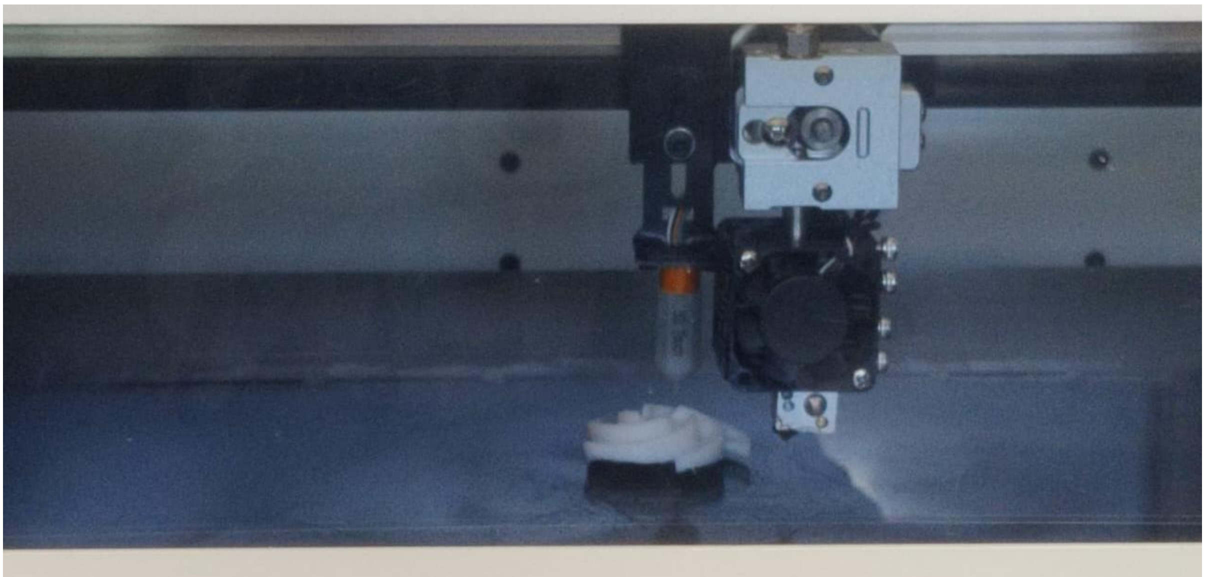

Fig 34. Printing

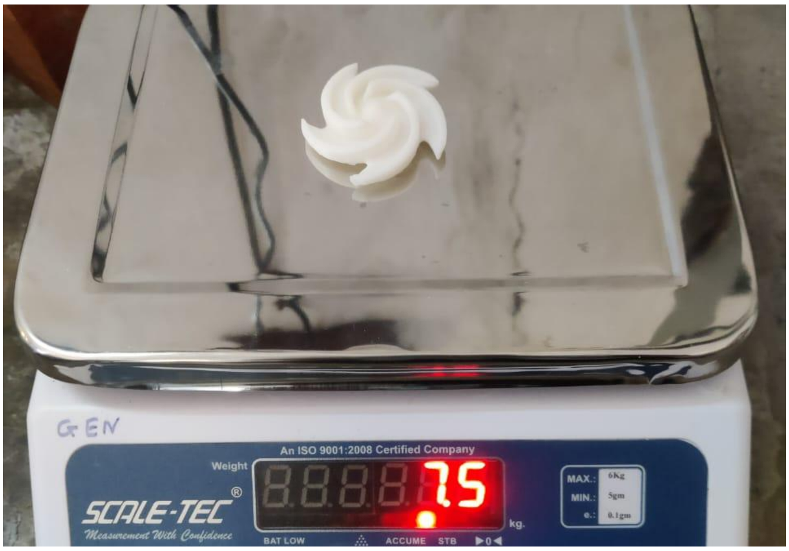

Fig 35. Weight of Impeller

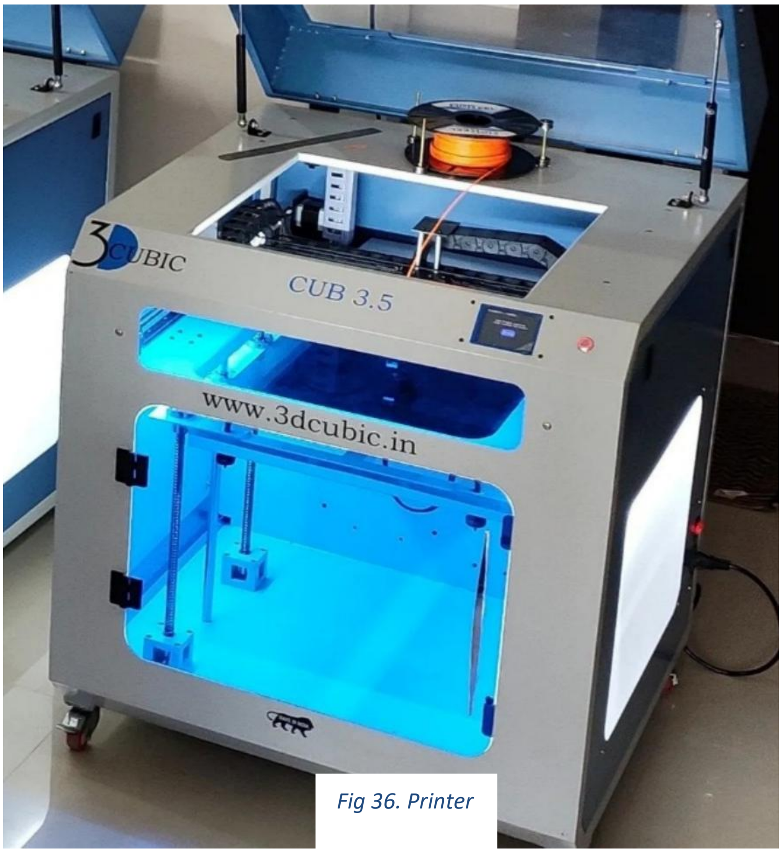

Fig 36. Printer

Dimensions Comparison: -

			Our 3D Printer						Industrial Printer		
Sr No.	**Parameters**	**CAD dimension**	**I1**	**A1**	**P1**	**I2**	**A2**	**P2**	**I3**	**A3**	**P3**
1.	**O.D.2**	8.69 mm	8.49 mm	-0.2mm	2.33%	8.40 mm	-0.29mm	2.52%	8.58 mm	-0.11mm	1.26%
2.	**O.D.1**	10.28 mm	10.02 mm	-0.26mm	2.52%	9.82 mm	-1.00mm	9.72%	10.10 mm	-0.18mm	1.75%
3.	**I.D.1**	3.97 mm	3.87 mm	-0.1mm	2.51%	3.83 mm	-0.14mm	3.52%	3.92 mm	-0.05mm	1.25%
4.	**I.D.2**	4.78 mm	4.65 mm	-0.13mm	2.69%	4.55 mm	-0.23mm	4.81%	4.69 mm	-0.09mm	1.88%
5.	**t**	1.37 mm	1.32 mm	-0.05mm	3.64%	1.29 mm	-0.08mm	5.83%	1.33 mm	-0.04mm	2.91%
6.	**t1**	0.86 mm	0.84 mm	-0.02mm	2.32%	0.81 mm	-0.05mm	5.81%	0.85 mm	-0.01mm	1.16%
7.	**t2**	2.28 mm	2.22 mm	-0.06mm	2.63%	2.18 mm	-0.10mm	4.38%	2.25 mm	-0.03mm	1.31%
8.	**t3**	3.05 mm	2.96 mm	-0.09mm	2.95%	2.91 mm	-0.14mm	4.72%	2.98 mm	-0.07mm	2.29%
9.	**R**	25.08 mm	24.77 mm	-0.28mm	1.05%	24.42 mm	-0.36mm	1.43%	24.88 mm	-0.20mm	0.79%
10.	**H**	14.49 mm	14.22 mm	-0.27mm	1.86%	13.99 mm	-0.50mm	3.45%	14.34 mm	-0.15mm	1.03%
11.	**h1**	3.91 mm	3.80 mm	-0.11mm	2.81%	3.7 mm	-0.21mm	5.37%	3.83 mm	-0.08mm	2.04%
12.	**h2**	3.05 mm	2.99 mm	-0.06mm	0.19%	2.95 mm	-0.10mm	3.27%	3.01 mm	-0.04mm	1.31%
13.	**D**	47.88 mm	47.11 mm	-0.77mm	1.60%	46.47 mm	-1.25mm	2.61%	47.49 mm	-0.28mm	0.58%
14.	**d**	8.69 mm	8.47 mm	-0.22mm	2.53%	8.39 mm	-0.30mm	3.45%	8.59 mm	-0.10mm	1.15%

I- Impeller, A- Accuracy, P- Percentage of Accuracy

Accuracy: -

Accuracy of our 3D Printer: - I1 (White Impeller): -

(8.49/8.69), (10.02/10.28), (47.11/48.88), (14.22/14.49) = 0.975660

around 97 to 98%

Tolerance- ±200 microns

I2 (**Red Impeller): -**

(8.40/8.69), (9.82/10.28), (46.47/47.88), (13.99/14.49) = 0.976380

around 96 to 97%

Tolerance- (±250 microns)

Accuracy of Industrial 3D Printer: - I3

(8.58/8.69), (10.10/10.28), (47.49/47.88), (14.34/14.49) = 0.98977

around 98.5 to 99.5%

Tolerance- (±75 microns)

Conclusion: -

These experiments have shown the importance of carefully selecting and configuring the printer's settings, such as the printing temperature and speed, to achieve optimal results. Overall, these experiments have shown accuracy and quality of output from our 3D printer are neck-to-neck with the output from industry-level 3D printers.

We should avoid using outdated PLA material, such as the red one we previously used. We observed that the nozzle tended to clog during the printing process, causing the build to adhere too strongly to the bed and making it challenging to remove. Additionally, the material exhibited a rubber-like consistency when we attempted to detach the build.

7. Actual costing of the project.

Raw Material Cost	1300/-
Bought out Part Cost	8000/-
Manufacturing Process Cost	500/-
Transportation Cost	1500/-
Inspection, Testing, Documentation Cost	900/-
Overhead Cost	1300/-

Total Cost (Estimated)	13500/-

Table no. 4. Comparison between estimated and actual project cost with probable reasons.

Material	Estimated Cost	Actual Cost
RAW MATERIAL COST	1500/-	1300/-
BOUGHT OUT PART COST	10000/-	8000/-
MANUFACTURING PROCESS COST	500/-	500/-
TRANSPORTATION COST	1500/-	1500/-
INSPECTION, TESTING, AND DOCUMENTATION COST	1500/-	900/-
OVERHEAD COST	1500/-	1300/-
TOTAL COST	16500/-	13500/-

The difference between the Estimated Cost and the Actual Cost is

= 16500 - 13500

= 3000/-

8. Actual project model photographs.

Fig 37. Group Photo

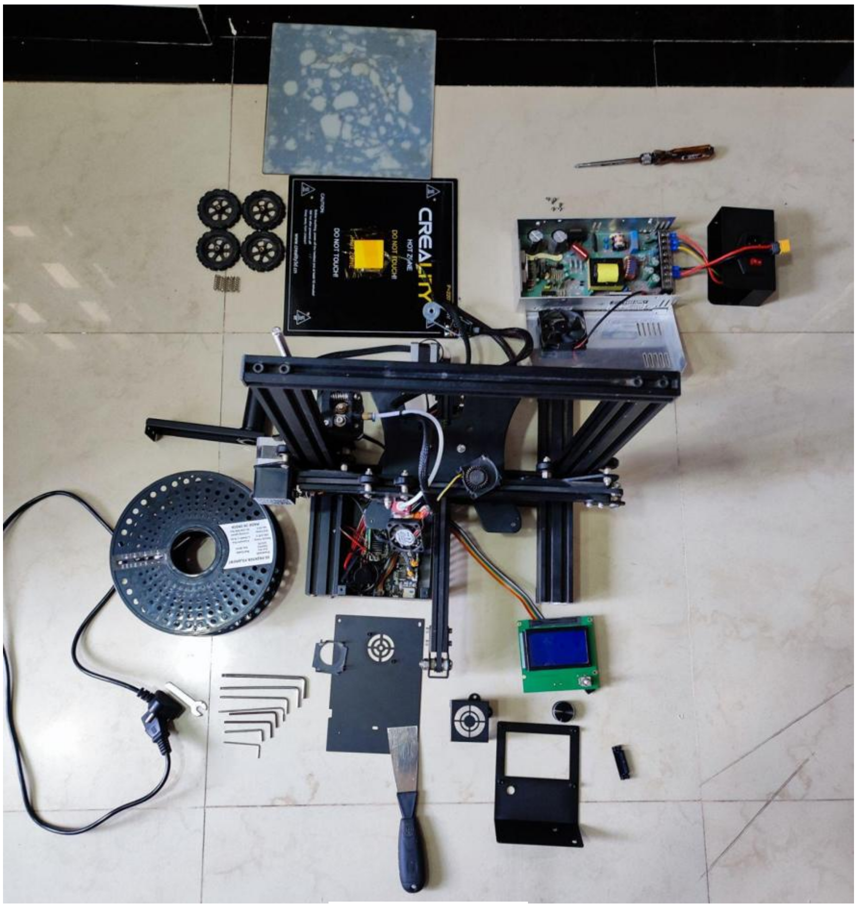

Fig 38. All Parts

Fig 39. Printer Frame

Fig 40. 3D Printer

9. CONCLUSION

In conclusion, this 3D printer project has successfully achieved its objectives of designing, developing, and implementing a functional and affordable 3D printer that can be used for prototyping and small-scale production. Through careful consideration of design, the use of off-the-shelf components, we were able to create a reliable and easy-to-use printer.

The printer's testing showed that it can print using a range of materials, including TPU, PLA, etc., and that the quality and accuracy of the prints are comparable to those of commercially available 3D printers. However, there is still room for improvement in terms of print speed and precision.

We recommend further testing and improvement of the printer's design and software, to ensure that it meets the evolving needs of the 3D printing industry. With continued research and development, we believe that 3D printing technology will continue to revolutionize manufacturing processes and open new possibilities in design and production.

10. REFERENCES

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