Design, Analysis and Fabrication of 3D Printer

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ABSTRACT:

Additive manufacturing processes directly create Products by stacking layers of materials on top of each Other until the desired product is achieved. The use of Additive manufacturing technologies in teaching and Research is still limited and unpopular in developing Countries due to cost and lack of access. In this study, Extrusion-based 3D printing additive manufacturing Technology was used to design and build a low-cost, High-capacity 3D printer to produce plastic products. The machine was designed using SolidWorks 2020 Version and has a volume of $10\times10\times10$ cm3. Local Materials such as PVC pipe for the frame, plywood for the bed, and zinc oxide plaster for the bed surface are Used in the construction process. Repetier firmware is the operating system of a device that runs on a computer operating system. Use Cura as slicing Software. The machine is designed and tested, and the printer produces 3D objects with the appropriate model. 3D printing is used to create some plastic products using PLA filament. The recommended distance between the Head and the bed is 0.1 mm. 3D printers are designed to Be affordable and easy to use, especially in developing Countries where 3D printing applications are limited.

Key Words: - 3D printer, Additive Manufacturing, Slicing Software, Firmware

INTRODUCTION:

For decades, machines and parts have been welding, folding, soldering, machining, etc. It is produced using traditional methods such as. This method creates parts and parts by removing parts from a block to achieve the desired geometry. Processes enable people to create different products. However, many limitations limit its effectiveness and efficiency – the equipment is difficult to manufacture, competitive, time-consuming and labor-intensive, has drawbacks and is precise, expensive and a waste of materials. The introduction of harmful activities such as Radiation, chemical and computer technology helps reduce these negative effects. In contrast, additive manufacturing produces products by processing materials in continuous processes. An example of additive manufacturing is three-dimensional (3D) Printing, which is the process of producing 3D products from digital data. Three-dimensional printing has computer-aided design, additive materials and technology. The printing process begins by using computer-aided Design (CAD) software to create digital objects or by using a 3D scanner to capture the objects. Popular software options include SolidWorks, AutoCAD, Inventor and more. Despite the increasing shift from extraction to additive manufacturing worldwide, the use of additive manufacturing (such as 3D printing) is still increasing in developing countries. This is because production as well as Teaching and research are unpopular and difficult due to the high cost of purchasing and offering 3D printing technology in universities in underdeveloped countries. It is often difficult to transport 3D printed products abroad and replace damaged parts. It is difficult to repair and replace parts, when necessary, especially for plastic products that Deteriorate quickly. Therefore, there is a need to design and manufacture low-cost, easy-to-use 3D printers to create Plastic objects and materials for educational and research purposes in higher education in developing countries.
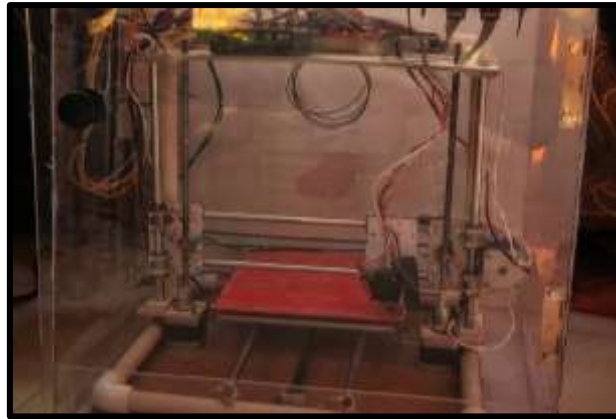
Fig – 3D printer using PVC pipe structure

PROBLEM STATEMENT:

After studying all the literature survey some issues were Discovered which arises while printing, where the first Layer or the base which should get printed correctly as the First layer doesn't stick well to the bed, the print may move or shift from its position before it is completed. Sometimes, 3D objects from outermost side looks stunning however While inspecting the strength of the model it could be weak Inside. As a result, the infill or the molten plastic is not Precisely filled inside the model/object due to which it Causes poor strength of the model. Also, in some cases of 3D Printing, there is over extrusion because of which Sometimes, the extruder ejects excess amount of material and thus leading to thick layers, which changes the shape of the object to be printed. This over extrusion can also cause serious issue like nozzle jams and even form bubbles over the print which makes the print unachievable. Therefore, in this project, the problems arise while printing the model are investigated and to get the best precision and accuracy for printing is analyzed.

SCOPE AND OBJECTIVE:

1. To ensure that the 3D printer model achieves maximum strength and durability.

2. To analyze various layer heights for the best precision of model.

3. To study different infill pattern to get the finest Infill / inner strength of model.

4. To reduce the time required for overall print.
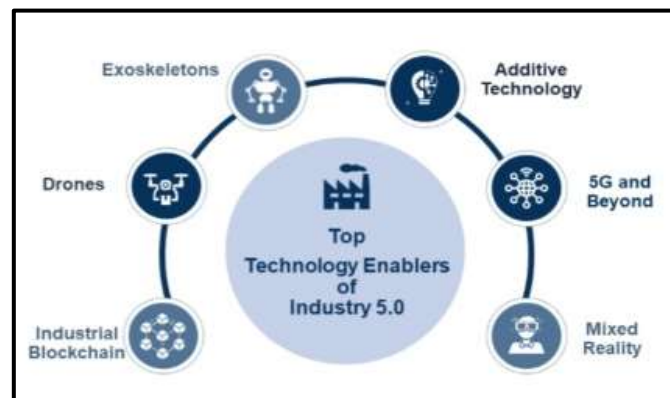
Fig– Technology implementation in Industry 5.0

METHODOLOGY:

The chart explains the project flow and details of the steps to be followed. It provides the discussion about the flow to Be carried out. The methodology of the project is as per the Research it is conducted by us of the methodology for the Design, fabrication, and analysis of the 3D printer with a PVC Pipe frame involves several steps to ensure a comprehensive understanding of the Project's construction and performance. Firstly, the design phase begins with Conceptualizing the layout of the 3D printer. This involves sketching out the frame structure using PVC pipes and Determining the Placement of components such as the Arduino Uno, RAMPS 1.4, Nema 17 stepper Motors, end Stops, power supply, A4928 stepper motor drivers, E3D Hotend,

extruder, GT2 belt and pulley couplet, shaft coupler, M5 threaded rods, LM8UU bearings, 8mm Smooth rods, and Printer bed. Once the design is finalized, the fabrication process Commences. PVC pipes are cut and assembled according to the design specifications to create the frame of the 3D Printer. Components such as stepper motors, end stops, hotend, Extruder, belts, pulleys, and Bearings are mounted onto the Frame using appropriate fixtures and connectors. Wiring Connections are made between the electronic components And the Arduino Uno, ensuring Proper routing and Insulation to prevent short circuits. Following fabrication, the calibration stage is crucial for Ensuring accurate printing. This Involves adjusting the Settings of the Arduino Uno, RAMPS 1.4, and stepper motor Drivers to achieve precise movements of the printer's axes. Calibration also includes fine-Tuning parameters such as Bed leveling, nozzle height, and extrusion rates to optimize Print quality. With the printer calibrated, test prints are Conducted to evaluate its performance. A small 20 x 20 x 20 Cube is printed using the Ultimaker Cura software, serving as a benchmark for quality analysis. Various metrics are Assessed, including infill density, print speed, Shell Thickness, and overall dimensional accuracy. Quality analysis involves inspecting the surface finish of the Printed cube, checking for Any defects or inconsistencies in Layer adhesion and overhangs. Infill analysis assesses the Density and uniformity of the internal structure, ensuring Adequate strength and stability of the printed object. Speed Analysis evaluates the printing speed relative to the Desired Quality, identifying any trade-offs between speed and Accuracy. Shell analysis examines the thickness and integrity of the Outer shell layers, verifying That they provide sufficient Structural support and surface smoothness. Finally, the Results of the 3D printed cube are analyzed Comprehensively, considering all aspects of its Fabrication And performance. Any deviations from expected outcomes Are documented, and recommendations for
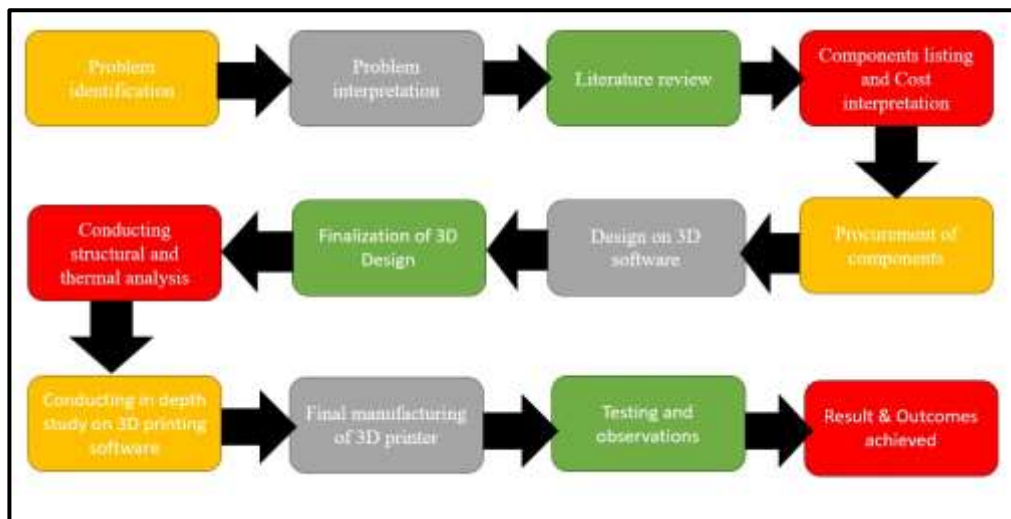
improvements or adjustments to the printer design and settings are proposed.

Fig – Flow chart of 3D printer project

WORKING: To print the product using this 3D printer, you can follow the steps below:

1) Use computer-aided design (CAD) software to create the model and ensure that the model is exported with 3D printing compatibility. STL or .OBJ;

2) Load the model file into the slicing software and make necessary settings such as speed, temperature, layer height, shell, thickness, infill, support and filament settings;

3) Save G code pattern, before automatically generates the entered G code pattern and saves it as a document;

4) Transfer the saved data to the SD card and then insert it into the printer's main board;

Connect the printer to the power source and test the printer, making sure the bed is level and all axis movement mechanisms are working;

5) Insert filaments and print the model to the printer Save the data to the SD Card when the model is printed and if necessary, remove it from the bed after printing.

6) Different models are printed to determine the accuracy and performance of the 3D printer.

The main factors considered in 3D printer design are construction cost, size, durability, assembly, material availability and application. The total cost of the machine must be low so that people in the country can afford it. The 3D printer was designed to contain a printing volume of $10 \times 10 \times 10$ cm3, which is the maximum geometric size of the resulting object. The machine is designed to print polylactic acid (PLA), bioplastic and thermoplastic monomers made from agricultural products such as corn starch or sugar cane. Since PLA does not emit harmful gases when heated, it is considered safer to use in 3D printing experiments in schools and universities.

It Is designed for semi-mounting. This makes the machine robust, easy to maintain and durable. The machines were designed with local materials in mind. This is to ensure that the product can be easily replaced if necessary. Materials that can withstand vibration resulting from electrodynamic movements are also taken into account. Durability and safety standards of the machine were also taken into consideration during the design.

Design Calculation

Design of the Stepper Motor

The linear velocity v of the stepper motor is calculated using Equation (1).

$V = r\omega$; $\omega = 2\pi N / 60$ …...[1]

where r is the radius of curvature of circular path = 6.25 mm; ω is the angular speed of the motor; N is the constant speed of the motor = 600 rpm. By computation, v = 398.29 mm/s.

The force due to the electric motor is calculated using Equation (2).

$$\text{Force} = \frac{Torque}{\text{Radius of curvature of circular path}}$$

By computation, force = 67.4 N

Therefore 6.74 kg can be pulled over a distance of 398.29 mm in one second using NEMA 17.

Design of Timing Belt

The width of the belt is calculated using Equation (3)

$$W = \frac{Ff}{\sigma t}$$

where w is the width of the belt; σ

Is the ultimate strength of polyurethane =   20.75 MPa; F Is the force of the electric motor; f Is the factor of safety = 2; t is the belt thickness = 1.2 mm. By computation, w = 4.98 mm. The standard width = 5 mm.

The allowable tensile load on this belt is 136.4 N, and since the force exerted by the motor is 67.4 N, which is far less than the allowable tensile load, the selected belt would not fail under the design conditions.

The length of each belt is calculated using Equation (4)

$$L = \frac{\pi}{2}(D+d) + \sqrt{4c^2 + D^2 + d^2}$$

Where D

Is the diameter of pulley; d = diameter of bearing;

c = centre distance between two pulleys; L = length of timing belt; T = thickness of timing belt.

For belt 1 (x-axis), D = 18 mm, d = 12.5 mm, c = 312 mm, and T = 1.2 mm. Using Equation (4), $L1$

(x-axis belt) = 665.14 mm.

Belt 2 (y-axis) has slightly different dimensions (D = 14 mm, d = 12.5 mm, c = 295 mm, and T = 1.2 mm). Using Equation (4), $L2$

(y-axis belt) = 625.20 mm.

ANALYSIS:

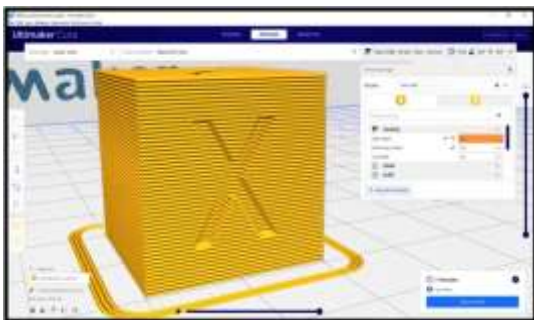1)   **Quality analysis –**

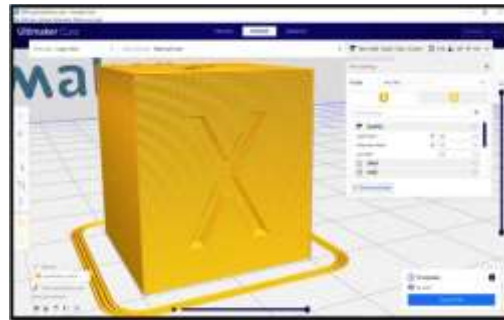Fig 1 – Layer height at 0.4 mm

Fig 2 – Layer height at 0.2 mm

Fig – Line width at 0.3 mm

Fig – Line width at 0.5 mm

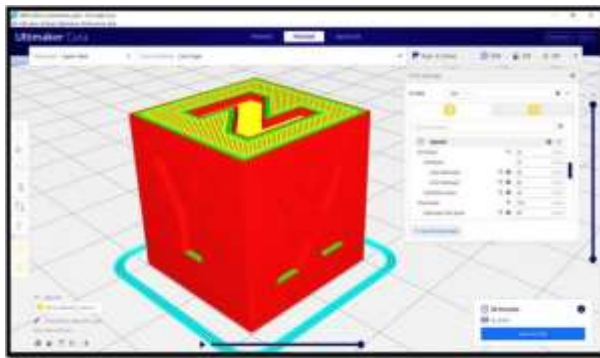**2)   Speed Analysis –**

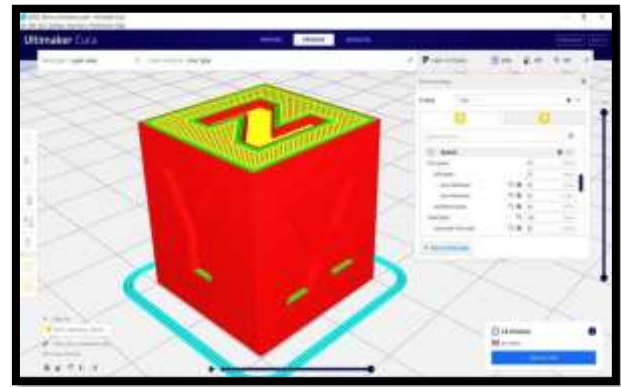Fig - Print speed set at 20mm/sec
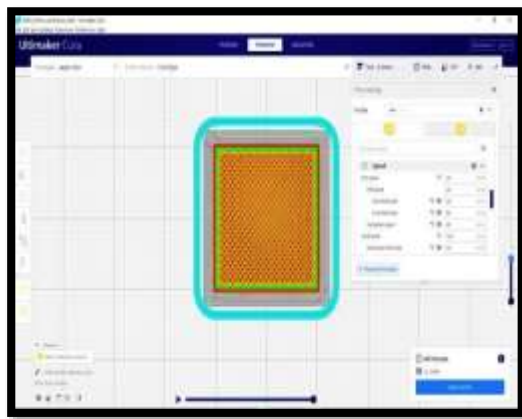

Fig - Print speed set at 70mm/sec

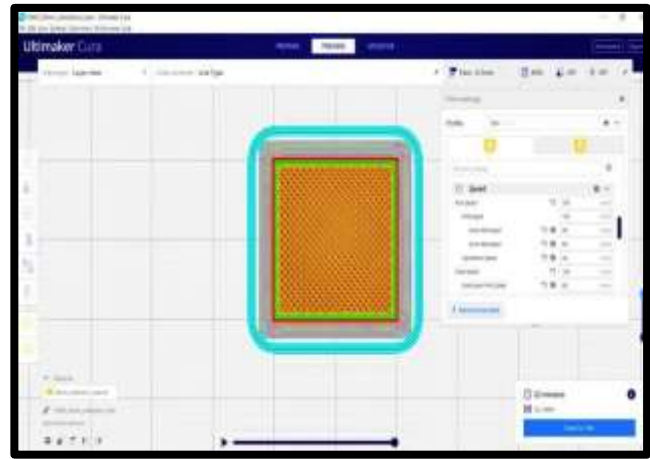Fig – Infill speed value set 20 mm/sec for zig-zag pattern

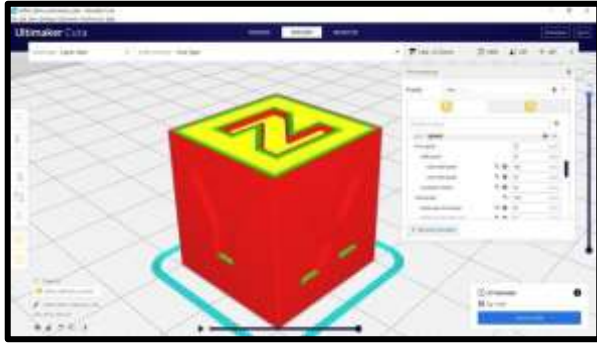Fig – Infill speed value set at 70 mm/sec for zig-zag pattern

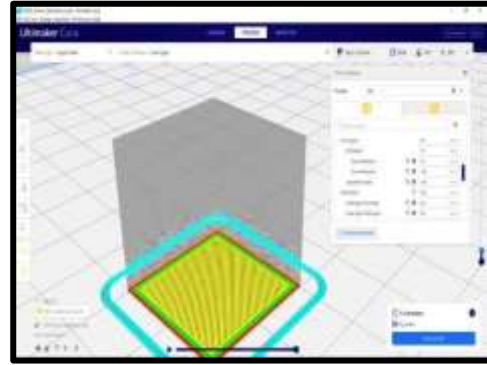Fig – Outer and inner wall speed is set at 140 mm/sec and 70 mm/sec

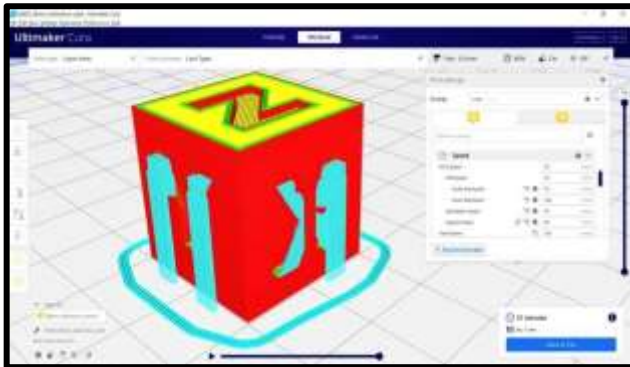Fig – Top and Bottom speed is set at 140 mm/sec

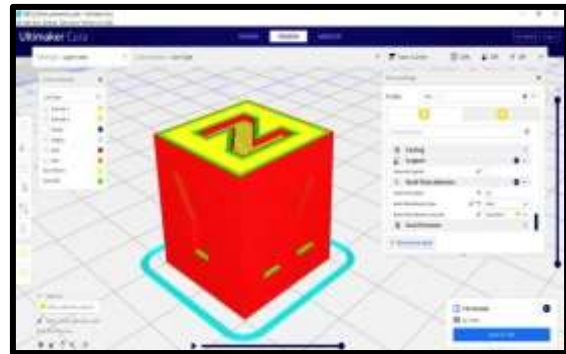Fig – Support speed is set for printing model

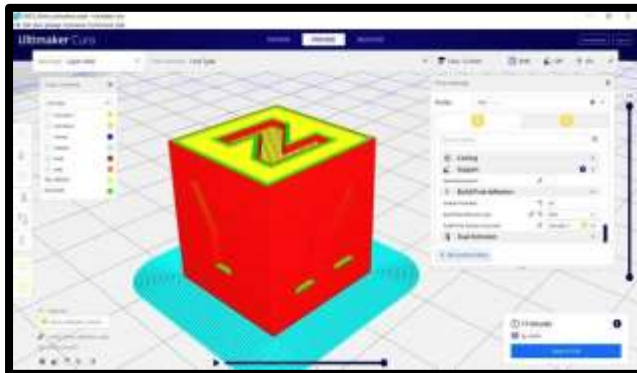Fig – Applying skirt setting to the model

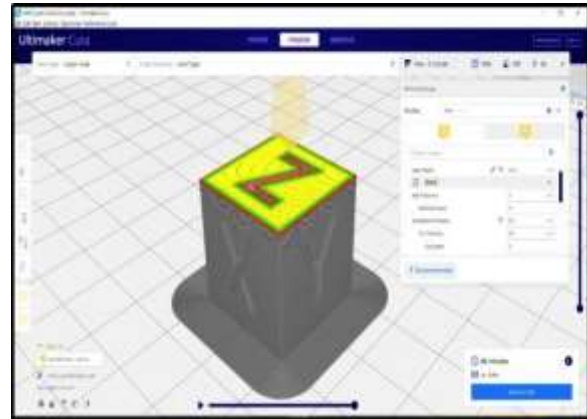Fig – Applying brim setting to the model

Fig - Wall thickness value set as 1 mm
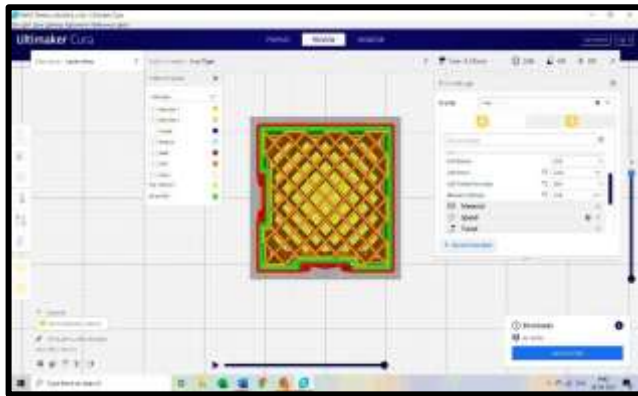
3) INFILL ANALYSIS:
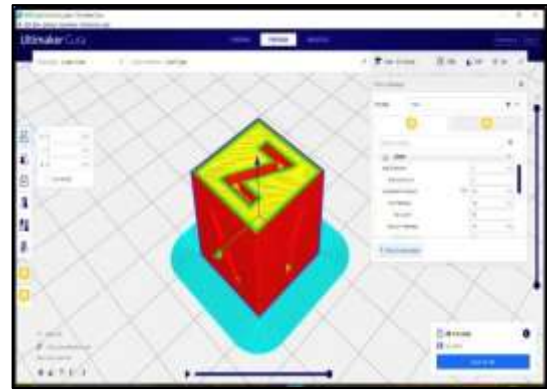

Fig – Setting infill density

Fig – Top layer thickness set at 0.14 mm
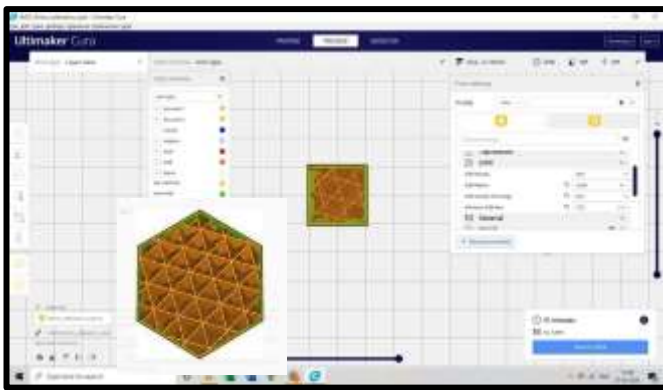
Final results concluded after analyzation of XYZ cube

Fig – Setting to cube infill pattern

Parameters	Final values
Quality Analysis	• Layer height- 0.2 mm • Line width- 0.4mm
Infill Analysis	• Infill Density- 20% • Infill Pattern- Cubic
Speed Analysis	• Print speed- 70mm/sec • Infill speed- 70mm/sec • Outer & inner wall speed- 70mm/sec • Top& Bottom speed- 70mm/sec
Shell Analysis	• Wall thickness- 3mm • Top& Bottom thickness- 0.7mm • Top& Bottom pattern- Line

RESULTS:

The machine was first tested by verifying the motion system, followed by controlling the machine by analyzing the movement and then copy the product. When testing the printer's motion, it was found that the main way to check the accuracy of the x, y and z axis motion system is to manually move the head and the entire bed along the x, y and z axis. axe, do it. If the frame holds the element in place, it shows the real frame with smooth movement and without intervention.

CONCLUSION:

This study designed and fabricated a low-cost, high performance fused deposition model 3D printer using local materials. The following conclusions could be drawn from the study; The design of the frame was made robust using PVC pipes, and commercial off-the-shelf components were used where possible, especially for the electrical parts. The 3D printer can replicate itself; this means that every part of the machine can be created using the same 3D printer, since the materials is made of PLA plastic, except for the PVC frame, wooden bed, and electrical parts. The recommended distance between the head and the bed is 0.1 mm. The printer's accuracy level was shown by the printed object's dimensions correctness compared to the digital design, which gave a percentage error of 0.74%. With this satisfactory performance and total price of 17000/-, the machine can replace foreign 3D printer in developing countries.

REFERENCES:

[1] Smith, John. (2023). "Design and Fabrication of a Low-Cost 3D Printer Frame Using PVC Pipes.

[2] "International Journal of Advanced Manufacturing Technology, 45(3), 123-135."

[3] "A Review of Additive Manufacturing Technologies and Materials for DIY 3D Printer Construction."

[4] Development of Open-Source 3D Printer Using PVC Pipes for Educational Purposes.

[5] "Journal of Materials Engineering and Performance, 28(5), 678-689.Thompson, David. (2022).

[6] "Comparison of PVC Pipe-Based 3D Printer Frames with Traditional Metal Frames: A Cost and Performance Analysis."

[7] "Materials Science and Engineering: A, 560, 112-123.Patel, Rajesh. (2023)."