Design & Fabrication of 3D Printing Machine

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Abstract - 3D printing technology used to create physical objects layer by layer from a digital model. In FDM, a thermoplastic filament is heated and extruded through a nozzle onto a build platform, where it solidifies as it cools, forming a precise structure. The process allows for complex geometries and custom designs to be produced with high precision. FDM is commonly used in prototyping, manufacturing, and even in healthcare and education, due to its affordability and versatility. Materials used in FDM include PLA, ABS, and PETG, which can be selected based on the desired properties such as strength, flexibility, or durability. This technology has revolutionized industries by making rapid, cost-effective production more accessible

***Key Words*:** stepper motor, extruder, PLA, Build platform, 24-volt power supply

1.INTRODUCTION

3D printing, also known as additive manufacturing, is a process that creates three-dimensional objects by adding material layer by layer based on a digital design. Unlike traditional manufacturing methods that subtract material (like machining or molding), 3D printing builds an object from the ground up, allowing for complex geometries and customized designs. The machine works by using materials such as plastic filaments, resin, or metal powders, which are heated or cured and deposited layer by layer onto a print bed to form the final product. This method is controlled by a computer that interprets the digital model into precise movements of the printer's head and bed.

3D printing machines are widely used across industries such as healthcare, aerospace, automotive, and consumer goods for prototyping, production, and even end-use parts. These machines offer several advantages, including the ability to create highly intricate and customized designs with reduced waste and faster production times. While various types of 3D printing technologies exist, including Fused Deposition Modeling (FDM), the core principle of adding material layer by layer. Despite some limitations, such as material variety and surface finish quality, 3D printing continues to revolutionize manufacturing and design processes.

2. LITERATURE SURVEY

Chunhua Sun et.al [1], 3D printing technology uses additive manufacturing to complete forming of 3D entity via layer by layer, which makes the whole process not limited by the complexity of design structure. Therefore, 3D printing has been applied in many fields. As one of representative technologies of the fourth industrial revolution, 3D printing is profoundly affecting all aspects and embodies extraordinary value. The main application value of 3D printing technology in the medical field is to provide better personalized treatment for patients with efficient and accurate digital design and manufacturing means owing to additive manufacturing mode

G. D. Goh et.al [2], Additive manufacturing (AM) techniques, or 3D printing, have matured and brought about a paradigm shift on how things are designed and manufactured. The layer-by-layer fabrication techniques enable the fabrication of parts with complex geometries and functionally graded properties. AM is also greener as they reduce material wastage in general

Mark Keanu James E. Exconde et.al [3], Plastics are widely used material in a wide-array of applications because of their relatively low costs and versatile properties. In the food packaging industry, plastics are utilized due to their light weight, durability, flexibility, and hygienic properties. They are manufactured in the form of bottles, containers, trays, boxes, cups, plastic bags, baby products, and a lot more. Aside from the packaging industry, plastics are also used in construction in the form of polyvinyl chloride pipes and flooring, polyurethane insulations, polycarbonate windows, and a whole lot more. They are also used in transportation due to their light weight coupled with high strength-to-weight ratio and corrosion resistance

Michael Hutchinson1 et.al [4], Material Extrusion (MEX) technique has garnered significant attention in additive manufacturing due to its ease of use, low cost, and ability to quickly modify the fabrication of complex parts The quality of MEX printed parts is often assessed using metrics such as surface finish smoothness, geometrical accuracy, and effective material properties. However, the quality of a part may depend on parameters such as filament material properties, feeding rate, extrusion temperature, and environmental conditions. For example, the temperature and humidity of the printing environment have been shown to play significant roles in print quality. The hot end assembly (HEA) is a critical component in MEX 3D printers, playing a vital role in the printing process. This component is essential for efficient, high-quality MEX printing for a given application. For example, the HEA is responsible for melting the polymer by maintaining a setpoint temperature as the melted polymer filament is extruded onto a heated surface

Jakub Bryła et.al [5], For about the last 20 years, extensive research has been carried out on the influence of various manufacturing process parameters on the strength and geometric properties of 3D prints Most of the tests have been conducted on the two most popular materials: PLA and ABS In recent years as well, researches have focused on composites, materials with impurities, and fiber reinforcement It should be, however, noted that one of the key issues regarding the obtained characteristics of the 3D-printed parts is the selection of both a 3D printer and a proper slicer. In fact, a number of 3D printers have been employed thus far to prepare samples to conduct laboratory tests. Amongst all the scientific investigations recently reviewed by the authors of the current work, the most frequently used device has been Makerbot Replicator 2x, as referenced, e.g., in [3,15,16]. Moreover, the studied cases have made use of Ultimaker cura

Adi Kurniawan Saputro et.al [6], In the process of making 3D printer objects, of course, it requires stable power consumption to minimize damage. Some of the parameters used to determine the state of the 3D printer are voltage, current and power values From this information, a study on information analysis was made which aims to determine the amount or amount of power consumption required by a 3D printer to create an object.

3. TECHNOLOGY AND HARDWARE IN PROJECT

The Ender 3 motherboard is the central control unit of the 3D printer, responsible for interpreting G-code commands and controlling various components such as motors, sensors, and the heating elements. It processes input from the user interface, like the screen or computer, and translates it into precise movements of the print head and bed. The motherboard manages the temperature of the extruder and heated bed, ensuring optimal printing conditions. It also ensures the proper coordination between stepper motors for movement and monitors endstops for position accuracy. Overall, the Ender 3 motherboard integrates all parts of the 3D printing system, enabling seamless operation. shown in Fig.1 Ender 3 motherboard

Fig.1 Ender 3 motherboard

A stepper motor is a type of DC electric motor that divides a full rotation into a number of precise steps. This makes them particularly useful in applications where precise control of position, speed, and rotation is required, such as in 3D printers, CNC machines, robotics, and camera systems. Shown in Fig.2 Stepper Motor

Fig.2 Stepper Motor

The extruder is the part of the 3D printer responsible for feeding the filament into the hotend where it will be melted and extruded through the nozzle. The extruder is made up of two primary sections shown in Fig.3 Extruder

Fig.3 Extruder

4. RESULTS & DISCUSSIONS

This section presents and analyzes the findings from the conducted 3D printing experiments, focusing on print quality, dimensional accuracy, and material performance under varying conditions. The results show that the printing parameters, including temperature, speed, and layer height, significantly influence the final output's precision and surface finish. Specifically, prints conducted at higher temperatures exhibited improved layer adhesion and reduced warping, whereas lower speeds resulted in finer details but increased print times. In contrast, prints with faster speeds displayed minor defects like stringing and incomplete layers.

The material choice also played a crucial role in the final results. PLA provided the best overall print quality with smoother surfaces and higher dimensional accuracy, whereas ABS exhibited better strength and durability but suffered from higher levels of warping and cracking. These findings align with previous research, confirming that material properties have a direct impact on the effectiveness of 3D printing in various applications. Additionally, the results revealed that the calibration of the Ender 3 printer, particularly the extrusion rate and bed leveling, was critical in achieving optimal print outcomes.

The discussion highlights the importance of fine-tuning printing parameters to enhance the accuracy and reliability of the printed objects. Despite the advances, issues such as print defects, material wastage, and the time-consuming nature of large prints remain significant challenges. This study suggests that further optimization of printing techniques, including advanced software algorithms for better error compensation and the development of more stable materials, could address these limitations. Future research should focus on exploring the impact of multi-material printing and the development of more efficient, cost-effective 3D printing technologies for industrial-scale applications

5. DESIGN OF CAD MODEL

The Fig.5 shows CAD model consists of following parts Stepper Motors, Guided Frame, Heat Bed, Extruder, Threaded Rods, Hotend, Screwing Nut

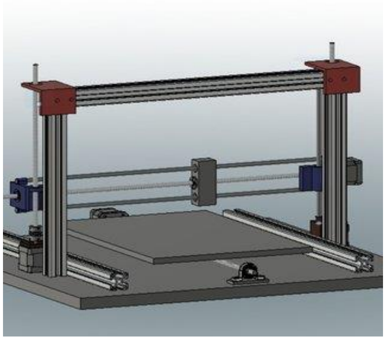

Fig. 5 CAD Model

6. ASSEMBLY OF THE PHYSICAL PROTOTYPE

The Fig.6 assembly consists of

Frame: The structure that holds all components in place and ensures stability during printing.

Extruder: The mechanism that feeds and pushes the filament into the hot end.

Hot End: The part that heats the filament to a specific temperature for melting and extrusion.

Print Bed: The flat surface where the printed object is built layer by layer.

Stepper Motors: Motors responsible for moving the print head and bed along the X, Y, and Z axes.

Controller Board: The brain of the printer that processes instructions from the software and controls the movement and temperature.

Filament: The material used for printing, typically in the form of a spool of thermoplastic filament like PLA or ABS.

Cooling Fan: Keeps the hot end cool and can also cool the printed layers for better precision.

Power Supply: Provides electrical power to all the components of the printer.

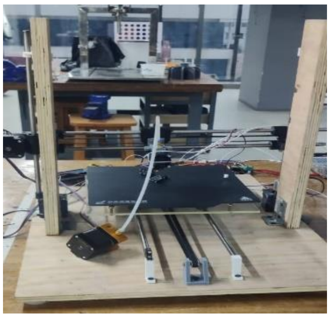

Fig. 6. Assembly of Project

7. CONCLUSION

Despite challenges faced during the assembly and calibration process, the project allowed us to develop a deeper understanding of how 3D printing works and its potential to revolutionize manufacturing, design, and even healthcare. Moving forward, we recognize the vast potential of 3D printing in fields such as custom manufacturing, rapid prototyping, and even education, and we are excited to see how this technology continues to evolve. This project has not only expanded our technical knowledge but has also highlighted the importance of innovation and creativity in engineering.

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