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A New Dimension in 3D Printing

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Abstract: *This paper introduces the concept of dual extruder printers and explores their design and development in the realm of 3D printing. By incorporating two extruders into a single printer, these innovative devices enable the simultaneous deposition of multiple materials or colors, expanding the range of applications and enhancing design possibilities. We delve into the technical aspects of dual extrusion, discussing issues such as nozzle arrangement, filament control, and software integration. Additionally, we examine the advantages and challenges associated with dual extruder printers, including improved efficiency, increased print complexity, and material compatibility. Through case studies and examples, we demonstrate how this technology has opened up a new dimension in 3D printing, empowering users to create intricate multi-material and multi-color prints with ease. Finally, we discuss future directions and potential advancements in dual extrusion, pointing towards an exciting future for additive manufacturing*

Keywords: Nozzle arrangement, 3D printer, Additive manufacturing, Dual extruder,Multi-material printing

I. INTRODUCTION

The field of 3D printing has witnessed significant advancements in recent years, pushing the boundaries of what is possible in additive manufacturing. One such breakthrough is the development of dual extruder printers, which have revolutionized the way objects are printed in three dimensions. By incorporating two extruders into a single printer, these innovative devices enable the simultaneous deposition of multiple materials or colors, opening up a new dimension of possibilities and capabilities.

The concept of dual extruder printers addresses the limitations of single-extruder systems, which are limited to printing with a single material or color at a time. With dual extrusion, designers and manufacturers can create complex objects with intricate details, varying material properties, and vibrant color combinations. This technology has found applications across various industries, including prototyping, product development, fashion, art, and education.

In this paper, we delve into the design and development of dual extruder printers, exploring the technical aspects, advantages, and challenges associated with this cutting-edge technology. We examine the key components involved, such as nozzle arrangement, filament control mechanisms, and software integration. Understanding the intricate workings of these printers is crucial for achieving optimal results and maximizing their potential.

Efficiency is a significant advantage offered by dual extruder printers. Simultaneous printing with multiple materials eliminates the need for separate print runs or assembly, saving time and resources. Complex designs that require support structures or intricate internal components can be seamlessly printed using dissolvable or breakaway support materials. Moreover, the ability to print with different materials in a single object opens up opportunities for creating functional prototypes with varying material properties, such as rigid and flexible sections.

However, dual extrusion also presents challenges that need to be addressed. Nozzle arrangement and alignment play a crucial role in ensuring precise material deposition, preventing cross-contamination, and achieving consistent print quality. Controlling the flow and temperature of two different filaments simultaneously requires careful calibration and monitoring. Software integration is another critical aspect that enables users to control and coordinate the extruders, ensuring synchronized operation and optimal printing outcomes.

Throughout this paper, we provide insights into the advancements and potential of dual extruder printers through the analysis of case studies and examples. By showcasing the capabilities of this technology, we aim to inspire and encourage further exploration and development in the field of additive manufacturing.

In the following sections, we delve into the technical details of dual extruder printers, discussing the nozzle arrangement, filament control mechanisms, and software integration. We also explore the advantages and challenges associated with this technology, providing real-world examples and case studies to demonstrate its impact. Finally, we discuss future directions and potential advancements, envisioning an exciting future for dual extrusion in 3D printing.

II. CONFIGURATION OVERVIEW

This section explores the mechanics and limitations of conventional single-nozzle extruders in 3D printing and introduces the potential improvements offered by multi-nozzle extruders.

A. Conventional Single-Nozzle Extruders:

In traditional 3D printing setups, single-nozzle extruders have been the standard. These extruders consist of a single hotend and nozzle responsible for melting and depositing the filament onto the print bed. While single-nozzle extruders have been widely used and are suitable for many applications, they do have limitations.

B. Limitations of Single-Nozzle Extruders:

Time-consuming Material Changes: With a single-nozzle extruder, changing materials during a print job requires purging the previous material completely from the nozzle, which can be time-consuming and result in material waste.

Limited Color Mixing: Single-nozzle extruders are limited in their ability to achieve intricate color mixing. Mixing colors in a single nozzle can be challenging, resulting in less precise color gradients and limited color variations within a print.

Limited Material Combinations: Printing objects with different materials, such as rigid and flexible filaments, using a single nozzle is difficult. Swapping filaments with different material properties requires stopping the print and manually replacing the filament, leading to interruptions and potential alignment issues.

C. Multi-Nozzle Extruders: Potential Improvements

To address the limitations of single-nozzle extruders, multi-nozzle extruders offer a promising solution. These extruders feature multiple hotends and nozzles, enabling simultaneous printing with different materials or colors. They introduce several potential improvements to the 3D printing process.

- Efficient Material Changes: Multi-nozzle extruders allow for quicker and more seamless material changes. By having dedicated nozzles for each material, switching between filaments becomes a matter of selecting the appropriate nozzle, reducing downtime and material waste.
- Enhanced Color Mixing and Variation: With multi-nozzle extruders, precise color mixing and a wider range of color variations can be achieved. Each nozzle can be assigned a specific color, allowing for more intricate and vibrant color gradients within a single print.
- Multi-Material Printing: Multi-nozzle extruders enable simultaneous printing with different materials. This opens up possibilities for creating objects with varying material properties, such as rigid and flexible sections, without the need for manual filament swapping or post-processing assembly.
- Increased Print Speed: With multiple nozzles working in parallel, multi-nozzle extruders have the potential to increase print speed compared to single-nozzle extruders. Simultaneous extrusion of different sections of a print can significantly reduce overall printing time.

While multi-nozzle extruders offer exciting possibilities, they also come with their own set of challenges. These include proper nozzle alignment, filament control and synchronization, and software integration to coordinate the movements of multiple nozzles. Overcoming these challenges requires careful design considerations and robust engineering.

The printing time canbe reduced by continuous operation of extruders as it is no need to spend extra time on changing filaments. In most cases, the second extruder of the dual extruders is used to print supporting material to hold the object's suspended volume part for complex 3D structural. In addition, some of the models use more than two nozzles at the same time.

III. LITERATURE SURVEY

Vedant Daramwar et al. focused on achieving efficient and accurate printing using multiple filaments. The research emphasized the selection of a robust, precise, reliable, and effective approach for utilizing multiple filaments. The authors concluded that the utilization of "Multiple Printing Heads" as a more efficient and accurate technique was explained, along with the design of the entire mechanism.

In another study conducted by Krisztian Kun, titled "Reconstruction and Development of a 3D Printer Using FDM Technology," the author outlined the milestones of reconstructing a 3D printer, including the restoration of technical documentations through reverse engineering. The study also involved calibration processes and measurement results. The author concluded that the designed printing unit was a compact and user-friendly jog unit with a head-holder console. Furthermore, a structure was created where the extrusion head unit performed simultaneous X-Y movements, enabling the printing of support materials.

Both studies contribute to the advancement of FDM 3D printing technology. Daramwar et al. focused on the design and development of a multi-material extrusion system, highlighting the efficiency and accuracy of using multiple printing heads. On the other hand, Kun's work focused on the reconstruction and development of a 3D printer, resulting in a compact and user-friendly printing unit capable of simultaneous X-Y movements. These research efforts provide valuable insights and advancements in the field of FDM 3D printing technology.[1].

Andi Dine, Edward Bentley, et al. contributed to the field of 3D printing by designing and integrating new subsystems into a conventional extrusion-based printer. Their research enabled the development of a dual nozzle 3D printing system specifically tailored for printing super soft composite hydrogels. By utilizing a liquid-to-solid phase change, the system achieved structural stability for large scaffold volumes, opening up new possibilities for biomedical applications. [2].

Tim Kuipers et al. presented a novel approach to create 3D objects with the appearance of continuous grayscale imagery on FDM printers. They addressed the limitation of droplet-based dithering techniques, which are not applicable to FDM printing due to the semi-continuous paths created by the extrusion process.

The proposed technique, called "hatching," leverages the line patterns naturally occurring in FDM prints, which are built up layer by layer. By applying line-based half-toning principles, the researchers achieved the desired grayscale appearance without compromising the surface geometry or structural properties of the printed objects. Unlike existing FDM coloring techniques that often influence surface geometry or require adjustments to the printing process, the proposed technique had minimal impact on printing time and maintained the original surface texture.

The study conducted experiments using a dual-nozzle FDM printer, which showed promising results. The authors also suggested the potential extension of the technique to FDM printers with more than two extruders, enabling the production of full-color prints by utilizing cyan, magenta, yellow, black, and white filaments. In such cases, hatching could be employed to generate textured mesh-like prints. When working with a limited range of colors, a mapping between color spaces would be necessary to achieve the closest possible resemblance to the desired textured mesh.

Overall, the research highlights the innovative application of hatching as a half-toning technique for FDM printers, enabling the production of 3D objects with continuous grayscale imagery. The technique shows promise for achieving high-quality prints without compromising surface geometry, structural properties, or printing time. Future work is suggested to refine the perceived tone and explore the adaptation of the technique to printers with multiple extruders and a wider range of colors.[3].

Roman Polak et al. worked on Determination of FDM Printer Settings with Regard to Geometrical Accuracy stating that material extrusion is one of the most used additive technologies. The most common application of this technology is in the production of prototypes and preparations.and small serial parts. This article deals with the relationship between different model geometries and parameters such as temperature, speed of printing and height of layer.

Typical features of this technology are ease of printing, but it depends on the type of material used and the device. Printers with Fused Deposition Modeling (FDM) technology have no feedback about printed material, such as printing accuracy. This paper aims to easily find ideal parameters for FDM printing technology using Polylactic Acid (PLA) material and concluded that it is hard to find these settings during real production; therefore, this experimental analysis was carried out. The collected data shows the dependence of the geometry on the print properties. The main tested parameters were speed, temperature and layer height. The results show the accuracy mainly depends on the temperature and layer height. The best results were obtained using lower temperature and thinner layers. Many articles deal with dimensional accuracy and model post processing regarding the surface finish. The information contained in this article can be used for verification of these properties and finding the ideal parameters on other FDM devices. This test has many possibilities for continuing and expanding the testing information for ideal FDM printer settings. Further research will continue with testing other print parameters, such as different nozzle sizes, other materials (ABS, Nylon, PETG etc.) and combining them with the parameters tested in this article [4].

Xiuxia Zhang et al. worked on Design and Simulation of Multi-nozzle FDM 3D printer for fabricated Solar thin-film cells to widely realize the personalized use of solar thin-film cells in every family, save costs and generate clean energy, our team wants to fabricate a 3D printer of solar thin- film cells. The solar film cells were 3D printed fabrication by FDM3D printer would improve their performance as battery. In this paper, for fabricating P nano-diamond/ZnO solar film cells the hot bed and nozzle of 3D printer were designed to achieve 3D printing of solar cells. A printer for fabricated magazine papers published on FDM 3D printers.[5]

IV. METHODOLOGY

The first step is to identify the need for an emerging market for portable, low-cost, standard-purpose, dual extrusion 3D printers. The problem with the existing FDM 3D printers on the market is that they are very expensive and not cheap for many interested parties. Then a market survey is done to find out who the potential customers are. And how much are they willing to pay for the new FDM 3d printer if available for purchase.

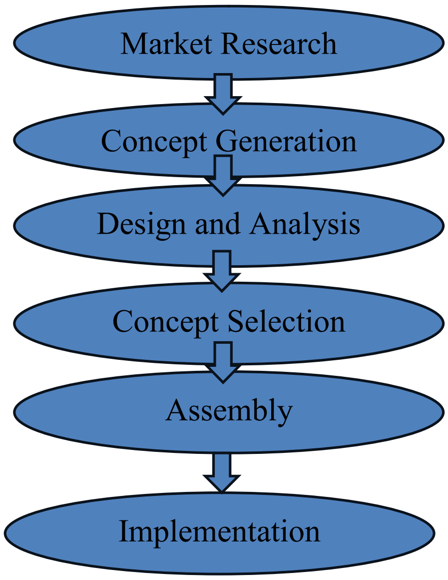

Fig.1.Methodology

Then the design and operation are visualized with a 3D printer available in IEM department and mechanical department and research is done on various MSME's Bangalore using 3D printers to make parts and fastprototyping. Observations and studies are also done with web resources and the feature considerations and targeted specifications that need to be achieved in the final product are done. The next step was to amend the Bill of All Materials, Electronics and other materials needed to build a FDM 3d printer and to conduct market research when available on the market at a low price. Thereafter assembling and inspecting various electrical and electrical equipment such as control boards, circuits, power supply unit drivers, actuators etc. Eventually it combines electronic components with various mechanical and structural elements and is tested and finally begins to use the machine to make the necessary materials.

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V. CONCEPT GENERATION

Concept generation is a crucial stage in the product design process, involving the creation of ideas that align with the target specifications and requirements. This phase focuses on developing concepts that outline the design principles and functionality of the product, addressing how it can meet customer needs effectively. The process begins with a comprehensive analysis of customer requirements from various perspectives and culminates in the development of a refined product design. Visualization of the proposed design can be presented through 3D models, blueprints, or preliminary sketches. Successful concept generation relies on the application of creativity and problem-solving skills to generate innovative and viable solutions. The four concepts which are generated are as follows:

i) CONCEPT -1

In this process with using single extruder to supply the filler material in one color automatically.

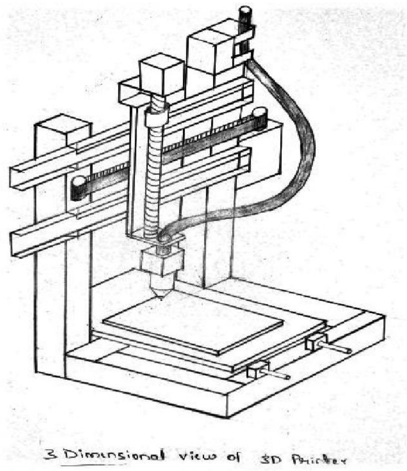

Fig.1. 3D Model of Concept One.

ii) CONCEPT-2

A roller mechanism is implemented to allow the 3d printer to move at y-axis. The filler material supplied by roller mechanism.

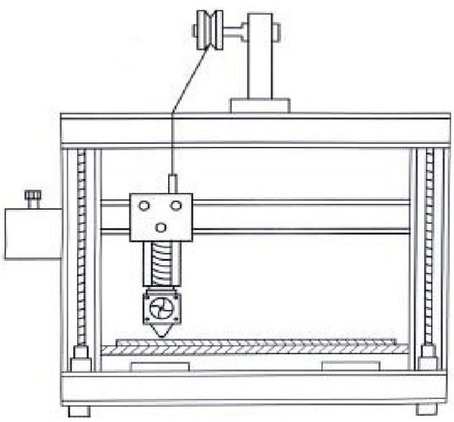

Fig.2. 3D Model of Concept Two.

VI. CONCEPT SELECTION

We generated four concepts based on the 3D printer. After comparing the advantages and limitations of these mechanisms.

- Hand feed mechanism
- Dual extrusion mechanism

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- Single extruder mechanism
- Roller feeding mechanism.

Among these given above mechanisms we have selected dual extrusion mechanism with less limitations and maximum benefits.

Advantages

1) Each material has a unique nozzle that is specifically designed for it, and it may even have a distinct extruder (direct or Bowden).
2) Because the printing heads are attached to the main body, there is no additional weight on the carriage (except from the servo motor).
3) The printing nozzle is not impacted by other nozzles, preventing interference, and leaking.
4) It is simple to replace an extruder and hot end component that isn't working.
5) The only restriction on the number of filaments (extruders) is the printer's size. Numerous printing heads can fit within large printers.
6) This mechanism has a broad range of applications since it may be utilized with various heads, such laser heads, without requiring significant modifications.

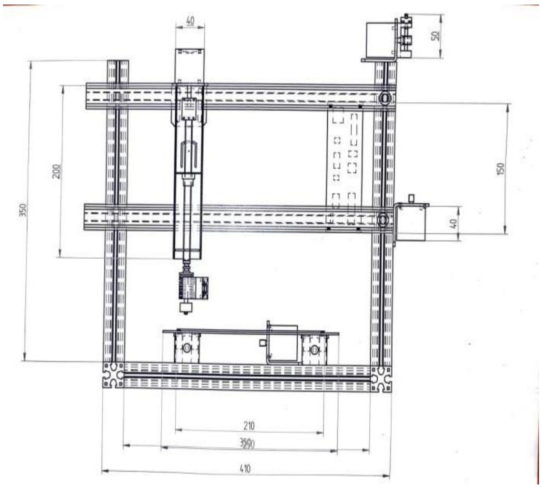
Disadvantages

1) The machine as a whole now weighs more.
2) Repair and maintenance may be a bit laborious.
3) The machine's initial cost would be fairly costly owing to the several printing heads, but it would be well worth it.

VII. PRELIMINARY DESIGN(2D)

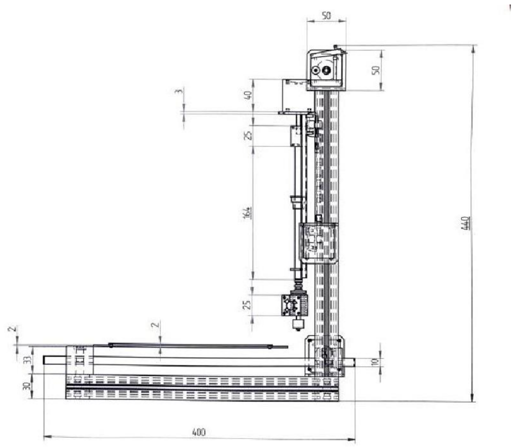
1. Font View:

Front view detail design is an important aspect of product design and refers to the detailed drawings and specifications of the front view of a product. The front view of a product is usually the first thing that a customer sees and interacts with, so it is important to ensure that it is aesthetically pleasing and functional.



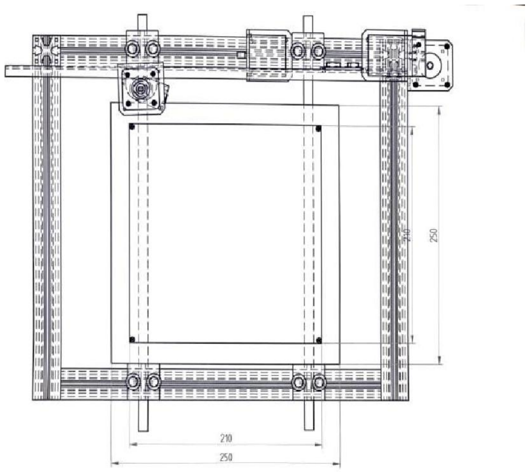
2. Side View:

Side view detail design is another important aspect of product design, which refers to the detailed drawings and specifications of the side view of a product. The side view of a product provides important information about the overall shape, size, and proportions of the product, as well as any features or components that may be located on the sides of the product.



3. Top View:

The top view of a product provides important information about the overall shape, size, and proportions of the product, as well as any features or components that may be located on the top of the product.



VII. DETAILED DESIGN(3D)

Detailed design, which takes on and develops the approved conceptual design, is a stage where the design is refined and plans are set. The result of the detailed design is the complete and precise physical description of all parts of the structure and how they are fit together.

IX. CALCULATIONS

Motion

Time to Accelerate = Speed/Acceleration =(300mm/s)/3000mm/s^2

= 0.1sec Min Distance = 1/2 x Acceleration x Time = 1/2 x 3000 x 0.1^2 = 15mm

Hot end

Max output Flow using 0.4mm nozzle is about 15mm^3/5 at 250c

Max Layer Height: Layer Height = Flow/Line width x Speed

= (15mm^3/5)/ 0.50mm x 300mm/s = 0.1mm

Extruder Filament speed = 4 x Flow/3.141 x Filament Dia^2

= 4 x (15mm^3/5)/3.141 x 1.75mm^2= 6.23mm/s

Motor RPM = (Voltage/Induction x 2 x Current x steps) x 60

= (12 x 0.004H x 2 x 1.68A x 400 steps/rev) x 60= 133.9rpm

Belt 20 Teeth Pulley Turn = Pitch x Teeth = 2 x 20 = 40mm

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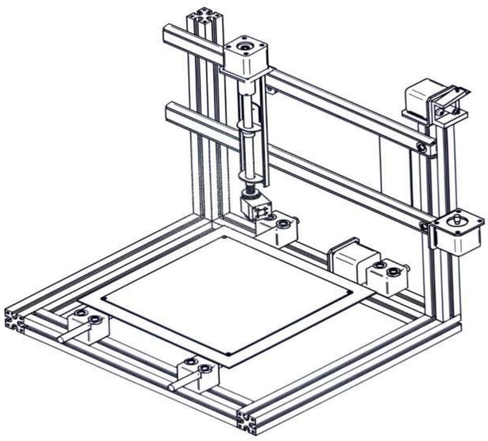
X. CONCLUSION

The design and development of dual extruder 3D printers have opened up new dimensions and possibilities in the field of additive manufacturing. Through this technology, simultaneous printing with multiple materials or colors has become a reality, expanding the range of applications and enhancing design capabilities.



The configuration of a dual extruder printer involves careful consideration of various components, including extruders, nozzles, filament paths, hotends, filament control mechanisms, and software integration. Proper alignment, precise calibration, and seamless filament control are essential to ensure optimal performance and print quality.

Literature survey indicates that significant research has been conducted in the realm of dual extrusion. Studies have explored techniques for dual extrusion, material compatibility, software integration, and real-world applications. The advancements made in this field have paved the way for intricate multi-material prints, improved efficiency, and enhanced creative possibilities.

Furthermore, specific research works have contributed to the development of dual extrusion technology. For instance, the incorporation of multi-nozzle extruders has enabled the printing of super soft composite hydrogels, opening new avenues in tissue engineering and regenerative medicine. Additionally, techniques such as half-toning have been explored to achieve continuous grayscale imagery in FDM printers, providing new possibilities for creating visually appealing prints.

In conclusion, the design and development of dual extruder 3D printers have revolutionized additive manufacturing, offering greater versatility, improved efficiency, and expanded design possibilities. Ongoing research and advancements continue to push the boundaries, addressing challenges and exploring new applications. As the technology continues to evolve, it holds tremendous potential for various industries and sectors, transforming the way we create objects and pushing the limits of what is possible in 3D printing.

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