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Design and Development of Additive Manufacturing Machine

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Abstract

Rapid prototyping, commonly referred to as 3D printing or additive manufacturing (AM), is the process of creating three-dimensional objects by layer-by-layer addition of material. It is very different from subtractive and conventional forming techniques. The goal of this special issue is to gather research and advancements in additive manufacturing (AM), with an emphasis on novel manufacturing techniques and substitute products and materials for feedstock. Although metal and polymer-based materials have been thoroughly studied in additive manufacturing (AM) methods, there is growing interest in the use of composite, glass, and ceramic materials in both creative and commercial AM processes. The final qualities and performance of AM products are largely determined by the material compositions and processing techniques used to shape and finish them.

Keywords: Additive Manufacturing (AM), Fused Deposition Modeling (FDM), Filament, Feeder System, conventional forming techniques.

INTRODUCTION

These days, 3D printing is a booming industry that is revolutionising industrial techniques. 3D printing is used in many fields, including the mechanical, electrical, biomedical, and aerospace industries, to improve design manufacturing and reduce lead times and tooling costs for newly made goods. Compared to traditional machining techniques like turning, milling, and drilling, which made it easier for people to construct goods decades ago, 3D printing is different. They are no longer as widely used as they once were, though, due to several restrictions and limitations, including the high expense of the production methods. The idea of 3D printing has been presented in this context. Another name for this type of rapid prototyping that allows three-dimensional items to be formed from digital files is additive manufacturing. The process of adding layers of a particular material to a given design until the desired thing is constructed is known as additive manufacturing. A horizontal cross-section of the product itself is everything that is represented by those layers that join one on top of the other. The material composition, the manufacturing process, the printing feeding rate, the filament flow rate, the type of 3D printer being used, and ultimately the dimensions of the printed component of the employed printer are some of the aspects that affect the quality of the parts produced by a 3D printer. Generally speaking, because of the amazing benefits to the industrial sector and its large influence on other disciplines, 3D printing technology has made a big contribution to the world in many aspects. The advancement has also been used in other domains, including failure mechanisms, modelling, and prototyping. However, because 3D printing technology has so many

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potential uses, the aerospace sector is one of the more intriguing ones. However, the use of 3D printing technology for educational purposes has begun to spread throughout universities and institutions.

Problem Statement

Designing, selecting materials, manufacturing, and assembling various parts to build an additive manufacturing machine is one of the most challenging tasks. Numerous studies on cellular metamaterials inspired by nature have led to worldwide developments with restricted multifunctionality and a single material. By employing multiple materials in the process of additive manufacturing (AM), complex shapes can be created with enhanced mechanical qualities, increased utility, and environmental adaptability. Multi-material additive manufacturing (MMAM) methods, encompassing multi-materials, design, and optimisation, have been the subject of numerous recent research. However, very few or none of the comprehensive and systematic reviews in this field of study have been carried out in the last six years.

Objectives

Conventional machines struggle to produce complex and lightweight components/parts. To overcome this limitation, we have built an additive manufacturing machine which enables the production of intricate, lightweight products using a wide range of materials.

Scope

The scope of additive manufacturing machines is vast, with capabilities that include versatile material usage, design freedom, rapid prototyping, small-batch and on-demand production, integration with digital workflows, industry applications, technological advancements, and sustainability benefits, while offering the potential to revolutionize manufacturing processes by enabling customization, reducing lead times, optimizing designs, and facilitating decentralized production.

METHODOLOGY

- *Specify the needs:* The machine's requirements must be specified before the design process can begin. This covers things like the kind of materials you want to use, the size and complexity of the pieces you want to make, and the precision and resolution you want.
- *Pick the right technology:* Fused Deposition Modelling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS) are just a few of the additive manufacturing technologies that are accessible. The technology that best meets your needs must be chosen.
- *Create the machine:* After deciding on the right technology, you must create the machine. This entails creating the control electronics, extruder or laser system, motion system, and frame designs. Along with these, you should think about things like simplicity of use, safety, and maintenance needs.
- *Obtain the components:* After designing the machine, you must obtain the parts. This comprises parts like pulleys, belts, motors, linear guides, and electronics.
- *Assemble the machine:* You can start the machine's assembly after locating the necessary parts. This includes attaching the parts to the frame, wiring the electronics, and setting the machine's calibration.
- *Put quality control in place:* After the machine is operating correctly, you must put quality control procedures in place to guarantee that every part produced satisfies the necessary requirements. This entails actions like checking every component for flaws, gauging the parts' dimensional accuracy, and tracking the machine's performance over time.
- *Test and optimise:* After the system is put together, you must test it to make sure everything is operating as it should. This entails evaluating the machine's resolution, accuracy, and reproducibility. To maximise the machine's performance, you might need to make some changes or adjustments.

One benefit of additive manufacturing technology is the ability to make things with hollow sections that are faster, cheaper, lighter, and still possess the necessary mechanical qualities as shown in

Figure 1. The freedom of shape is often a crucial aspect of a 3D printed object, and we can guarantee the right robustness by selecting the right amount of infill.

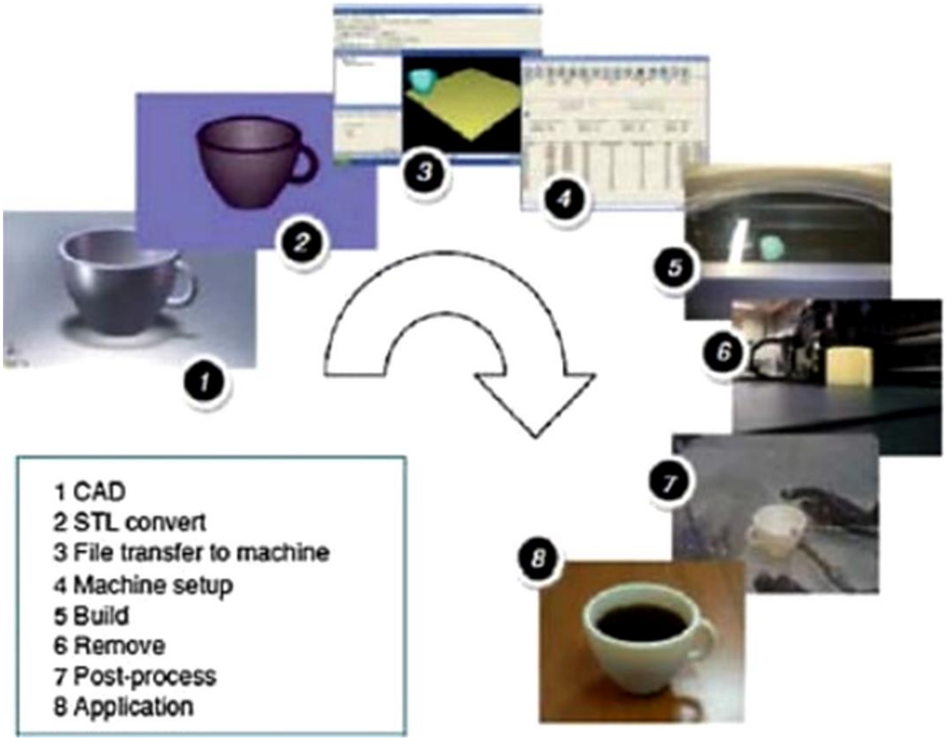

Figure 1. Methodology involved for the Additive Manufacturing Machine.

LITERATURE SURVEY

The goal of the review work by Nazir et al. [1] is to provide a thorough overview of MMAM systems and the underlying concepts that underpin them. Their article provides a methodical study of multi-material combinations along with their modelling, design, and analysis techniques. Specifically, the emphasis is on postprocessing MMAM-fabricated parts and potential uses of MMAM across several industries. Additionally, this analysis highlighted the drawbacks and difficulties with current software programmes, materials, joining methods, and MMAM procedures, particularly at the multi-material interfaces. In conclusion, they address potential approaches to surmount the previously described technological obstacles and outline forthcoming paths that will furnish scholars and technicians with valuable perspectives for crafting and producing intricate products inspired by nature.

In the paper by Márton et al. [2], the commercial Fused Deposition Modelling (FDM) technology is utilised to compare various infill patterns and volume related percentages. Non-standard bending tests with two loading orientations were conducted for the inquiry. The findings make it possible to clearly establish the relationship between the product's mass and production time, as well as the pattern, proportion, and decline in resilience when hollow sections are used in items.

Due to its biodegradability and environmental friendliness, polylactic acid (PLA) is the most used raw material in extrusion-based three-dimensional (3D) printing (fused deposition modelling, or FDM approach) in many fields. However, due to certain drawbacks, like mechanical weakness and water solubility rate, its use is restricted. When it comes to fabrication, FDM is easier to use and more affordable than other 3D printing methods. Regrettably, there are drawbacks to the FDM methodology, including the mechanical weakness of the components made using technology by Eda Hazal Tümer et al. [5] in comparison to those made using more traditional injection and compression moulding techniques. The most practical way to enhance the characteristics of the 3D-printed PLA components made using the FDM process is to prepare PLA composites with appropriate additives. The last ten years have seen widespread use of recently created PLA composites in both academic and industrial settings. The preparation techniques for the PLA composites that will be utilised as a raw material in 3D printers, as well as the chemistry and characteristics of pure PLA, are the main topics of this review. The first section also covers the primary disadvantages of using pure PLA filaments as well as the need to prepare PLA composites that will be used in FDM-based 3D printing applications. The second section outlines the existing procedures for obtaining PLA composites as the raw ingredients needed to make filaments for extrusion-based 3D printing. This review presents and critically discusses the applications of the novel PLA composites made possible by the FDM-based 3D printing technology in the areas of biomedical, tissue engineering, human bone repair, antibacterial, bioprinting, electrical conductivity, electromagnetic, sensor, battery, automotive, aviation, four-dimensional (4D) printing, smart textile, environmental, and luminescence applications.

K. El Bikri, H. Aboulchadi, H. Salem [7], the application of additive manufacturing (AM) is expanding across several industries. It was initially limited to proof of concept and prototyping. It's used in a lot of places these days. With additive manufacturing (AM), non-removable assemblies made of two or more different materials can be created all at once. The parts' intricacy is not constrained by tool access or other obstacles that come with using conventional procedures. The designer's creativity is the sole restriction. This raises the need for a paradigm shift in the way that new parts are designed, and current assemblies are reengineered. It is necessary to create a new design strategy that considers the unique aspects of the process and aids the designer in discovering the best solutions to reap these benefits. The design techniques are long-standing and primarily intended for a certain life cycle or manufacturing process. The design thinking of these processes is critical in AM laboratories because of the diversity in AM technology. The purpose of this study is to show the conventional approaches, discuss the requirement for a particular approach, and introduce a novel approach to the DFAM (design for additive manufacturing), along with the elements that affect the design and the added value above the previously mentioned approaches.

Mustafa Saleh, Abdullah Alfaify, Fawaz M. Abdullah, and Abdulrahman M. Al-Ahmari [6] Technologies for additive manufacturing, or AM, have grown rapidly in the last few decades. AM has introduced a cutting-edge production process for design, manufacturing, and end-user delivery. As a result, AM technologies have greatly increased design freedom for creating complicated components, highly customised goods, efficient waste reduction, a wide range of material options, and sustainable goods. The evolution of engineering design to capitalise on AM's uses and prospects is the subject of this review study. It covers topics including materials, part complexity, build orientation, part consolidation and assembly, design of cellular and support structures, and sustainability of the final product.

According to John Solomon, P. Sevvel, and J. Gunasekaran [3], Fused Deposition Modelling (FDM) is a special kind of additive manufacturing (AM) in which computers are used to create layers upon layers to create a three-dimensional (3D) object. The primary limitation of the FDM approach is its limited industrial applicability, as the components created by this method may only be utilised as conceptual models or demonstration pieces, not as fully working components. An increasing amount of research is being done to broaden the range of materials that may be employed, which could lead to a rise in the use of FDM in a variety of industrial scenarios. An increased focus on this extrusion-based approach has been brought about by higher cost efficiencies and material process ability. The development of several composite materials, including metal matrix, fiber-reinforced, ceramic-based, and polymer composites, has drawn the attention of numerous researchers. The main goal of this work is to evaluate the significant advancements made in the creation of different samples and parameter optimisation for FDM.

Jerry Ying Hsi Fuh, Hao Wang, Xing Peng, and Lingbao Kong [4] Advances in research on AM methods, materials, and designs have led to a rapid evolution of AM technology. AM has several advantages over traditional methods, including as increased capacity to create parts with intricate geometries, increased operational flexibility, and shortened manufacturing times. But there are also serious problems with AM methods, like inadequate mechanical characteristics and poor surface quality. As a result, several post-processing techniques are used to raise the additively created parts' surface quality. The purpose of this study is to catalogue post-processing technologies and their uses with reference to various AM techniques. The integration of several post-process treatment types with the AM process is analysed and explored.

ADDITIVE MANUFACTURING COMPONENTS

- Controller Board
- Filament
- Frame
- Stepper Motors
- Timing Belts
- Threaded rods
- End Stops
- Power Supply Unit (PSU)
- Print Bed
- Print Bed Surface
- Print Head
- Feeder System
- User Interface and Connectivity
    - *Controller Board:* An AM machine's controller board is the main part that controls how the machine operates. It gets commands from the software, manages the power supply, moves the motors in a controlled manner, and keeps an eye on the sensors to ensure safe and effective printing.
    - *Filament:* In AM machines, filament is the raw material that is used. The plastic wire is melted and then extruded through the print head, making it long and thin. Different filament types—like PLA or ABS—offer a range of qualities, hues, and printing applications.
    - *Frame:* The AM machine's frame offers stability and structural support. It ensures precise positioning and movement during printing and holds all the parts together.
    - *Stepper Motors:* These fine-tuned motors are employed in additive manufacturing machines to regulate the motion of different components, including the print bed and print head. They make it possible to precisely position objects and manage the printing process.
    - *Timing Belts:* In AM machines, timing belts are utilised to transfer motion between various parts, including the print head and the stepper motor. They ensure perfect placement throughout the printing process by offering precise and synchronised movement.
    - *Threaded Rods:* Usually used to manage the z-axis movement or modify the print bed height, threaded rods allow vertical movement within the AM machine. They make it possible to alter the printing process precisely and precisely.
    - *End Stops:* The mechanical switches known as end stops identify the actual physical boundaries of the AM machine's motion. They act as safety measures, keeping the equipment from going beyond its designated range and possibly breaking anything.
    - *Power Supply Unit (PSU):* The AM machine receives the electrical power it needs from the power supply unit. It transforms the supplied electricity into the proper voltage and current needed by the parts of the machine.
    - *Print Bed:* The surface that the object is built upon is known as the print bed. It offers a firm surface for printing and can be heated or left unheated. Adhesion and print removal ease may be impacted by the material selected for the print bed.
    - *Print Bed Surface:* The substance or coating that has been applied to the print bed is referred to as the print bed surface. It has an impact on the adherence of the printed product to the

bed, guaranteeing adequate layer bonding and averting warping or separation throughout the printing process.

- *Print Head:* The filament is melted and deposited onto the print bed by the print head, also referred to as the extruder. Layer by layer, it manipulates the molten material's flow and deposition to produce the desired object.
- *Feeder System:* The filament is fed into the print head by the feeder system. It makes sure that the filament flows steadily and under control, which makes printing easier.
- *User Interface and Connectivity:* Through the user interface, users may communicate with the AM machine by adjusting settings, starting prints, and keeping track of their progress. Wi-Fi and USB connectivity options allow the computer to communicate with external devices.

ADDITIVE MANUFACTURING MACHINE

Fused Deposition Modelling (FDM)

Fused Deposition Modeling (FDM) is a popular additive manufacturing technology that utilizes a thermoplastic material to create 3D objects layer-by-layer. FDM was first developed in the late 1980s by Stratasys and has since become a widely used technology in industries ranging from aerospace to consumer products. The FDM process starts with a 3D digital model that is sliced into thin layers using specialized software. The software then generates a toolpath for the printer, which controls the movement of the printer's extruder as it deposits melted plastic onto a build platform layer by layer as shown in Figure 2. The printer's extruder heats up a spool of thermoplastic material, usually in the form of a filament, until it melts into a viscous liquid. The liquid plastic is then extruded through a nozzle onto the build platform, where it quickly cools and solidifies, creating a layer of the object. The printer's extruder then moves to the next layer and repeats the process until the entire object is complete.

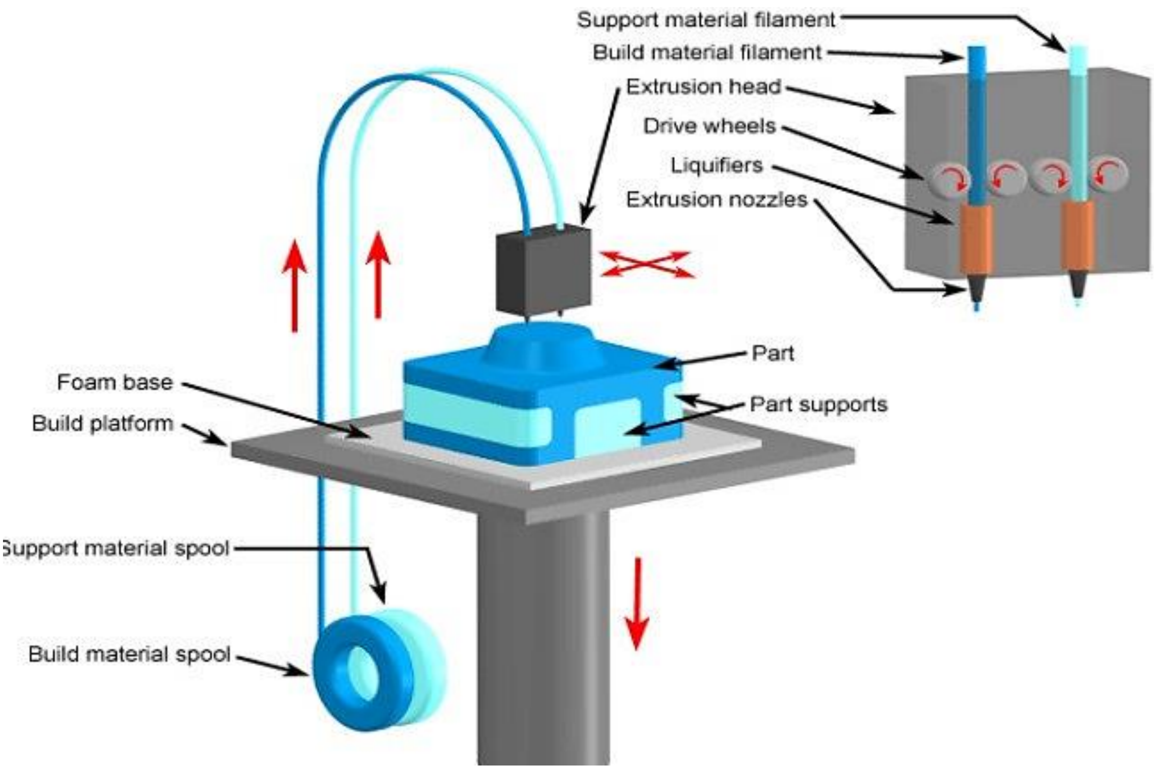

Figure 2: Fused Deposition Modelling.

One of the main advantages of FDM technology is its ability to produce complex geometry and shapes with relative ease. The technology is also relatively affordable and accessible, with a range of desktop and industrial 3D printers available on the market. FDM technology also offers a wide range of materials to choose from, including different types of thermoplastics, which can be chosen based on the specific application and required mechanical properties. One of the main limitations of FDM technology is its limited resolution compared to other additive manufacturing technologies, such as Stereolithography (SLA) or Digital Light Processing (DLP). This is because the printer's extruder nozzle limits the minimum size of the features that can be printed. Another limitation is the need for support structures when printing complex geometries, which can be difficult to remove and can lead to surface imperfections on the finished object. FDM technology is widely used in industries ranging from aerospace to consumer products. Its ability to produce functional prototypes and end-use parts with complex geometries and a wide range of materials makes it a versatile technology.

CONCLUSION

When compared to traditional manufacturing, additive manufacturing offers a few clear advantages. Careful consideration of several aspects, such as the technique to be employed, the materials to be used, and the requirements of the intended application, go into the design and development of an additive manufacturing machine. In addition to being simple to operate and maintain, the equipment must be built with accuracy, dependability, and safety in mind. To build a useful and effective additive manufacturing machine, several parts, including the frame, feeder system, print head, print bed, power supply unit, control board, end stops, and filament, need to be carefully chosen and integrated. Many opportunities and advantages are presented by additive manufacturing technology, like FDM. These include the capacity to produce extremely intricate and complicated designs, lower manufacturing costs and times, and less waste by utilising only the appropriate amount of material.

REFERENCES

1. Aamer Nazir, Ozkan Gokcekaya, Kazi MdMasumBillah, Onur Ertugrul, Jingchao Jiang, Jiayu Sun, Sajjad Hussain, "Multi-material additive manufacturing: A systematic review of design, properties, applications, challenges, and 3D printing of materials and cellular metamaterials", Materials & Design, Volume 226, February 2023, 111661.
2. Márton Tamás Birosz, Dániel Ledenyák, Mátyás Andó, "Effect of FDM infill patterns on mechanical properties" Polymer Testing, Volume 113, September 2022, 107654.
3. I. John Solomon, P. Sevvel, J. Gunasekaran, "A review on the various processing parameters in FDM", Materials Today: Proceedings, Volume 37, Part 2, 2021, Pages 509–514.
4. Xing Peng, Lingbao Kong, Jerry Ying Hsi Fuh and Hao Wang, "A Review of Post-Processing Technologies in Additive Manufacturing", Manufacturing and Materials Processing, 2021, 5, 38.
5. Eda Hazal Tümer and Husnu Yildirim Erbil, "Extrusion-Based 3D Printing Applications of PLA Composites:A Review", Coatings 2021, 11, 390.
6. Abdullah Alfaify, Mustafa Saleh, Fawaz M. Abdullah and Abdulrahman M. Al-Ahmari, "Design for Additive Manufacturing: A Systematic Review", Sustainability, 2020, 12, 7936.
7. H.salem, h.abouchadi, k. El bikri, "design for additive manufacturing", Journal of Theoretical and Applied Information Technology, 15th October 2020, vol.98. No 19.
8. Zocca A, Wilbig J, Waske A, Günster J, Widjaja MP, Neumann C, Clozel M, Meyer A, Ding J, Zhou Z, Tian X. Challenges in the technology development for additive manufacturing in space. Chinese Journal of Mechanical Engineering: Additive Manufacturing Frontiers. 2022 Mar 1;1(1):100018.
9. Javaid M, Haleem A. Using additive manufacturing applications for design and development of food and agricultural equipments. International Journal of Materials and Product Technology. 2019;58(2-3):225–38.
10. Murr LE, Johnson WL. 3D metal droplet printing development and advanced materials additive manufacturing. Journal of Materials Research and Technology. 2017 Jan 1;6(1):77–89.

