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Recent Development in Working Principles of 3D Printing Machine- A Review

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A B S T R A C T

This study focuses the applications, working principles, functions, and development of 3D printing machines. It explaining the progress of 3D printing from its earlier stages to current applications in fields such as medicine, aerospace and constructions. Also discussed about the various technologies like Fused Deposition Modelling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS) and highlighting their advantages its structure and functions. Furthermore, 3D printing is becoming more eco-friendly by using sustainable materials like biodegradable plastics and recycled components. This study is providing a comprehensive understating. how 3D printing enables faster production, lowers manufacturing costs, and facilitates the creation of complex designs that are impossible to achieve with traditional methods. After comprehensive literature, it is concluded that 3D printing is an essential tool for modern industries.

Keywords: 3D printing, Fused Filament Fabrication (FFF), Structure, Additive manufacturing.

1. Introduction

3D printing is known as additive manufacturing, it is a process of creating three-dimensional objects by layering materials based on a Digital designing model it is ongoing research. In 2010 NASA's Marshall Space Flight Center in Huntsville was actively working in 3D printing development to create engine parts. This is the effort to create complex components for aerospace applications. Since then, technology has evolved significantly towards sustainable, and more versatile solutions and also allowing the usage of materials such as plastic, metals, ceramics, and biological materials, Resins used as Fused Filament Fabrication (FFF) for various applications in reducing pollution caused by 3D printing.

The 3D printing machine typically consists of several key components such as a frame, a printing bed, an extruder or nozzle, and a controlling system. The basic working principles of the 3D printing process are Design, Slicing, Printing, and Post-Processing. 3D printing machine uses digital designs usually in CAD software and slices them into layers and these are used to guide the machine to create the 3D objects.

The 3D printing machine usage has increased in different applications such as the medical field, Automotive and Aerospace, Construction, Education, and Research. Based on the uses they invented different types of 3D printing technologies for various works, the technologies such as Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), and direct metal Laser Sintering (DMLS). Nowadays 3D printing is quickly becoming popular it can easily create prototypes, and customize products to make complex shapes which cannot be done by traditional methods it is also evolving in industries by making manufacturing easier and more effective.

2. Literature survey

2.1 Application of 3D printing in different areas

3D printing process nowadays merges with various eco-friendly materials especially polymer-based materials. 3D printing has different types of applications in various fields due to its ability to create various types of complex geometrical materials and it is used to increase efficiency and mechanical properties of materials [1]. It is an advanced technology compared to traditional manufacturing to reduce waste caused by working. In various fields, 3D printing is used mainly in tissue engineering, the medical field, and various technologies like Fused Deposition Modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), are playing a key role in surgery and pharmaceutical applications [2]. As we compared to traditional methods the 3d printing process allowed for svery highly personalized and precision solutions with fewer complications such as reducing transplant rejection in bone grafting procedures [3]. Beyond medicine 3D printing has impacted other different fields such as dentistry, scanning visualization, and CAD technological enhancements in dental procedures. The 3D printing is also mainly used in construction. Concrete 3D printing is becoming more effective and automated it presents an alternate process for traditional building methods for creating different types of structures

and is highly adaptable [4]. Furthermore, ceramic 3D printing is more advanced in agriculture, food processing, and environmental protection. This reduces the environmental effect by reducing the consumption of resources and also supports monitoring efforts [5]. Every 3D printing method like Stereo lithography (SLA), fused deposition modeling (FDM), and powder bed fusion has its advantages and disadvantages based on that the research is focused on expanding its capability across various applications. Mainly graphene quantum dots (GDQ) in polymer matrices are explored for specific potential enhancement as mechanical, electrical, and optical properties and printed materials and also in further broadening 3D printing industrial applications [6].

2.2 Different types of 3D printing machines

Fused Deposition Modeling (FDM) is the technique used to extrude the filament by heating through a nozzle to build an object by a layering process [7, 8]. Photo polymerization is the combination of different types of techniques they are Stereo lithography (SLA), Digital light processing (DLP), and Continuous Liquid Interface Production (CLIP) [9-10]. Inkjet printing for creating deposit conductive inks, and fine electronic circuits while Micro-Stereo lithography (μSLA) utilizes UV light to cure photopolymer resin for high-precision components [11].

Biocompatible Extrusion printing is used in medical and dental applications, especially with bioactive Nano-materials [12]. For mechanical properties for printed PA12 samples using the Taguchi method for experimental design, these are the various parameters for the FDM process. The experimental design (L8), four different layer thicknesses (0.1, 0.15, 0.2, 0.25 mm), extruder temperature (250 and 260C), filling structure (Rectilinear and Full Honeycomb), and occupancy rate (25 and 50%) were determined [18][19]. GQD deals with the synthesis methods of surface functionalization and application in polymer composition [13].

2.3 Structure and Function integration of 3D printing

The harder liquid technique hardens liquids like projectors while others like squeezing toothpaste. This lets them 3D print complex objects with different materials at once, useful for devices with many functions [14]. Moreover, so much research done to make tiny chemical factories these factories made of metals like iron, cobalt, and nickel can turn simple chemicals into valuable ones like fuels [15]. This method is more beneficial to environmental sustainability, Electricity they made super strong, thin threads that form a spongy mesh that is perfect for medicine because spongy mesh acts like our body tissues by combining with 3D printing, they created complex shapes for medical devices like health sensors, scaffolds, and also used to create artificial tissues [14].

3D printing is also used to create smart materials that can change shape or function in response to things like temperature or light. Imagine a bandage that can release medicine when it gets warm or a phone case that can change color. These are just a few examples of what's possible with this technology [16]. In 3D printing, artificial intelligence is added to design stronger and lighter materials. This technology can be used to create better implants and bone scaffolds, which can help people recover from injuries and illnesses [17]. And also, by using carbon fiber we can create faster, green vehicles and other products. 3D printing is changing the way we make things. It allows us to create custom products without needing expensive tools or molds [18]. This means we can make more complex and unique products, faster and cheaper. It has developed a new material that can generate electricity it’s pressed or squeezed. This material can be used to power small devices, like sensors and robots. It's a big step forward in the field of flexible electronics and energy harvesting [19].

2.4 Importance in 3D printing Technology for sustainability and Eco-friendly materials

3D printing technology into the sustainable fashion and jewelry sectors, by focusing on zero-waste standards. This aims to create beautiful pleasing and functional items that contributes to reducing waste in the fashion industry. They utilized computer-aided design (CAD) software to create innovative, zero-waste fashion and jewelry concepts that minimize material use and optimize production operations efficiency [20]. The use of environmentally friendly materials in 3D printing. It focuses on selecting and testing biodegradable polymers, recycled plastics, and natural fibers to assess the performance and environmental sustainability of these materials for additive manufacturing, reducing environmental impact and promoting sustainable practices in the industry [21]. 3D printing filaments from recycled solid wastes involves collecting and processing waste materials, fabricating filaments through extrusion, and testing their properties before using them, then they are used to print interior and furniture design prototypes, this promotes sustainable practices by utilizing recycled materials in 3D printing for practical applications in design. [22]. In 3D printing operation, the polymer material dominates the Fused Filament Fabrication (FFF) landscapes, by using polynomials like polylactic acid (PLC), polypropylene (PP), high-density polyethylene (HDPE), etc. that creates a new bio polynomial (FFF). This is used in the recycling process; it does not reduce environmental impact but creates a cyclic economy in the 3D printing industry [23]. The potential of 3D printing using bamboo is a naturally occurring material, focusing on its application in the built environment. By exploring the unique properties (strength and sustainability) of bamboo, the study aims to identify different ways to use this natural material in construction and design. The research includes the testing of various 3D printing techniques and evaluating the performance of materials. Additionally, it seeks help to understand the environmental benefits of using bamboo as a renewable resource [24]. Ultimately with this source, we can construct a building with 3D printing offering a sustainable environment, a cost-effective solution for affordable housing with low cost in Brazil as well as in Russia utilizing locally sourced materials and recycled materials, and addressing the need for technical expertise. Research should focus on the materials combination and training programs for co-workers. By addressing these needs, 3D printing can significantly impact Brazil's and Russia’s housing crisis. Embracing this technology can lead to more inclusive and environmentally friendly solutions for housing. [25, 26].

3. Conclusion

3D printing is playing a key role in daily production. Optimizing these parameters can lead to improved strength-to-weight ratios and other desired characteristics in the final products. Its approaches in various applications like medical, aerospace, automobile, agriculture industries, and tissue engineering offer new insights for treating bone defects through the production of scaffolds with better mechanical strength and favorable structures, further research on 3D printing technology with concrete materials, which is crucial for unlocking the full potential of concrete 3D printing in the construction sector.

FDM is widely used due to its ease of use and affordability. The Taguchi method helps find the best layer thickness and extruder temperature. Vat photopolymerization techniques like SLA, DLP, and CLIP enable precise 3D printing. The results suggest that PA12 filament material is suitable for printing various machine parts.

The hybrid 3D printing system combines speed, resolution, and flexibility. It enables the creation of complex, customized devices and structures printing combines tiny particles and natural materials to create artificial tissues and organs. Machine learning helps design stronger, complex 3D structures for implants and bone scaffolds. 3D printing and carbon fiber combine to create strong, lightweight materials for faster, greener vehicles and innovative products. 3D printing creates a flexible material that converts pressure into electricity, ideal for sensors, robots, and artificial muscles.

Based on sustainability it marked the first successful attempt at 3D printing biodegradable zero-waste fashion works and accessories. They use polylactic acid (PLA) to maintain the sustainability of the environment. By decreasing non-biodegradable waste. Also, eco-friendly materials are used in 3D printing compared to traditional materials. Eco-friendly materials like polylactic acid, Recycled plastic, bamboo powder Natural fibers, and various solid wastes, such as plastic bottles, packing materials, and other discarded plastics create an eco-friendly filament fabrication, to decrease the environmental effect. Brazil and Russia made the first step to create sustainability and less wastage in 3D printing objects based on the wastage in constructions.

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