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Composite Material Printing Using Additive Manufacturing: A Review of Materials, Processes, Recent Trends and Future Aspects

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Abstract:
Additive Manufacturing (AM) or popularly known as 3D printing has transformed the manufacturing by producing complex geometries with minimum material wastage. The use of composite materials in additive manufacturing has opened new possibilities to improve mechanical strength, thermal stability and functional performance. Composite materials are created by combining a matrix with fibres, particles or nanomaterials which gives them better properties than traditional polymers and metals. This paper reviews the recent development of additive manufacturing of composite materials, discussing different AM techniques, composite materials, processing parameters, challenges and industrial applications. Future research directions are also pointed out focusing on sustainable materials, multi-material printing and intelligent manufacturing.

Keywords: Additive Manufacturing, Composite Materials, 3D Printing, Fiber-Reinforced Composites, FDM, SLS, SLA

I. INTRODUCTION

Additive manufacturing (AM) is a novel and advanced technique that has appeared in the manufacturing industry. This technique, also called 3D printing, has been proved very efficient in the use of reinforcements such as fillers and Fibres in the fabrication of polymers and metals. AM can produce composites using a layer-by-layer material deposition technique, whereas similar product development can be achieved using traditional subtractive manufacturing methods [1]. The combination of the latest technology, like 3D printing, with composite materials opens up new possibilities for development and use. The advent of these two processes results in complex structures that are extremely difficult, if not impossible to fabricate by conventional means, and the customised properties achieved can be employed to meet the requirements of a variety of applications [2]. Additive Manufacturing (AM) is a process of making three-dimensional parts layer-by-layer from digital models directly. Unlike traditional subtractive manufacturing, AM reduces material waste and speeds up production cycles, while also enabling highly customised products. Composite materials are of great interest due to the combination of two or more materials to obtain superior mechanical and physical properties. The application of composites in additive manufacturing has allowed for the production of lightweight, high strength components for the aerospace, automotive, biomedical, and construction industries. Recent advances in continuous fibre reinforcement, nanocomposites and multi-material printing have greatly enhanced the performance of printed composite structures. Compared to conventional manufacturing processes, additive manufacturing of fibre reinforced composites provides exceptional design flexibility and potential for functional integration, resulting in improved structural performance and enhanced production efficiency [3].

2. COMPOSITE MATERIALS USED IN ADDITIVE MANUFACTURING

Composite materials are typically applied in making lightweight parts and structures in different fields. Composite materials are extensively applied in the aerospace industry, where such materials have been extensively utilized for the production of various components of the airplanes. At present, nearly half of the air frame of the airplanes is produced using composite Materials. Composite materials are extensively utilized in many applications, including transport, construction, automobiles, and aerospace due to their excellent mechanical characteristics, design flexibility, affordability, and high performance. Figure (1) illustrates important materials and techniques for polymer composites in additive manufacturing [4].

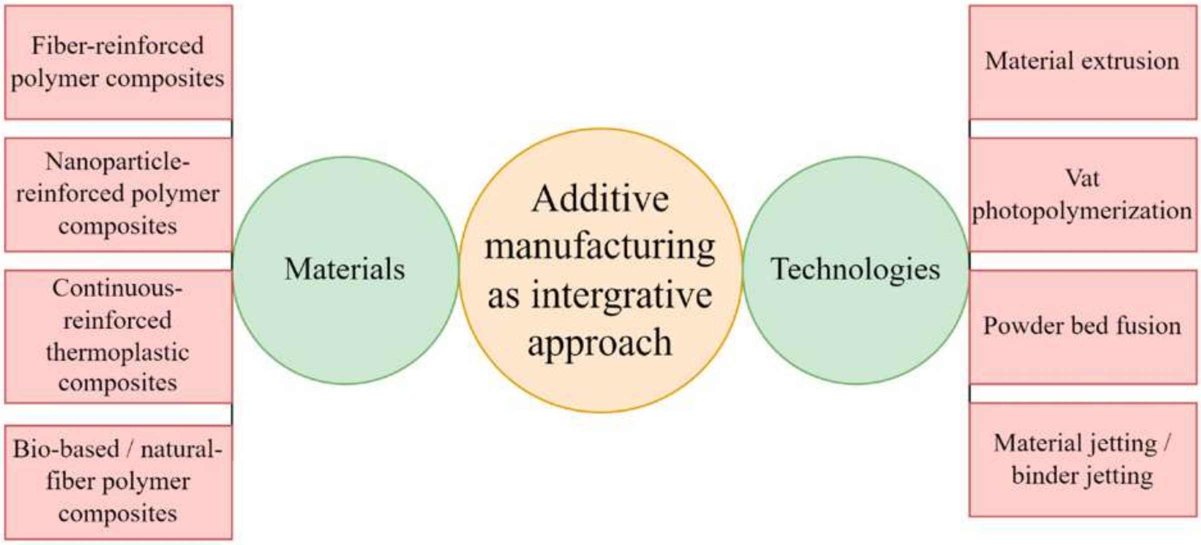

Figure 1. Key materials and processes of polymer composites in additive manufacturing.

Composite materials used in AM are generally classified into:

2.1 Fiber-Reinforced Composites

- Carbon Fiber Reinforced Polymer (CFRP)
- Glass Fiber Reinforced Polymer (GFRP)
- Kevlar Fiber Composites
- Basalt Fiber Composites

2.2 Particle-Reinforced Composites

- Silicon Carbide (SiC)
- Alumina (Al_2O_3)
- Titanium Carbide
- Hydroxyapatite

2.3 Nanocomposites

- Graphene
- Carbon Nanotubes (CNTs)
- Nano-clay
- Nano-silica

3. ADDITIVE MANUFACTURING TECHNIQUES FOR COMPOSITS

3.1 Fused Deposition Modelling (FDM)

FDM stands for Fused Deposition Modelling, and it is one of the most popular types of additive manufacturing technology employed in creating polymer and composite products. FDM technology involves heating up a plastic filament to a partially molten condition and then extruding it through a nozzle based on a 3D model of the object. The introduction of reinforcement in the form of fibres, nanoparticles, or fillers into the polymer results in composites with improved mechanical, thermal, and functional properties being manufactured using FDM. The structure of a typical FDM 3D printer is illustrated in Figure (2).

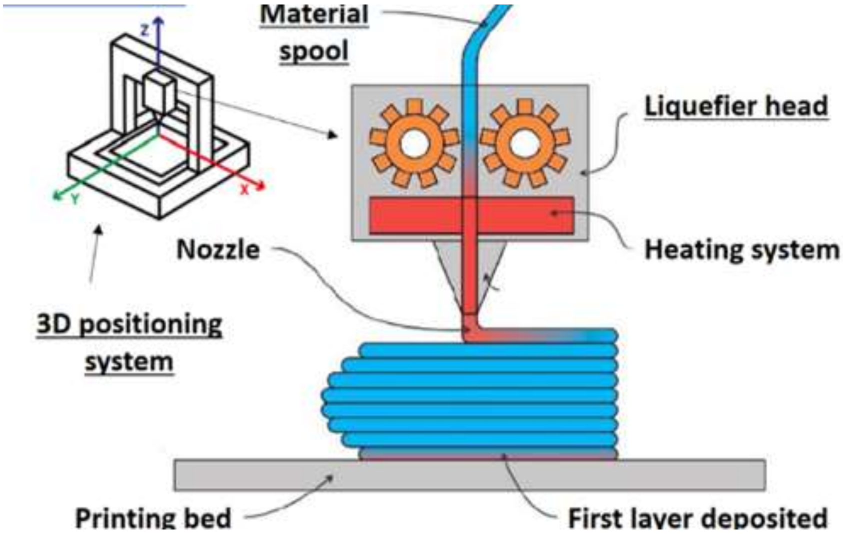

Figure 2. Schematic illustration of the working principle for FDM process.

3.2 Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is a technology within additive manufacturing (3D printing), which involves the use of a powerful laser beam to melt and bond layers of powder materials to form parts. In case of composite materials, SLS involves melting of a polymer matrix along with other components to increase their mechanical or thermal strength. Selective Laser Sintering of composites allows creating lightweight and high-performance parts using thermoplastic powder combined with reinforcing materials (carbon or glass fibres). This technology is popular in aerospace, automotive, medical and other industries due to the ability to produce parts with complicated shapes, high mechanical properties, and minimal waste of materials. Figure(3) presents the schematic of a typical Selective Laser Sintering system [6]:

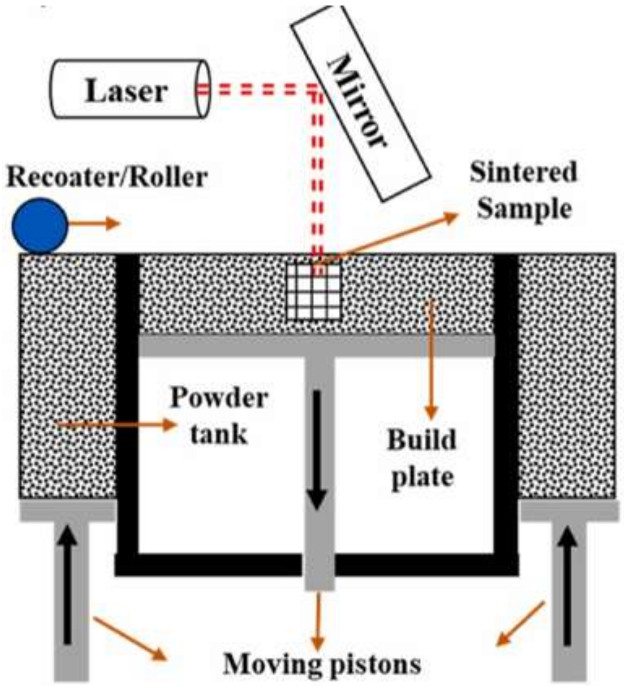

Figure 3. Selective Laser Sintering System

3.3 Stereolithography (SLA)

Stereolithography (SLA) refers to additive manufacturing technology that employs either a UV laser beam or projected light to selectively harden successive layers of liquid photosensitive materials into high-precision components. Figure (4) shows how Hull's stereolithography machine operates to build up 3D objects layer-by-layer using photosensitive materials that could be hardened by ultraviolet (UV) radiation [7]. In case of composite manufacture, the resin gets modified through addition of reinforcement materials such as Stereolithography (SLA) represents a 3D printing technology that can produce composite parts through curing of fibre-reinforced photopolymer resins. It is characterized by excellent precision and quality but is constrained with respect to materials and incorporation of large amounts of reinforcement.

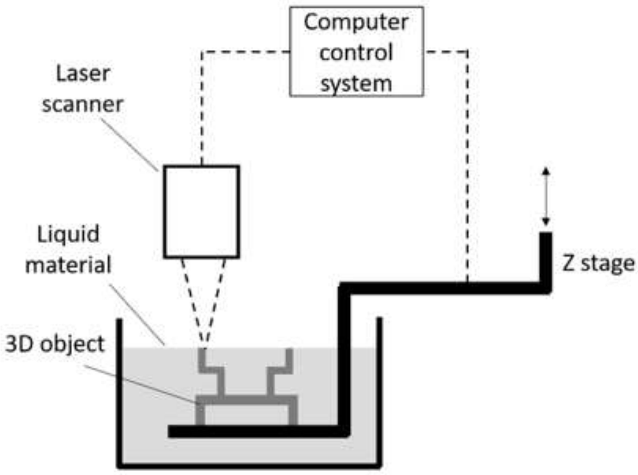

Figure 4. Hull's stereolithography system.

4. RECENT RESEARCH TRENDS AND FUTURE SCOPE

The additive manufacturing of composite materials is developing fast from traditional polymer-based composite materials towards advanced and multifunctional composites. The current research in AM composites is being concentrated around continuous fibre composites, nanocomposites, multi-material printing, artificial intelligence in manufacturing processes, digital twins, and eco-friendly materials. The future trends of development are likely to be oriented toward smart composites, 4D-printing, autonomous manufacturing, recyclable materials, and industrialization of AM. All recent scientific research results are converted to three main directions of development in AM multi-material polymer composites. First, AI-driven process optimization makes possible real-time modification of the parameters on the basis of model prediction of melt pool dynamics with the help of convolutional neural network technology, while on the contrary, the new generation of the design algorithms is able to generate structures with varied mechanical properties in space and therefore creates a functionally graded structure. Second, there are new hybrid systems that integrate laser assisted deposition and material extrusion processes to increase the interface strength, as well as multi-nozzles set up to print conductive-dielectric composites for incorporating electronics [8].

5. CONCLUSION

Composite material fabrication through additive manufacturing is one of the most exciting innovations in manufacturing technologies in contemporary times. Through the combination of geometric freedom of additive manufacturing and high-quality characteristics of composite materials, companies have been able to manufacture light, durable and customized goods. Even though there are certain problems in terms of anisotropy, fibre dispersion, and optimization, there are many advancements that are being made in terms of material properties and efficiency in manufacturing. In the future, further development involving AI, sustainable material development, and multi-material printing will lead to increased number of industrial applications. Polymer-based composites, which have been quite a silent revolution in AM technology, particularly in aerospace, biomedical device production and electronics where lightweight and multifunctional parts are needed, have been manufactured by adding reinforcements such as carbon fibers, graphene, CNTs or even natural fibers to polymers, resulting in enhancement of mechanical properties, heat resistance or electrical conductivity in many cases. However, results may vary depending on the quality of fillers distribution or interface bonding strength.

REFERENCES

1. Rajendran, S. et al. Metal and Polymer Based Composites Manufactured Using Additive Manufacturing—A Brief Review. Polymers 2023,
2. Alarifi, I. M. (2024). Revolutionising fabrication advances and applications of 3D printing with composite materials: a review. Virtual and Physical Prototyping, 19(1).
3. Houcheng Fang, et Li Xi, Yixing Huang, Tian Zhao, Rujie He, Xiao Kang, Ying Li, Daining Fang, Fiber-reinforced composites: A comprehensive review of traditional and additive manufacturing processes and material architectures, Composites Part A: Applied Science and Manufacturing, Volume 205, 2026
4. Rahman, M.M.; Islam, S.; Mubasshira; Islam, M.S.; Ahammad, R.; Islam, M.A.; Hasib, M.A.; Rahman, M.S.; Moshwan, R.; Ehsan, M.M.; et al. Polymer Composites in Additive Manufacturing: Current Technologies, Applications, and Emerging Trends. Polymers 2026, 18.

5. Zotti, A.; Paduano, T.; Napolitano, F.; Zuppolini, S.; Zarrelli, M.; Borriello, A. Fused Deposition Modeling of Polymer Composites: Development, Properties and Applications. Polymers 2025,
6. Muhammad Umar Azam et al, Progress in selective laser sintering of multifunctional polymer composites for strain- and self-sensing applications, Journal of Materials Research and Technology, Volume 30, 2024.
7. Huang, J.; Qin, Q.; Wang, J. A Review of Stereolithography: Processes and Systems. Processes 2020.
8. Rahman, Md et al (2026). Polymer Composites in Additive Manufacturing: Current Technologies, Applications, and Emerging Trends. Polymers.