



PROSPECTS FOR THE DEVELOPMENT OF ADDITIVE MANUFACTURING

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The evolution of additive manufacturing technology has been characterized by a significant increase in capabilities and applications, which have led to its expansion in scope and influence across industries. Additive manufacturing, once considered a rapid prototyping technique, has evolved over time into a wider range of capabilities than originally thought. Technology is now transforming manufacturing processes in industries such as automotive, aerospace, healthcare, and consumer products, allowing the design and creation of complex parts that were previously not possible or would take a long time to create [1]. Such radical changes have been driven by the continuous development of additive manufacturing technologies, resulting in more variety, more efficient and more creative solutions than traditional manufacturing methods [2]. In addition, the transition from low volume production to mass production is important due to its significant continuous improvement and increasing prevalence. This transition is important not only because of the increased reliability and efficiency of the technology, but also implies the potential for mass production of the technology, which will expand the range of its applications in various fields [1]. Also, according to some reports and data (GVR Report cover 3D Printing Market Size, Share & Trends Report 3D Printing Market Size, Share & Trends Analysis Report By Component), the global 3D printing market size was valued at US \$20.37 billion in 2023 and is expected to grow at a CAGR of 23.5% from 2024 to 2030 years. This growth is driven by active research and development and the growing demand for prototyping applications across various industries.

Building on fundamental steps in the field of additive manufacturing, a significant advance has been the evolution of materials used in 3D printing. Initially, this technology had the ability to primarily use polymer materials for 3D printing. The use of this 3D printing method was driven primarily by the simple manufacturing method and straight-line nature of polymers, making them an ideal choice for the early stages of additive manufacturing [3]. However, as the technology's capabilities expand and demand increases in other areas of production, the variety of materials for 3D printing has increased significantly. Today, the variety of materials for 3D printing is increasing, which can be used to create different models and parts, such as ceramics, metal, rubber, polymers, different types of plastic, etc. This expansion has led to the emergence of new opportunities for the use of 3D technology. print. Technology is now used in a wider range of industries, including aerospace, automotive and medical. In these industries, the properties of metals and ceramics are important because they influence the application of the technology [3]. The shift from using polymer-based materials to using a diverse range of materials represents a significant evolution in the capabilities of additive manufacturing technology.



The development of additive manufacturing is broader than the evolution of materials for 3D printing, as a result of which it has a significant impact on various areas of production, thereby changing processes. As technology has evolved, its primary use has shifted from rapid prototyping to an integral part of manufacturing processes in many applications [4]. This shift is primarily driven by the development of advanced additive technologies and the increasing variety of materials, including metals and ceramic components [5]. Industries such as aerospace, automotive and healthcare have particularly benefited from this technology [6]. This has helped enable the use of additive manufacturing in both prototype production and the production of complex, high-performance end-use parts. The versatility and efficiency of 3D printing not only challenged traditional manufacturing principles, but also led to the introduction of new manufacturing methods [5]. As additive manufacturing matures, its impact is expected to increase, causing the distinction between manufacturing and product development to be continually redefined in the future.

This manufacturing method is changing the way companies approach design and innovation, it provides a variety of practical benefits that simplify the development process. This technology allows businesses to quickly create, test, and improve products, which reduces the time and expense associated with traditional manufacturing methods [7]. By utilizing the power of additive manufacturing, companies can quickly reformulate designs, this will allow for a more dynamic and reactive approach to product development [7]. This agility is particularly beneficial in industries that have a high demand for safety, quality, and performance, such as aerospace, healthcare, and automotive. Additive manufacturing not only fulfills these stringent requirements, it also promotes innovation by allowing the creation of complex, custom, and previously impossible products [7]. The strategic adoption of additive manufacturing has the potential to serve as a powerful catalyst for businesses to re-design their product creation processes, this will lead to innovation and a competitive advantage in their respective markets.

Despite the significant evolution and steps towards success in the additive manufacturing sector, its incorporation into mainstream production has been slow due to regulatory and standardization issues. The current percentage of additive manufacturing in the global manufacturing market is 0.04 percent [8]. This is underscored by the young age and limited use of the technology in other industries [8]. This small-scale market access is primarily attributed to several factors, including regulatory and standardization issues. These issues have a significant impact on the market's access. Industries that would reap significant benefits from additive manufacturing, such as the aviation and automotive industries, have financial and technical barriers that are amplified by the lack of clear regulations and standardized procedures. These issues are problematic in the absence of a clear regulatory framework and formal procedure for additive manufacturing [8]. These industries require high levels of precision and consistency in the manufacturing processes, these requirements are hard to meet consistently by additive manufacturing because of its inherent process variability. Additionally, the requirement of post-processing to



achieve the desired surface qualities and tolerances increases the complexity of the process and introduces a potential for human error, this further complicates the regulatory compliance process. This is particularly detrimental to sectors like aerospace and automotive, the production of components is exacting and non-negotiable. The route to a larger adoption of additive manufacturing, therefore, necessitates dedicated efforts toward addressing these regulatory and standardization issues, to ensure that the technology can fulfill the stringent requirements of these specialized industries.

One of the most pressing technical challenges in expanding additive manufacturing capabilities is the current limitation in the production of multi-material models and prototypes. Currently, only a few high-cost 3D printing systems have the ability to print multiple materials simultaneously, which is a critical requirement for mass adoption of this technology [8]. This limitation not only limits the range of applications for which additive manufacturing can be used, but also significantly hinders innovation in the sector. Additionally, the lack of business and costing models specifically designed for additive manufacturing complicates financial planning and feasibility analysis for businesses considering the adoption of AM technologies [9]. The lack of tailored financial models makes it difficult for manufacturers to accurately estimate the return on investment of introducing additive manufacturing into their production processes. Additionally, the uncertainty surrounding ownership and authorship of digital models and prototypes poses a significant technical and legal obstacle. This problem occurs due to the creation of digital 3D models, resulting in an impact on additive manufacturing processes where designs are easily transferred and modified, leading to potential intellectual property disputes, and complicating the legal environment for additive manufacturing [9]. Taken together, these challenges highlight the need to advance additive printing technologies and policies to realize their full potential.

In summary, the outlook for additive manufacturing is very promising, with a number of trends pointing to a bright future. Below is a look at the forecast and trends in the field of additive manufacturing (tab. 1).

Table 1 – Forecast and trends in the field of additive manufacturing

Trend	Description
Multimaterial Printing	Improving additive manufacturing performance to enable printing on multiple materials simultaneously, thereby optimizing productivity, quality, and functionality.
AI Integration	Integrating artificial intelligence and machine learning into additive manufacturing processes, thereby improving materials development, machine setup, part design, and workflow automation.
Full-Scale Production	There is a need to find a balance between full-scale production and product customization with a tendency towards prototype production.
Sustainability	The need to focus on improving commercial and environmental sustainability by rethinking the concept of scrap and material recycling.
Machine Connectivity	There is a need to improve connections between additive manufacturing hardware and software to the manufacturing environment, which is critical to scaling up operations.
Cost Reduction	Continued efforts are needed to reduce costs and improve technology to facilitate wider adoption of 3D printing.
Market Growth	Despite macroeconomic challenges, there's a push towards mainstream applications and production flexibility.



The importance of additive manufacturing is various as it is essential for the modern industries. The high advantage of using this technology in the production process is it can give an effect on the cost of production over time. The technology furthermore leads to flexible manufacturing and improves the design capability.

Conclusion. The future of additive manufacturing is filled with possibilities and problems, as evidenced by the development and advanced nature of the technology. From its humble begin as a rapid prototype to its current status as a powerful influence in multiple disciplines, additive manufacturing has experienced a significant evolution over the course of a remarkable journey. The transition from small batch production to large-scale manufacturing is significant in the evolution of the technology, this transition shows the increasing reliability and efficiency of the technology. The inclusion of materials derived from polymers into metals and ceramic has enhanced the capabilities of additive manufacturing, this previously couldn't have been accomplished. However, this evolution also shows a significant difference between the technical demands of additive manufacturing technologies and the current capacity of the profession, this difference is of great importance and should be addressed immediately. As companies recognize the value of additive manufacturing in rapid design, personalization, and design evolution, there is a significant demand for educational initiatives that will cover the gap for knowledge in this area. Additionally, the problems associated with digital design ownership and the limited availability of educational programs dedicated to additive manufacturing careers have led to a necessity for continued research and development in this area. The discussion regarding the future of additive manufacturing is not only significant because of its tremendous potential, but also because it highlights the necessity of strategic actions in order to address the gaps and ensure that the skilled population has the full capacity to take advantage of the technology.

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