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The Impact of 3D Printing on Manufacturing: An Analysis of Current Trends and Future Possibilities.

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ABSTRACT-

The traditional production process has been changed by 3D printing technology, presenting both new potential and difficulties. This study examines present trends and potential futures to examine how 3D printing has affected the manufacturing sector. The report offers a thorough analysis of the benefits and drawbacks of adopting 3D printing in manufacturing, taking into account factors like cost effectiveness, customer customization, and product quality. The report also looks into how the market for 3D printing is doing right now, identifying important companies and the future possibilities of this ground-breaking technology. The report finishes with a review of the potential applications of 3D printing in production, including the possibility of a manufacturing revolution and the anticipated effects on the world economy.

Keywords- Manufacturing, 3D printing, Future

1. Introduction

Additive Manufacturing (AM), including 3D printing, is a technique that employs computer control to add successive layers of material on top of each other, resulting in the production of three-dimensional objects. In contrast to conventional technologies such as sand moulding, machining, etc., complicated geometries and intricate shapes are easily replicated in a short amount of time since material is added layer by layer. A suitable computer application is used to create a 3D model of the desired product, which is then loaded straight into the printer.

Although Hideo Kodama of the Nayoga Municipal Industrial Research Centre is widely recognized as the creator of the first solid object printed from a digital design, Charles Hull is often credited as the inventor of the first 3D printer. Hull founded 3D Systems Corp. and pioneered the stereolithography solid imaging technique as well as the STL (stereolithographic) file format, which remains the most commonly used file type for 3D printing today.

Since the invention of the first 3D printer in 1984, technological developments have made it less expensive and simpler to manufacture these printers on a big scale. Beginning in the early 2010s, the phrases 3D printing and additive manufacturing have evolved to serve as two distinct umbrella categories for AM technologies, with one being used indiscriminately by consumer maker groups and the media and the other by industrial AM end-use component makers, AM machine manufacturers, and international technical standards organisations. Both names refer to the same technology, which is the successive addition and connecting of layers of material throughout a 3D work envelope under automated control.

- **Principles behind 3D Printing**

a) Modelling: Using computer programmes like Blender and CAD software, a 3D model of the final product is created. The model's size and shape will vary on the requirements, but the fundamental idea—converting the object to be created into an electronic or digital format so a computer can easily oversee production—remains the same.

b) Printing: The produced model is then fed into a program called Slicer that divides the model into series of thin layers to be worked upon and this data is then converted into G-code automatically for the printer. There are *Open-Source* slicer program available of which are commonly used for this purpose. In order to create a model from a set of cross-sectional pieces derived from a CAD model, a 3D printer uses G-code instructions to deposit successive layers of liquid, powder, or sheet material. These layers correspond to the virtual cross-sections of the CAD model and are fused together to produce the final shape of the model.

c) Finishing: The object produced can readily be used without any machining operation required. Or The specific finishing process may be used depending on the material, geometry, and intended use of the 3D-printed part.

- **Processes used in 3D printing**

a) Stereolithography: Using photochemical processes, stereolithography—also referred to as vat photopolymerization or resin printing—is a unique 3D printing technique used to build models, prototypes, patterns, and production parts layer by layer. Chemical monomers and oligomers are incident with light, often ultraviolet. These photosensitive compounds solidify chemically under the influence of light to form the three-dimensional solid's body. In addition to numerous other uses, stereolithography is used to create prototypes, goods that are still in development, medical models, and computer hardware. Although it is quick and can manufacture practically any design properly, the method is pricey.

b) Selective Laser Sintering (SLS): Selective laser sintering involves the fusion of powder using high energy laser. The laser melts powdered material such as Plastic, Glass, Metal or Ceramic by precisely aiming on specific points of cross-section on powder surface as determined by the modeling software. This fusion generates object of desired geometry and dimensions. The density of finished area depends on peak power of laser. For this purpose, the powder is generally heated to a temperature just below its melting point and pulsed laser beam is used. Because the finished part is surrounded by sintered powder intricate geometries can be easily generated without the need of overhanging gear or supporting fixture.

c) Electron Beam Additive Manufacturing: Using an electron beam and metal powders in a high vacuum atmosphere, electron beam additive manufacturing builds up a solid mass layer by layer. This process creates fully dense metal pieces with the desired properties directly from metal powder. The EBM machine applies successive layers of powdered material after reading data from a 3D CAD model. An electron beam that is controlled by a computer is used to melt these layers together. The procedure is suitable for producing parts made of reactive materials with a strong affinity for oxygen, such as titanium, because it is performed under vacuum.

d) Metal Additive Manufacturing: Metal additive manufacturing uses metal powder using which layers are made and each layer is held together using a bonding adhesive. Different types of metal additive techniques are present in the market.

2. Current Trends

1) Automated Assembly
2) Acceleration of Digital Information Coding Into 3D Printed Textures
3) Rise in demand of 3D thinking
4) Customization of product on individual and mass scale
5) Increase in efficiency of supply chain
6) Introduction of advance software and AI

- **Automated assemblies**

Automated assembly system is a combination of automated and mechanized devices that are used to perform set of tasks during manufacturing process. Large industries favour automated assembly system for the manufacturing and the assembling of product for its large volume handling capacity, ease in material handling, less interference of labour, low percentages of defective product manufacturing and reduction in operation time all of which in turn helps in increasing profit.

An automated assembling systems basic requirement are:

1) High production rates
2) Stable and continuous production
3) Assembly of product is comprised of limited components
4) Product is assembly compatible

Automated assembly is different from machining as it doesn't have large force to do machining of parts. Its popularity stems from the fact that it can deliver speed and precision in product assembly. These factors make it not only cost effective but help the manufacturer meet supply demand. Setting an assembly line is capital intensive job and making a product assembly line compatible is not all businesses can take this risk.

Various types of system are discussed below.

In-line assembly machine system:

In this type of arrangement automated machines are present in a straight line and assembling happens one machine at a time and then moves to second machine. Used to handle both synchronous and asynchronous type of work transfer.

Dial-indexing machine:

A circular dial table's fixtures or nests are used to load base parts, while workstations positioned around the dial's perimeter are used to add components to the base part.

Carousal assembly system:

A hybrid between circular work flow of dial type and straight work flow of in-line system. The workstation kind of forms a loop in which the starting base and ending base is located near and the product goes around the system

Single station assembly:

Assembly operation in this system is performed on the base part at a single point, sometimes using robot in the assembly process.

Nowadays the design trend changes every now and then based on market demand and customers mood. High competition in market, product designing has to stay updated with market causing the requirement of a flexible system to be high. To achieve flexibility custom machines, have to be made according to job demand which is a very capital-intensive decision.

The second problem is the requirement of space required to install the machines since they can be small or large depending on type of work and the number of tasks they can perform.

The third problem that arises is that they need a stable and continuous product design to work efficiently. For large industries such as that in automobile sector, health sector whose production rates are high installing an automated assembly system is an easy task. Small Businesses and such whose production depend on season and market demand cannot afford an automated system for production either because of lack of capital or not a stable supply of product design.

These types of problems are solvable using 3D printing techniques. 3D printing techniques don’t rely on individual parts, rather they make product from start to finish without using parts/component separately in one place and they don’t even need machining as they already have high surface finish. Thus, the need for automated machines and extra parts are eliminated. The manufacturer doesn’t need to stock on parts as the product is made in one go.

- **Acceleration of Digital Information Coding and 3D Printed Textures**

IT sector is growing at a large scale globally and bringing in new technological advancement with it. Digital information coding refers to the process of converting real world object in machine code for more interactive and real-life experience of objects in software.

One example is NVIDIA's Ray-tracing technology which uses new and more enhanced rendering engines for creating real world light characteristic in object digitally. This helps in near to real world experience increasing the user engagement with software.

The characteristics of a real-world object is observed and stored into codes. The use of this information for creating texture of an object helps in creating more depth finish of the product.

This provides with the opportunity of creating object closure to real world definition using just printing without the use of machining.

Not only this but by using advance 3D printing technique, digital information can easily be coded onto the surface of the product providing with a bigger information payload about the product rather than just the serial number. And this information can either be made visible or hidden. This is one way to tag product so that both human and machine can read the product whenever required. Furthermore, tagging each part and storing into a database will ensure tracking is easy.

- **Rise in demand of 3D technique**

Individuals now have access to global ideas thanks to smart devices with worldwide connectivity, which encourages innovation. Soon, 3D printing technology will be widely used in homes, enabling people to create unique designs and goods. The demand for 3D printing methods has increased as a result, and new materials are being created to boost printing capabilities while maintaining affordability. For instance, sheet metal additive manufacturing employs metal powder to create objects with specified properties, altering the metal ratio in the powder to produce the required effects.

Now pre-designed 3D models are available on internet which one can use for reference and change its dimension to suit his need and make product at home. This is made convenient with the rise in 3D technique types. Follow these steps to print at home using 3d printer:

- Downloading the model from internet
- Uploading the model in slicer program and get g-code and m-codes
- Transferring the codes in 3D printer
- Printing the model

One may develop and modify the product several times to suit his needs using these four procedures. Using continuous carbon fibres and thermosetting polymers, a team of researchers from the University of Delaware have created a 3D printing process that enables the flexible, affordable manufacture of products composed of fibre-reinforced polymer composites. Their results were recently published in the journal Matter. There is still time until full potential of 3D printing can be seen.

Customization of product on individual and mass scale

By making personalization possible and inexpensive, 3D printing has changed the industrial industry. In contrast to conventional manufacturing methods, which necessitate costly molds or tooling, 3D printing enables the production of distinctive items without incurring a considerable cost. This has made it possible for both individualized customization and mass customization, enabling businesses to design products that are tailored to the unique requirements and tastes of their customers.

In addition, 3D printing has created new avenues for product innovation and design by making detailed designs and complicated geometries that were previously impractical or impossible to produce. We may anticipate even higher degrees of personalization and innovation in the industrial sector as technology continues to advance.

- **Increase in efficiency of supply chain**

3D printing can significantly increase supply chain efficiency by allowing on-demand production of parts and products, reducing inventory costs and lead times. For example, companies can produce spare parts on-demand, reducing the need for large inventories and improving maintenance and repair operations' responsiveness. On-demand production also reduces transportation costs and associated emissions by producing parts closer to end-users. Furthermore, 3D printing offers supply chain flexibility and adaptability, allowing companies to quickly adjust production to respond to changes in demand or supply chain disruptions. While more efficient printing technologies and materials are needed, the benefits of on-demand production are already being realized by companies in various industries. With further technological advancements and wider adoption, we can expect to see even more improvements in supply chain efficiency and resilience.

- **Introduction of advance software and AI**

The development of 3D printing in the manufacturing sector has been significantly aided by the incorporation of cutting-edge software and AI. The production process has been streamlined and more sophisticated designs have been made possible by these technologies. In order to improve the quality of printed parts and streamline the printing process, machine learning algorithms can be utilised. This reduces the need for manual inspection and correction. AI can also be used to find trends in errors or faults and enhance the entire manufacturing process by analysing data from sensors. Software and artificial intelligence have also made it simple for designers and engineers to produce extremely sophisticated and detailed designs, cutting down on the time and expense involved in the design process.

As 3D printing continues to evolve and become more widely adopted, we can expect to see even greater integration of advanced software and AI into the manufacturing process. This will enable manufacturers to create highly complex and innovative products with greater speed, efficiency, and quality, and to better meet.

3. Potential future upgrades

A. **Enhanced efficiency and productivity:** They are one of the key areas of 3D printing technology development. Nowadays, printing 3D items can be a time-taking process, especially when producing larger and more complicated objects. This can be caused by a number of things, such as how quickly the printing material is applied, whether layers need to cool between them, and how long it takes to alter the printing bed or the printer's parameters. As a result, efforts are being undertaken to increase the 3D printing process' speed and effectiveness so that it will be more useful and affordable for a wider range of applications.

- Using several print heads is one technique to increase the speed and effectiveness of 3D printing. In order to create objects that require several materials, such as those that are flexible in some places and hard in others, multiple print heads can print multiple materials at once. By requiring fewer print runs to produce the object, this can decrease the total print time and improve efficiency.
- Creating novel printing materials that can be deposited more quickly or with fewer layers is another strategy for enhancing 3D printing's speed and effectiveness. For instance, scientists are developing materials that can be heated or lit to cure them, eliminating the requirement for chilling between layers. Moreover, some 3D printing techniques, such Continuous Liquid Interface Production (CLIP), employ a layer less technique that allows for the faster and more efficient production of items.
- Optimizing the printing process itself is another tactic to increase the 3D printing process's speed and effectiveness. This may involve creating new algorithms to more effectively slice 3D models into printable layers or tweaking the design of the printing head or the printer's software. In some instances, combining these tactics can help to further speed up and improve the effectiveness of 3D printing.

B. **Advanced materials:** A variety of advanced material types, each with a distinct set of features and applications, are now being developed and employed in 3D printing. These materials include, as examples:

- Conductive materials: Circuits, sensors, and other electronic components can be built with these materials and integrated into 3D-printed things. Typically, conductive materials are created by mixing plastic with conductive substances like copper powder or carbon black.
- High-performance polymers: Unlike conventional 3D printing polymers like ABS or PLA, high-performance polymers have improved mechanical, thermal, or chemical qualities. Applications for these materials typically include aerospace, automotive, and medical equipment. PEEK, ULTEM, and PEKK are a few high-performance polymers as examples.

- Materials that have the capacity to restore themselves when injured are known as self-healing materials. These materials are often employed in applications like biomedical implants or corrosive-prone parts. Microcapsules containing a healing ingredient are combined with a polymer matrix to create self-healing materials.
- Shape memory materials: These are substances that may alter their shape in response to stimuli like changes in temperature or light. Applications for these materials often include robotics, aircraft, and medical devices. Shape memory alloy particles and a polymer matrix are combined to create shape memory materials.

C. **Customization:** Customization is a key advantage of 3D printing, allowing users to create objects that are tailored to their specific needs and preferences. With 3D printing, objects can be easily customized by modifying the 3D model used to create them. This allows users to create objects that are unique and personalized, with specific shapes, sizes, and features that are not possible with traditional manufacturing methods.

- One of the key benefits of customization in 3D printing is the ability to create objects that are tailored to a specific individual's needs or preferences. For example, in the medical field, 3D printing is being used to create customized prosthetics and implants that are designed to fit the specific anatomy of each patient. Similarly, in the fashion industry, 3D printing is being used to create custom-fitted garments and accessories that are designed to fit the individual shape and size of each wearer.

D. **Miniaturization:** Miniaturization is the process of making small-scale objects or devices, and it is an important aspect of 3D printing technology. With 3D printing, it is possible to create objects that are much smaller than those produced with traditional manufacturing methods, making it an ideal technology for the production of miniature objects and devices.

- One of the key benefits of miniaturization in 3D printing is the ability to create objects with intricate details and complex geometries. With traditional manufacturing methods, creating objects with small or intricate features can be difficult or even impossible. However, with 3D printing, these objects can be easily created using a range of materials, including plastics, metals, and ceramics. This allows designers to create miniature objects with high levels of detail and precision, such as tiny gears, intricate jewellery pieces, or dental implants.
- Another advantage of miniaturization in 3D printing is the ability to create custom-fit objects. With traditional manufacturing methods, creating custom-fit objects, such as hearing aids or dental aligners, can be a complex and time-consuming process. However, with 3D printing, these objects can be easily created using digital models that are customized to fit the individual needs of each user. This allows for a more personalized and efficient production process.
- Miniaturization in 3D printing also has the potential to revolutionize fields such as medicine and electronics. For example, in the medical field, 3D printing is being used to create miniature implants and devices that can be inserted into the body with minimal invasion. In the electronics industry, 3D printing is being used to create miniature circuits and sensors that can be integrated into a range of devices, from smartphones to wearables.

E. **Integration with other technologies:** Integration with other technologies refers to the ability of 3D printing to work in conjunction with other technologies, such as scanning, CAD (computer-aided design) software, and automation systems. By integrating with these other technologies, 3D printing can be used to create highly complex objects

F. and systems that are tailored to the specific needs of a given industry or application.

- One of the key benefits of integration with other technologies is the ability to capture and digitize real-world objects and convert them into 3D models that can be used for printing. For example, 3D scanners can be used to capture the shape and dimensions of an object, and the resulting data can be used to create a 3D model that can be printed using a 3D printer. This allows for the creation of highly accurate and detailed replicas of real-world objects, such as historical artifacts or works of art.

The Anticipated Effects on the World Economy

The potential uses for 3D printing in manufacturing are enormous and might spark a revolution in the industry. With the help of 3D printing, products can be made altogether differently, cutting out the use of conventional production processes completely. Significant cost reductions, shorter lead times, and greater production flexibility could result from this.

The entire economy could be significantly impacted by 3D printing. It's probable that many employments in conventional manufacturing industries will be lost as a result of the ability to make items more cheaply and effectively. Yet, the addition of new jobs in the 3D printing sector and associated fields like design and engineering may compensate for this displacement.

In addition to eliminating jobs, 3D printing might also affect international trade. The demand for international trade may be lessened if commodities could be produced locally. For nations whose economies rely on foreign trade, this might have severe ramifications.

Conclusion

In conclusion, 3D printing technology has brought significant changes to the traditional production process, with both potential and challenges. This report has examined the present trends and future possibilities of 3D printing in the manufacturing sector, taking into account factors like cost effectiveness, customer customization, and product quality. We have analysed the benefits and drawbacks of adopting 3D printing in manufacturing, and identified important companies in the market. The potential applications of 3D printing in production, including the possibility of a manufacturing revolution and the anticipated effects on the world economy, are promising. Overall, 3D printing has shown to be a valuable tool for manufacturers, and with further development and adoption, it has the potential to transform the manufacturing industry in the years to come.

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