international journal for
SCIENTIFIC RESEARCH INNOVATIONS

Volume 1, Issue 1
May 2023, pp. 17-24
Date of Publication: 29/05/2023

Analysis of 3D Printing Technology and Challenges

Unni Kisan[1]
[1] *Khwaja Moinuddin Chishti Language University, Lucknow*
Corresponding author's mail id: krishnaswami1996@gmail.com

***Abstract* - In this new age the development of 3D printing technology is rapidly. 3D printing technology is known as additive manufacturing. This paper presents a comprehensive analysis of 3D printing technology and the challenges it faces. The goal is to present a comprehensive overview of the technology, its possibilities, and the obstacles that must be removed before it can be widely used. The analysis starts with a summary of the basic ideas that drive 3D printing. It has various techniques employed, such as fused deposition modeling (FDM), stereo-lithography (SLA), selective laser sintering (SLS), and binder jetting. Getting high printing speeds and scaling up production to satisfy industrial demands are big challenges as well. The study examines the existing speed, scalability, and manufacturing cost constraints of 3D printing and discusses ongoing research and development initiatives to address these challenges. The advantages of 3D printing are highlighted, along with their prospective effects on sectors like healthcare, aerospace, automotive, and consumer products. These advantages include personalization, quick prototyping, and reduced material waste. By overcoming these difficulties, 3D printing will be able to reach its full potential and eventually replace traditional production techniques.**

***Keywords* – 3D Printing, Additive Manufacturing, Material Technology;**

1. Introduction

Additive manufacturing (AM), also known as 3D printing involves use of digital CAD modelling to build 3D objects by joining materials layer-by-layer. The ability of this technology to execute several print operations and "print-it-all" structures will determine its demand in the future [1].

A technology for generating a variety of structures and intricate geometries out of three-dimensional (3D) model data is 3-D printing, or additive manufacturing (AM). The method entails printing consecutive layers of materials on top of one another. Charles Hull first created this technique in 1986 using a method called stereo-lithography (SLA), which was then followed by innovations including powder bed fusion, fused deposition modelling (FDM), inkjet printing, and contour crafting (CC). Manufacturing and logistics procedures can be changed by 3D printing, which has grown over time and uses a variety of techniques, materials, and tools. Construction, prototyping, and the biomechanical fields are just a few of the businesses that have extensively used additive manufacturing. 3D printing's adoption in the construction sector, in particular, was extremely sluggish and constrained despite its benefits, such as minimal waste, design freedom, and automation. As innovative materials and AM techniques are regularly created, new applications are emerging. The expiration of earlier patents, which allowed manufacturers to create new 3D printing gadgets, is one of the key factors contributing to this technology's accessibility. Recent innovations have decreased the price of 3D printers, extending their use in labs, homes, libraries, and schools. Due to its quick and affordable prototyping capabilities, 3D printing has initially been widely employed by architects and designers to create aesthetically pleasing and practical prototypes.

The additional costs associated with developing a product have been reduced to a minimum thanks to the use of 3D printing. But the full potential of 3D printing for everything from prototypes to finished goods has only recently come to light. The high expense of developing items that are specifically suited for end customers has made product customization difficult for manufacturers. On the other hand, AM may 3D print tailored goods in small quantities for comparatively less money. This is particularly helpful in the biomedical industry, where distinctive, patient-tailored products are frequently needed. According to Wohler's Associates, who envisioned that about 50% of 3D printing will revolve around the manufacturing of commercial products in 2020 [2].

2. Materials of 3D Printing

Thermoplastics: Commonly used materials in 3D printing include various thermoplastics, such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PETG), and nylon. These materials offer a wide range of properties, including strength, flexibility, and heat resistance [16]. 3D printing with metals, such as titanium, aluminum, stainless steel, and cobalt-chrome alloys, has gained significant attention. Metal powders or wires are selectively melted and fused using processes like selective laser melting (SLM) or electron beam melting (EBM).

Resin-based 3D printing, such as stereo-lithography (SLA) or digital light processing (DLP), utilizes liquid photopolymer resins that solidify when exposed to specific wavelengths of light. Composite materials, combining polymers with reinforcing agents like carbon fibers or glass fibers, offer enhanced strength and stiffness. They are used in applications where high-performance characteristics are required. Ceramic-based 3D printing involves materials like zirconia, alumina, or porcelain. Ceramic powders are selectively bonded or sintered to create objects with high-temperature resistance, electrical insulation, or biomedical compatibility [3].

3. Process of 3D Printing

A three-dimensional digital model is converted into a physical instantiation through the process of three-dimensional (3D) printing (Fig.1). A 3D printer is used in this translation process, which creates a spatially accurate representation of the digital geometry defined material(s) assembly. A geometric approximation, such as rounded corners, surface roughness, trapped cavities, or other flaws, is inextricably involved in the translation of a precisely defined digital entity into a physical duplicate. The machine, the assembled material components, and the trade-offs between size, resolution, and manufacturing speeds all impose these approximations [4].

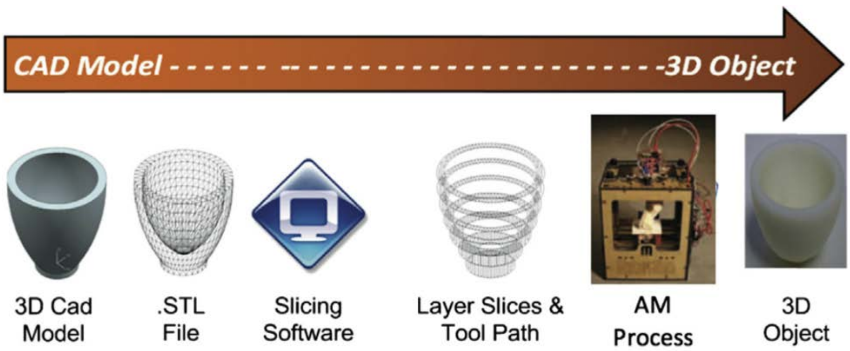

Fig.1 General process flow for 3D print methods

The manufacturing of 3D Printing product have various process of steps in which first of all designation the 3D models and other process as preparation of model, slicing the model, setting up the printer, printing of object, final process is prost processing. From the initial design stage to the final production of the printed object, the 3D printing process often entails numerous important processes.

Process-1 is Designing the 3D Model in which the process begins with creating or obtaining a digital 3D model of the object to be printed. This can be done using computer-aided design (CAD) software, obtained from online repositories, or generated through 3D scanning techniques.

Process-2 is Preparing the 3D Model in which Once the 3D model is obtained, it may require preparation before printing. This step involves ensuring that the model is manifold (water-tight), scaling it to the desired size, and making any necessary adjustments to optimize it for 3D printing.

Process-3 is Slicing the Model in which The 3D model is then sliced into a series of 2D layers using slicing software. This software analyzes the 3D model and generates instructions for the 3D printer on how to build each layer. Parameters such as layer thickness, print speed, and support structures are determined during this stage.

Process-4 is Setting Up the Printer in which The 3D printer needs to be prepared for printing. This involves tasks such as ensuring the printer is clean and calibrated, loading the appropriate printing material (filament or resin), and setting up the print bed or build platform.

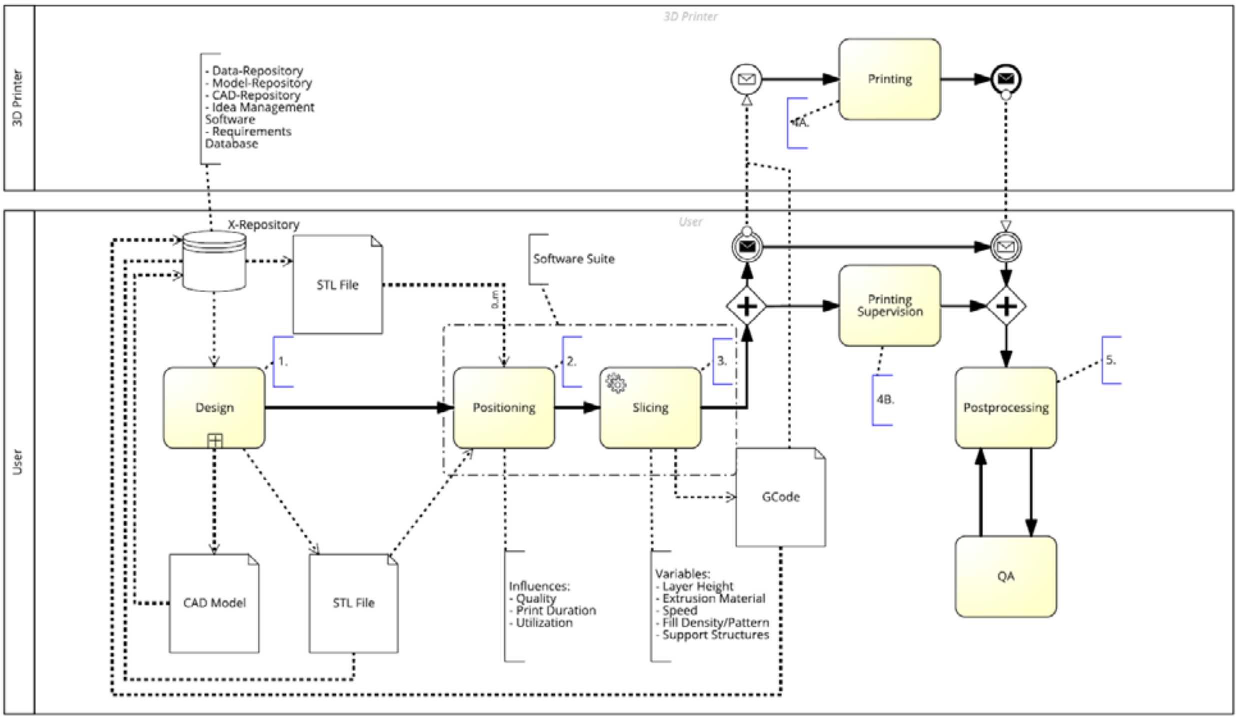

Fig. 2 Process of 3D Printing

Process-5 is Printing the Object in which with the 3D printer properly set up, the printing process begins. The printer follows the instructions generated during the slicing step. The print head or nozzle moves in a specific pattern, depositing the material layer by layer to build the object. The printer may adjust parameters such as temperature, extrusion speed, or exposure time (in the case of resin-based printing) as required.

Process-6 is post-processing in which Once the printing is complete, the object may require post-processing. Post-processing steps depend on the specific printing technology, material, and desired finish. Common post-processing steps include removing support structures, cleaning the object (e.g., removing excess material or residue), and applying surface treatments such as sanding, polishing, or painting [5].

4. 3D Printing Techniques

There are various additive manufacturing technologies, generally referred to as 3D printing, each with its own distinct method for layer-by-layer construction of three-dimensional items. The Technology of 3D Printing are fallowing [4,6,].

4.1. Fused Deposition Modeling (FDM) / Fused Filament Fabrication (FFF):

FDM is one of the most popular 3D printing techniques. It involves melting and extruding a thermoplastic filament through a nozzle. The material is deposited layer by layer, and as it cools, it solidifies, creating the object. FDM printers are widely available, relatively affordable, and can use various thermoplastics like ABS, PLA, and PETG.

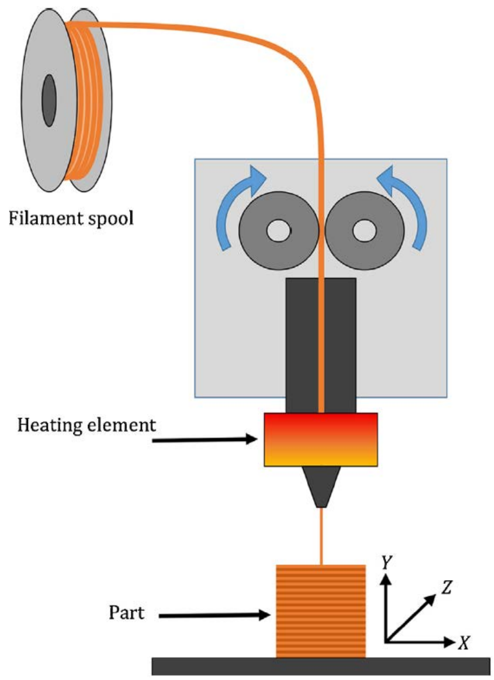

Fig. 3– The FFF technique relies on one or more heated nozzles that spatially distribute extruded polymer as a fine filament in the layer-by-layer building approach using spatially translatable platform.

4.2.Stereo-lithography (SLA):

SLA utilizes a vat of liquid photopolymer resin. A UV laser is used to selectively cure and solidify the resin, layer by layer, according to the digital model. SLA produces high-resolution prints with smooth surface finishes, making it suitable for applications that require intricate details and accuracy.

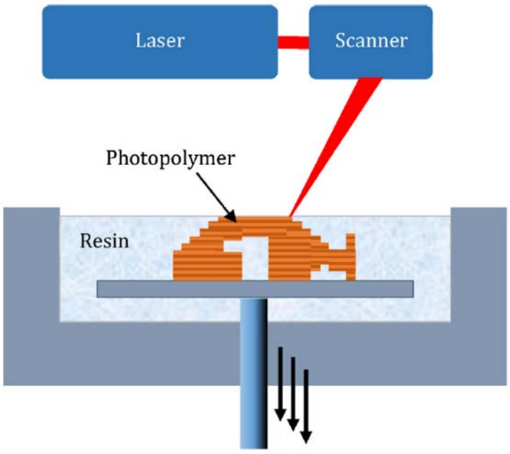

Fig. 4 – Schematic of a photo polymerization-based, top-down stereolithographic apparatus (SLA) part production process. There are also devices that photo cure with a bottom-up approach where the bath has a UV transmissivity, no adhesive base and the inverted support platform is incrementally raised throughout the process, which minimizes need for sacrificial support structures.

4.3 Selective Laser Sintering (SLS):

SLS employs a high-powered laser to selectively fuse powdered materials, typically polymers or metals. A thin layer of the powder is spread on a build platform, and the laser sinters the powder, bonding it together to form the desired shape. SLS is known for its ability to produce complex geometries and functional parts without the need for support structures.

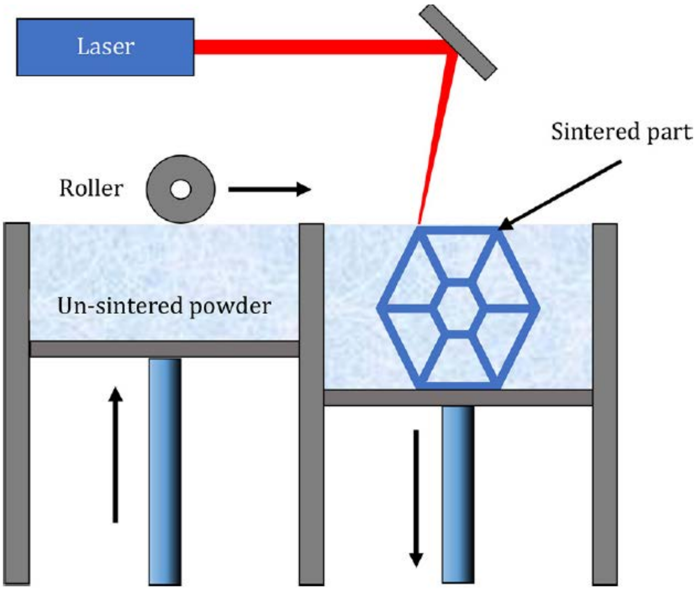

Fig.5 -The SLS approach uses a scanned laser to locally fuse pre-polymer particles on the surface of a preheated build chamber that is incrementally lowered as the process progresses.

4.4 Binder Jetting:

Binder jetting is a powder-based technique where a powdered material, such as sand, metal, or ceramic, is selectively bonded together using a liquid binder. The printer deposits the binder onto a thin layer of powder, and the process is repeated layer by layer until the object is formed. Binder jetting is often used for full-color printing and for producing large, sand-like objects.

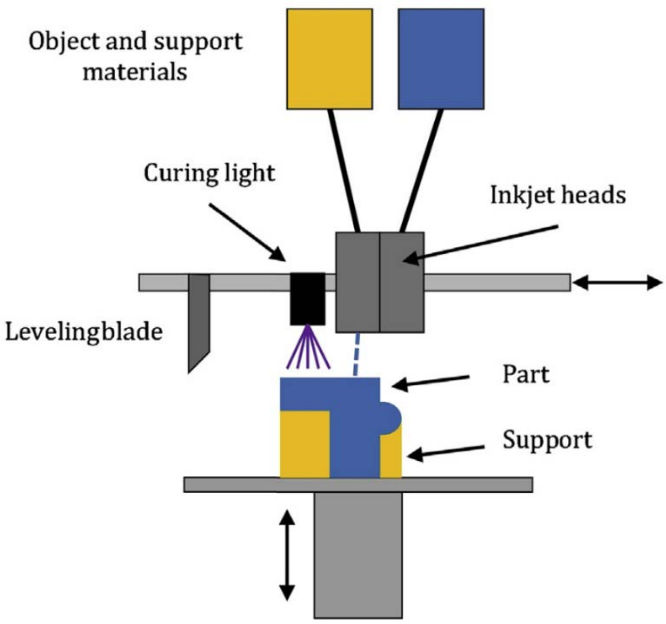

Fig.6 - Material jetting/Binder jetting 3D Printing method [13]

5. Challenges of 3D printing technology

Despite the advantages of 3D printing, such as design flexibility, customizability, and the capacity to create complex structures, there are a few downsides that call for additional study and technological advancement. These downsides include exorbitant prices, a lack of mass production and huge structural applications, subpar and anisotropic mechanical qualities, material restrictions, and flaws. Some of these difficulties have been overcome thanks to research and method and material improvement. However, there are still a few issues that must be resolved if additive manufacturing (AM) is to be applied to more applications and sectors of the economy. Some difficulties are more noticeable when using a specific printing technique or material, although just a few are present in nearly all AM techniques. For example, using AM to create a product often requires more time than using more conventional techniques like casting, extrusion, fabrication, or injection moulding. In comparison to inkjet printing and fused deposition modelling, the powder bed method and stereo-lithography take more time. Additionally, high resolution 3D printing processes like powder-bed (SLS or SLM) require more energy to produce and costs more in terms of ingredients. The main difficulties that prevent the mass manufacture of any repeating parts, which can easily be accomplished by other traditional technologies at a fraction of the time and cost, are the lengthy processing time and higher cost of 3D printing [2].

Some of the challenges of 3D printing technology are following [1,7, 8,9,10]:

- **Limited Material Selection:** Although the range of available 3D printing materials has been expanding, it still lags behind the wide variety of materials available in traditional manufacturing processes. Certain materials, such as high-performance metals or ceramics, can be challenging to 3D print due to their properties or cost.
- **Printing Speed:** 3D printing is generally slower compared to traditional manufacturing methods, especially for large or complex objects. Building objects layer by layer requires time, and faster printing often comes at the expense of resolution or quality. Improving printing speed without compromising quality remains an ongoing challenge.

- **Post-Processing Requirements:** 3D printed objects often require post-processing to achieve the desired finish, accuracy, or functionality. This can involve tasks such as removing support structures, sanding, polishing, or applying additional coatings. The need for post-processing can add time, cost, and complexity to the overall production process.
- **Quality Control and Standardization:** Maintaining consistent quality and dimensional accuracy in 3D printing can be challenging. Factors such as printer calibration, material properties, environmental conditions, and process variability can impact the final output. Establishing robust quality control measures and industry-wide standards is necessary to ensure reliable and consistent 3D printed products.
- **Intellectual Property and Legal Considerations**: 3D printing raises concerns regarding intellectual property (IP) rights and copyright infringement. With the ability to replicate objects easily, protecting the IP of designs becomes a challenge. Addressing legal and ethical considerations related to 3D printing, including IP rights, is crucial for the technology's sustainable growth.
- **Cost of Equipment and Materials:** Although the cost of 3D printers has decreased over time, high-quality industrial-grade printers can still be expensive. Additionally, the cost of printing materials, especially specialized or high-performance materials, can also be significant. Managing the costs associated with 3D printing, including equipment, materials, and post-processing, can be a challenge, particularly for small businesses or individuals.
- **Size and Scalability:** The size limitations of 3D printers can pose challenges when attempting to produce large-scale objects. Scaling up the printing process without compromising quality, precision, or cost-effectiveness remains an ongoing area of research and development.
- **Sustainability and Environmental Impact:** While 3D printing has the potential to reduce waste by enabling on-demand production and minimizing excess material usage, it still poses environmental challenges. The production and disposal of 3D printing materials, energy consumption, and emissions from certain printing processes need to be carefully managed to ensure the technology's sustainability.

6. Conclusion

A disruptive technology that has the potential to completely change production in a variety of industries is 3D printing. To be widely adopted, it must, however, overcome a number of obstacles, including a constrained material range, speed and scalability, quality control, and environmental effect. This analysis seeks to present a thorough knowledge of these difficulties and to explore potential solutions. These challenges can be overcome in order to fully utilise 3D printing and transform the industrial industry. The analysis of 3D printing technology indicates numerous major issues that must be resolved in order for it to be widely used and adopted. Limited material options, printing speed, post-processing specifications, quality control, issues with intellectual property, financial considerations, scalability, and sustainability are some of these difficulties. To overcome these obstacles, a multifaceted strategy that incorporates improvements in materials, procedures, technology, standardization, automation, cost containment, and stakeholder participation is needed.

Reference

[1] N. Shahrubudin,, P. Koshy, J. Alipal, M.H.A. Kadir, T.C. Lee, Challenges of 3D printing technology for manufacturing biomedical products: A case study of Malaysian manufacturing, Heliyon, Vol. 6, 2020.

[2] T.D. Ngoa, A. Kashania, G. Imbalzanoa, K.T.Q. Nguyena, D. Hui, Additive manufacturing (3D printing): A review of materials, methods,applications and challenges, Composites Part B, Vol. 143, pp. 172–196, 2018.

[3] N. Shahrubudin, T.C. Lee, R. Ramlan, An Overview on 3D Printing Technology: Technological, Materials, and Applications, Procedia Manufacturing, Vol. 35, pp. 1286–1296, 2019.

[4] J.R.H. Awad, S.A. Habash, C.J. Hansen, 3D Printing Methods, 3D Printing Applications in Cardiovascular Medicine, Ch. 2, pp. 11-32, 2018.

[5] F.W. Baumann, O. Kopp, D. Roller, Abstract API for 3D printing hardware and software resources, Int J Adv Manuf Technol, 2017.

[6] J.W. Stansbury, M.J. Idacavage, 3D printing with polymers: Challenges among expanding options and opportunities, Dental Materials, Vol. 32, pp. 54–64, 2016.

[7] W. Oropallo, L.A. Piegl, Ten challenges in 3D printing, Engineering with Computers, 2015.

[8] S.E. Sayegh, L. Romdhane, S. Manjikian, A critical review of 3D printing in construction: benefits, challenges, and risks, Archives of Civil and Mechanical Engineering, Vol. 34, 2020.

[9] H. Quan, T. Zhang, H. Xu, S. Luo, J. Nie, X. Zhu, Photo-curing 3D printing technique and its challenges, Bioactive Materials, Vol. 5, pp. 110–115, 2020.

[10] A. Ghilan, A.P. Chiriac, L.E. Nita, A.G. Rusu, I. Neamtu, Trends in 3D Printing Processes for Biomedical Field: Opportunities and Challenges, Journal of Polymers and the Environment, Vol. 28, pp.1345–1367, 2020.