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# A Review on 3D Component Manufacturing System

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**Abstract**: **Digital fabrication technology, also referred to as 3D printing or additive manufacturing, creates physical objects from a geometrical representation by successive addition of materials. 3D printing technology is a fast-emerging technology. Nowadays, 3D Printing is widely used in the world. 3D printing technology increasingly used for the mass customization, production of any types of open-source designs in the field of agriculture, in healthcare, automotive industry, locomotive industry and aviation industries. 3D printing technology can print an object layer by layer deposition of material directly from a computer aided design (CAD) model. This paper presents the overview of the types of 3D printing technologies available in manufacturing industry**.

***Keyword:*** Additive manufacturing, *slicing, CAM, filament.*

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## I INTRODUCTION

3D Printing technology, also known as Additive Manufacturing (AM), refers to processes used to generate a 3D object in which layers of material are successively formed under a computer-controlled program to create a physical object. The 3D file source is usually sliced into several layers, each layer generating a set of computer-controlled instructions. Both 3D printing and additive manufacturing reflect that the technologies share the theme of sequential-layer material addition or joining throughout a 3D work. 3D printing technologies can be split up into 2 groups: direct and indirect 3D printing.[1] The main difference lies in the fact that the design is directly made from 3D printing (direct) or 3D printing was used in the process of creating your model (indirect). The objects manufactured through 3D printing processes can be of almost any shape or geometry. They are typically produced using digital model data from a 3D model or another electronic data source such as a Stereolithography (STL) file, one of the most common file types that 3D printers can read. The term 3D printing originally referred to a process that deposited a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the term 3D printing is being used in popular vernacular to encompass a wider variety of additive manufacturing techniques. For professionals, the additive manufacturing name remains more popular for its broader sense and longer existence. Other terms are also employed, such as desktop manufacturing, rapid manufacturing, direct digital manufacturing, and rapid prototyping. Additive manufacturing invention can be traced back to the 1980's by Japanese, French and American researchers.[2] The very first patent of 3D printing was coined in 1984 by Chuck Hull of 3D Systems Corporation. Hull defined the 3D printing process as a system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed. His invention consists of a stereolithography fabrication system, in which layers are added by curing photopolymers with ultraviolet light lasers. Stereolithography is still one very popular 3D printing manufacturing technique, also known as SLA. Yet, the technology used by most 3D printers in the 2010's, especially by hobbyist and consumer-oriented products, is Fused Filament Fabrication (FFF), also known as material extrusion or the proprietary Stratasys denomination's Fused Deposition Modeling (FDM). FDM was patented in 1989 by S. Scott Crump just before he launched the Stratasys Company with his wife, Lisa Crump. Metal 3D printing only became available in the 1990's with the invention of laser melting and sintering techniques. Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) are often grouped under the umbrella term Direct Metal Laser Sintering (DMLS).[3]

## II. LITERATURE REVIEW

3D printing was known as "rapid prototyping". Chuck Hull, of 3D Systems Corporation, created the first working 3D printer in 1984. Later in the 80's, Selective Laser Sintering (SLS) technology was developed by Dr. Deckard at the University of Texas at Austin during a project sponsored by

Defense Advanced Research Projects Agency (DARPA). In the 1990s, the technology was further improved with the development of a method that used ultraviolet light to solidify photopolymer, a viscous liquid material. In the late 20th century, 3D printers were extremely expensive and could only be used to print a limited number of products.[4] The majority of the printers were owned by scientists and electronics enthusiasts for research and display. Although it was still in limited development, the printing technology was a combination of modeling both science and construction technology, using some of the newest technological advancements of the time. Consequently, 3D printing began to lead a worldwide manufacturing revolution. In the past, surface design was mainly dependent on the production process. However developments in the field of 3D printing have allowed for the design of products to no longer be limited by complex shapes or colors.[5]

## III. PRINCIPLE AND PROCESSES OF 3D PRINTING

### 3.1 Principle of 3D printing

All 3D printing techniques are based on the same principle: a 3D printer takes a digital model (as input) and turns it into a physical three-dimensional object by adding material layer by layer. It is way different than traditional manufacturing processes such as injection molding and CNC machining that uses various cutting tools to construct the desired structure from a solid block. 3D Printing, however, requires no cutting tools: objects are manufactured directly onto the built platform.[6]

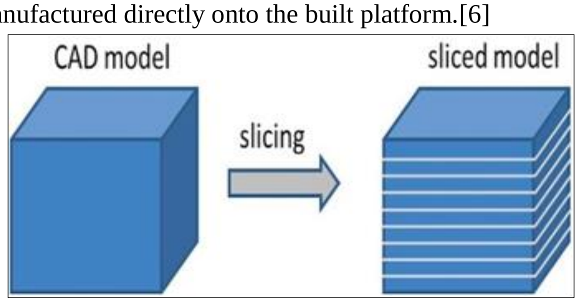


**Fig 1 Slicing process**

The process starts with a digital 3D model (a blueprint of the object). The software (specific to the printer) slices the 3D model into thin, two-dimensional layers. It then converts them into a set of instructions in machine language for the printer to execute. Depending on the type of printer and size of the object, a print takes several hours to complete. The printed object often requires post-processing (like sanding, lacquer, paint, or other types of conventional finishing touches) to achieve the optimal surface finish, which takes additional time and manual effort. Different types of 3D printer employ a different technology that processes different materials in different ways. Perhaps the most basic limitation of 3D Printing, in terms of materials and applications, is that there is no one-size-fits-all solution.[7]

### 3.2 Processes Of 3D Printing

As per the ISO/ASTM 52900 standard, all 3D printing processes can be categorized into seven groups. Each has pros and cons associated with it, which usually involve aspects such as cost, speed, material properties, and geometrical limitations.[8]

**1. Vat photopolymerization**

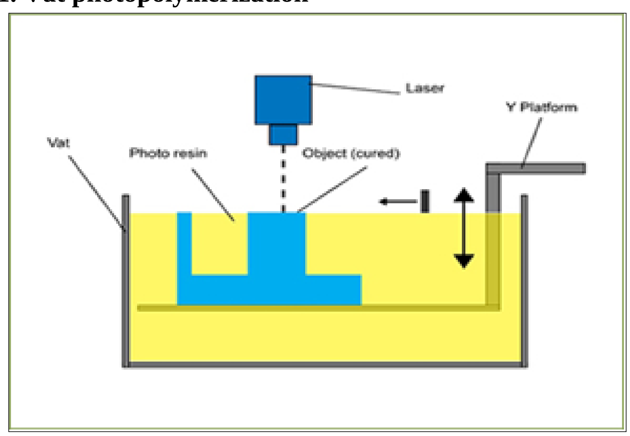


**Fig 2** Vat photopolymerization

A 3D printer based on Vat photopolymerization has a container filled with photopolymer resin, which is hardened with an ultraviolet light source to create an object. The three most common forms of Vat Polymerization are:

**1a) Stereolithography (SLA):** Invented in 1984, SLA uses an ultraviolet laser to crosslink chemical monomers and oligomers to form polymers that make up the body of a three-dimensional solid. While the process is fast and can construct almost any structure, it can be expensive.

**1b) Digital Light Processing (DLP):** It utilizes conventional light sources such as arc lamps (instead of lasers). Each layer of the object is projected onto the vat of liquid resin, which is then solidified layer by layer as the lifting platform moves up or down.

**1c) Continuous Liquid Interface Production (CLIP):** It is similar to stereolithography but continuous and up to 100 times faster. CLIP can produce rubbery and flexible objects with smooth sides, that couldn't be created with other techniques.

**2. Material Extrusion**

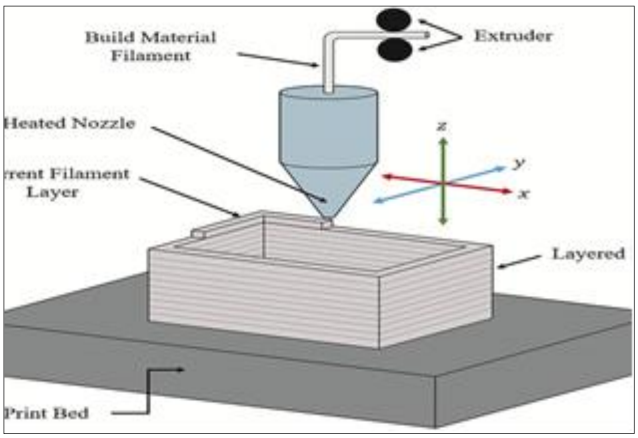


**Fig 3** Material Extrusion

Illustration of material extrusion: Nozzle (1) is depositing material (2) on a build platform (3).

In this process, a filament of solid thermoplastic material is pushed through a heated nozzle, which melts the material and deposits it on a build platform along a predetermined path. This material eventually cools and solidifies, forming a three-dimensional object. The most commonly used techniques in this process are

**2a) Fused Deposition Modeling (FDM):** It uses a continuous filament of a thermoplastic material, such as nylon, thermoplastic polyurethane, or polylactic acid.

**2b) Robocasting:** It involves extrusion of a paste-like material from a small nozzle while the nozzle is moved across a build platform. The process is different from FDM as it doesn't rely on drying or solidification of material to retain its shape after extrusion.

**3. Sheet Lamination**

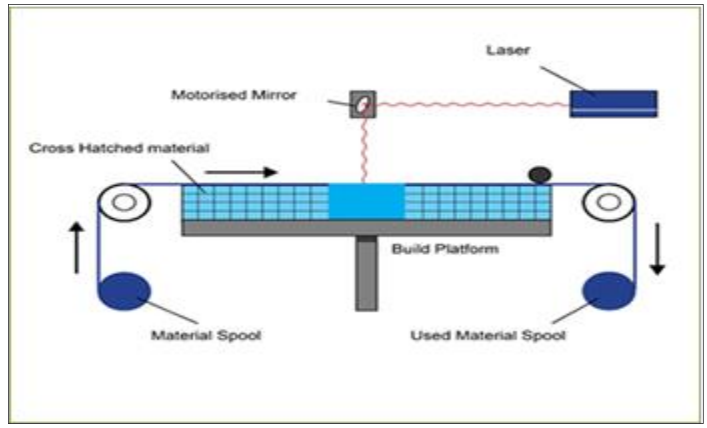


**Fig 4** Sheet Lamination

Some printers use paper and plastic as the build material to lower the cost of Printing. In this technique, multiple layers of adhesive plastic, paper, or metal laminates are successively joined together and cut to shape using a laser cutter or knife. The layer resolution can be defined by the material feedstock. Typically, it ranges between one and a few sheets of copy paper. The process can be used to make large parts, but the dimensional accuracy of the final product will be quite lower than that of stereolithography.

**4. Directed Energy Deposition**

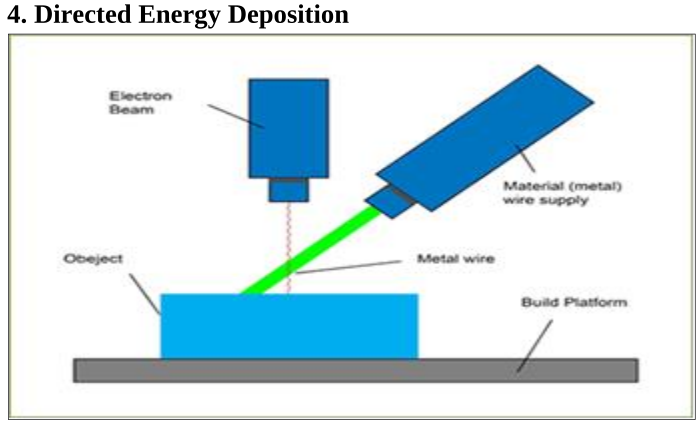


**Fig 5** Directed Energy Deposition

Directed energy deposition technique is commonly used in the high-tech metal industry and rapid manufacturing applications. The printing apparatus contains a nozzle that is fixed to a multi-axis robotic arm. The nozzle deposits a metal power on the build platform, which is then melted by a laser, plasma or electron beam, to form a solid object. This type of 3D Printing supports various metals, functionally graded materials, and composites, including

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aluminum, stainless steel, and titanium. Not only can it construct completely new metal parts but can also attach material(s) to existing parts, enabling hybrid manufacturing applications.

**5. Material Jetting**

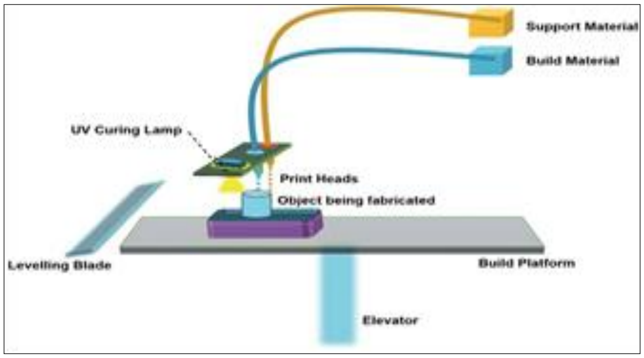


**Fig 6** Material Jetting

Parts printed with the material jetting process Material jetting operates in a similar fashion to inkjet paper printers. In this process, a photosensitive material is applied in droplets through a small diameter nozzle and then hardened by ultraviolet light, building a part layer-by-layer.The materials used in this technique are thermoset photopolymers (acrylics). Multi-material printing and a broad range of materials (including rubber-like and transparent materials) are also available. Since material jetting 3D Printing can construct parts of high dimensional accuracy with a smooth surface finish, it's an attractive option for manufacturing both visual prototypes and commercial tools.

**6. Binder Jetting**

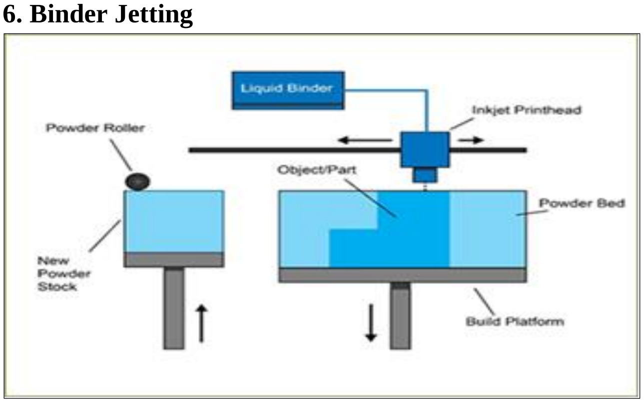


**Fig 7** Binder Jetting

A full-color print printed in sandstone with Binder Jetting | Image credit: 3D Hubs Binder jetting uses two materials: powder base material and a liquid binder. The powder is distributed in even layers in the build chamber, and binder is applied through jet nozzles, which 'glue' the powder particles to build the desired object. Wax or thermoset polymer is often mixed with bonded powder to increase its strength. After the 3D print is completed, the leftover powder is collected and used for printing another structure. Since the technique is very similar to an inkjet-like process, it is also called the inject 3D Printing. It is mostly used for printing elastomer parts, overhangs, and colorful prototypes.

**7. Powder Bed Fusion**

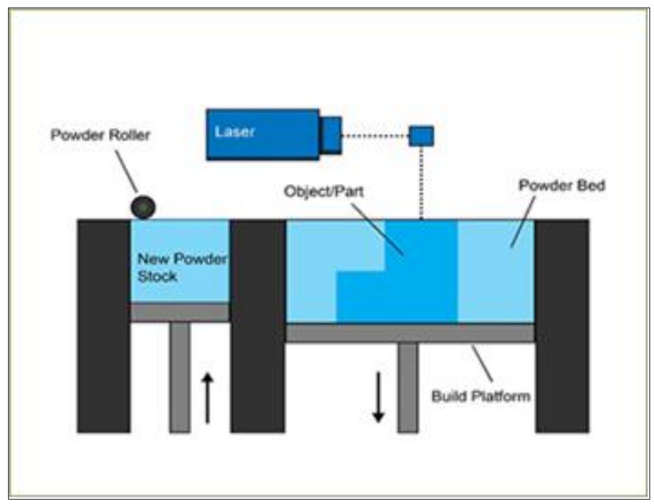


**Fig 8** Powder Bed Fusion

Powder bed fusion is a subset of additive manufacturing whereby a heat source (such as thermal print head or laser) is used to consolidate material in powder form to build physical objects. The five most common forms of this technology are

**7a) Selective Laser Sintering (SLS):** It uses a laser as the power source to sinter powdered material like polyamide or nylon. Here the term sinter refers to the process of compacting and forming a solid mass of material by applying pressure or heat without melting it to the point of liquefaction.

**7b) Selective Laser Melting (SLM):** Unlike SLS, this technique is designed to completely melt and fuse metallic powders together. It can create fully dense materials (layer by layer) that have mechanical characteristics similar to those of traditional manufactured metals. This is one of the fast-developing processes that is being implemented in both industry and research.

**7c) Electron Beam Melting (EBM):** In the process, the raw material (wire or metal powder) is placed inside a vacuum and fused together using an electron beam. Although EBM can only be used with conductive materials, it has superior build speed because of its higher energy density.

**7d) Selective Heat Sintering (SHS):** It uses a thermal printhead to apply heat to layers of powdered thermoplastic. As soon as the layer is finished, the powder bed moves down, and a new layer of material is added, which is then sintered to form the next cross-section of the model. This technique is best for manufacturing inexpensive prototypes and parts for functional testing.

**7e) Direct Metal Laser Sintering (DMLS):** It is similar to SLS but uses metal power instead. The leftover power becomes a support structure for the object and can be reused for the next 3D print. DMLS parts are mostly made with powdered materials like titanium, stainless steel, aluminum, and several niche alloys. It's an ideal process for custom medical parts, oil and gas components, and tough functional prototypes.

## IV. CONCLUSIONS

Though 3D printing is still a growing technology, it already has many benefits and drawbacks. While many people agree that this technology could change the world, there are also those who believe it could have extreme consequences if it is not researched and tested thoroughly. As the technology beings to grow more and more throughout the next couple of years there will be more information and data that will determine whether it is a technology that is here to stay or it is something that will simply not make it. For now it is something that has to be further looked into in order to fully understand its extents whether good or bad.

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