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Different Aspects and Processes in 3D Printing: An Overview

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Abstract

3D Printing or Additive manufacturing produces actual items from geometric representations by layering on materials one after the other. 3D printing is a rapidly developing technology. These days, 3D printing is employed all over the world. The application of 3D printing technology is expanding in the fields of agricultural, healthcare, automotive, locomotive, and aviation. It is utilized for mass modification and fabrication of various open-source designs. An object can be printed directly from a computer-aided design (CAD) model, layer by layer with the use of 3D printing technology. The varieties of 3D printing methods, their applications, and the materials utilized for 3D printing in the production industry are all summarized in this paper.

Keywords: 3D Printing, additive manufacturing, CAD, Vat photopolymerization, laser sintering

INTRODUCTION

The development and production processes must meet ever-tougher standards in today's marketplace. Modern additive manufacturing technologies have been developed to fulfill such market demands. The primary characteristic of these procedures is the addition of material, often in layers, until the finished result is created. An additional feature of this process is to build 3D model directly from CAD model without any jigs and fixture. The following criteria can be used to categorize additive manufacturing: material type, source of energy, layer formation technique, and end product shape. The seven categories of additive manufacturing are Vat photopolymerization (VPP), Material extrusion (MEX), Sheet lamination (SHL), Powder bed fusion (PBF), Material jetting (MJT), Directed energy deposition (DED), and Binder jetting (BJT), as per the International Standardization Organization (ISO) and American Society for Testing and Materials (ASTM) in ISO/ASTM 52,900 [1]. Binder jetting is a type of additive manufacturing in which powder materials are joined by selectively depositing a liquid bonding agent; this method includes 3D printing. This paper includes the different aspects and processes of 3D-printing. 3D printing is as same as ink jet printing. In 3D printing instead of ink the binder or glue is injected to bind the powder of required material into the required shape [2]. A digital file can be used to create three-dimensional solid items through additive manufacturing, also known as 3D printing. It starts with a CAD file and it can be prepared using any CAD software like Autodesk, Onshape, Solid works etc. Then CAD file will be exported as an STL file, which is universal file type for 3D printers. Then after exporting the part, upload the STL file to slicing software of printer. After the part has been uploaded, the user can orient it appropriately, choose the material and other print options, and then let the software process the part automatically. The program creates tool paths for each layer after slicing the file into layers. Finally, press print. The part is printed layer by layer. The thickness, surface quality and durability of the final product are determined by various processes and materials,

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whereas print time is limited to part size [3].

DIFFERENT PROCESSES OF 3D PRINTING

Since late 1970s, a wide range of 3D printing technologies and processes have been developed. Some of the 3D printing processes are explained below.

a. *Selective Laser Sintering:* A high-power laser is used in the additive manufacturing (AM) process of selective laser sintering to fuse tiny powdered polymers into a solid structure that is based on a three-dimensional (3D) model. For many years, manufacturers and engineers have used SLS 3D printing. Due to its high productivity, cheap cost per part, and reliable materials, the technology is ideal for a wide range of applications, such as bridge manufacturing, small-batch customization, and rapid prototyping.
A growing number of firms are now able to adopt SLS printing, which was previously only available to a restricted few high-tech industries [4].

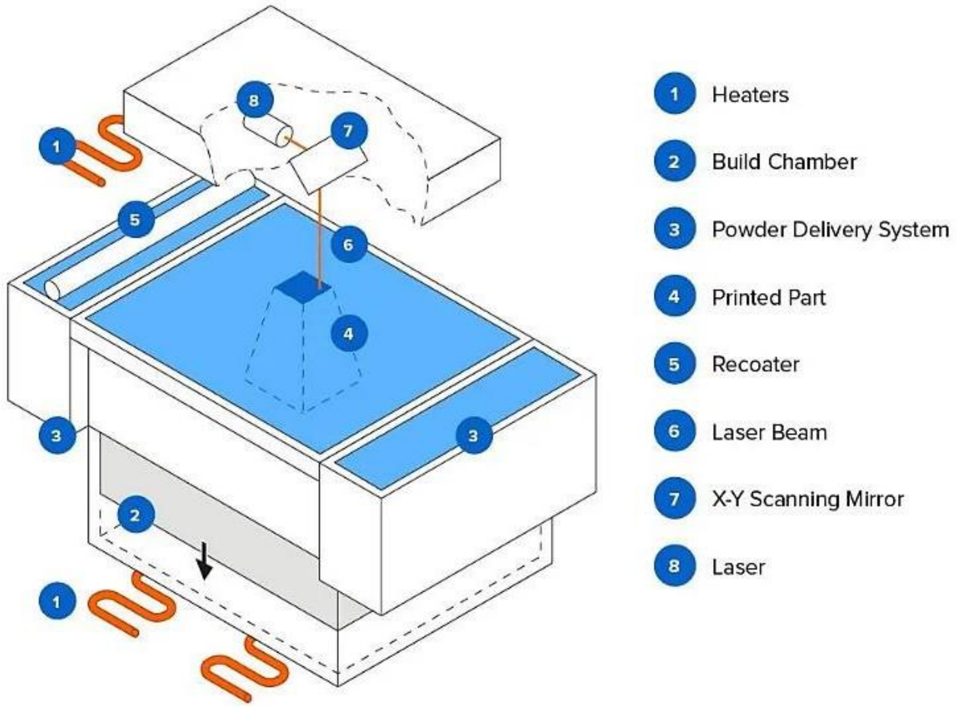

Figure 1. Selective laser Sintering.

Figure 1 shows Selective laser sintering process. In SLS, a thin coating of powder spread over a platform within the build chamber. The powder is heated by the printer to a temperature that is slightly below the raw material's melting point. This allows the laser to more easily increase the temperature in particular areas of the powder bed as it follows the model, solidifying a section of it. By heating the powder to a temperature just below or exactly at the material's melting point, the laser slices through a cross-section of the 3D model. As a result, the particles mechanically fuse together to form a single, solid portion. The part is supported by the unfused powder during printing, therefore no special support structures are required.
The platform then declines into the build chamber by one layer, usually ranging from 50 to 200 microns. Every layer goes through this procedure again until all of the parts are made. Then, in order to assure ideal mechanical qualities and prevent component warping, the build chamber must first slightly cool down inside the print enclosure. The constructed elements must be taken out of the construction chamber, dispersed, and powder-free cleaned. The printed elements can undergo media tumbling or media blasting as additional post-processing, and the powder can be recycled.

b. *Fused Deposition Modeling:* As shown in Figure 2, an FDM 3D printer layers melted filament material over a build platform to create pieces one at a time until the part is completed. By submitting the digital design files to the computer, FDM transforms them into physical dimensions. A variety of polymers, such as PLA, ABS, PETG, and PEI, are utilized in FDM materials. These are fed through a heated nozzle by the machine in the form of threads [4]. To operate an FDM machine, we must first place a spool of thermoplastic filament into the printer. The filament is fed into the printer through an extrusion head and nozzle after the nozzle reaches the proper temperature. This extrusion head can move across the X, Y, and Z axes because it is connected to a three-axis system. Layer by layer, the printer applies small strands of molten material along a route predetermined by the design. The material solidifies and cools after it is placed. Fans may be fastened to the extrusion head in specific circumstances for rapid cooling. It takes several passes to fill an area, much like when you color in a shape with a marker. The build platform lowers and the printer starts working on the subsequent layer when it has completed the previous one. In certain machine configurations, the extrusion head elevates. These steps are repeated, until the parts are finished.

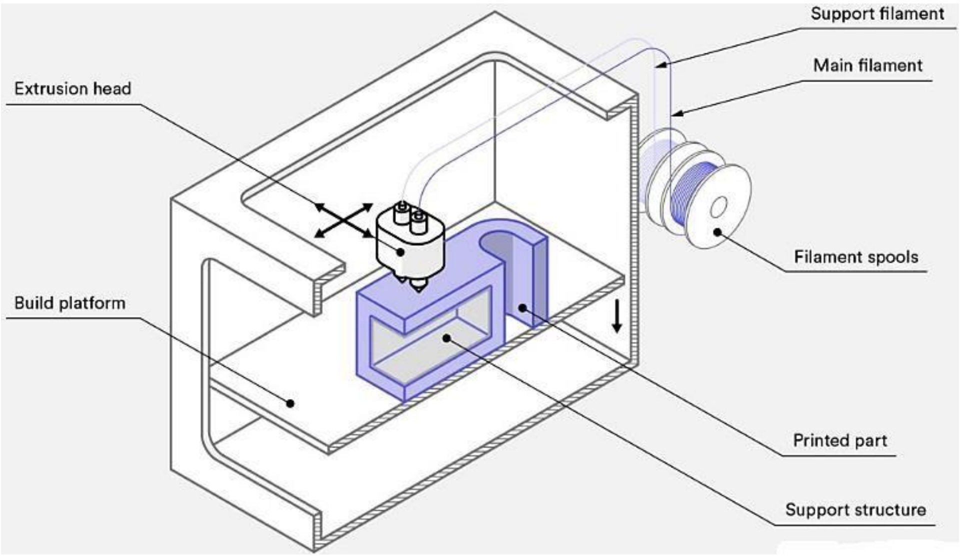

Figure 2. Fused Deposition Modeling.

c. *Stereolithography:* Resin 3D printing, or vat photopolymerization, is a family of additive manufacturing technologies that includes stereolithography, as illustrated in Figure 3. The basic idea behind all of these devices is the same: liquid resin has been dried into rigid plastic using a light source, such as a laser or projector. The primary physical distinction is found in the configuration of the main parts, which include the resin tank, the build platform, and the light source. The thermoset, light-reactive materials utilized in SLA 3D printers are referred to as "resin". Short molecular chains bind together in SLA resins when they are exposed to specific light wavelengths, polymerizing monomers and oligomers into rigid or flexible geometries [5]. Stereolithography (SLA) offers the smoothest surface finishes, sharpest details, and finest resolution and accuracy of all 3D printing technologies; however, its greatest advantage is its versatility. Material manufacturers have created new SLA resin formulae with a wide range of optical, mechanical, and thermal capabilities in an effort to match the properties of industrial, engineering, and ordinary thermoplastics.
d. *Laminated Object Manufacturing:* A series of feed rollers in a LOM machine drags a continuous sheet of material—like plastic, paper, or—less frequently—metal—over a build platform as illustrated in Figure 4. Building materials made of plastic and paper are frequently covered in adhesive. The material sheet on the build platform is formed by passing it over a heated roller, which melts the adhesive and presses the material onto the platform. Then, using a computer-

controlled laser or blade, the material is cut into the desired pattern [5]. In addition, the laser creates a crosshatch pattern that cuts up any extra material, making it simpler to remove after the object is fully created. The build platform is lowered by roughly one-sixteenth of an inch, which is the normal thickness of one layer, once the item has developed one layer. After that, fresh material is dragged across the platform, and the heated roller goes over it once more to connect it to the layer below it. Repeat this procedure until the object is entirely produced. When an object completes its "printing," it is taken off the build platform and any extra material is chopped off. Paper-printed objects have the same qualities as wood and can be polished or sanded accordingly. Paper goods are usually painted or lacquered to keep moisture out.

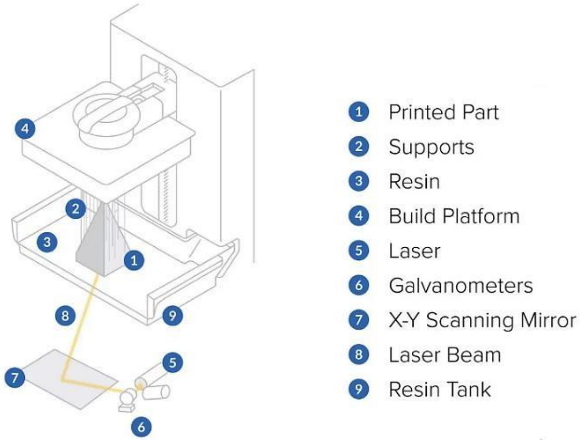

Figure 3. Stereolithography.

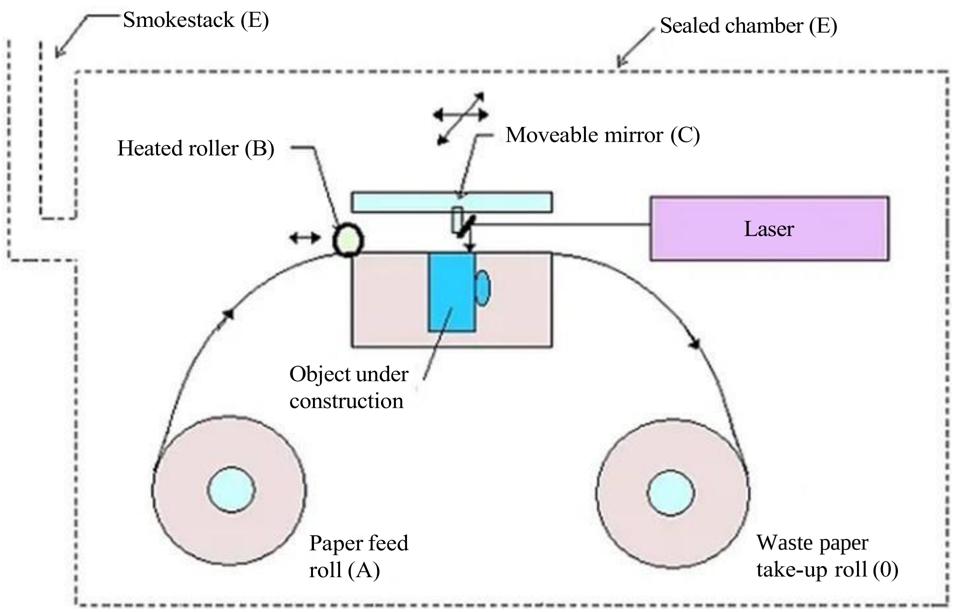

Figure 4. Laminated Object Manufacturing.

DIFFERENT MATERIALS USED IN 3D PRINTING

a. *Nylon:* The most popular plastic material is nylon, also referred to as polyamide. It is a synthetic thermoplastic linear polyamide. Its flexibility, resilience to corrosion, minimal friction, and durability make it a popular filament for 3D printing. Nylon is another material that is frequently used to make apparel and accessories. One can use nylon to create intricate and delicate geometries. It is mostly utilized as filaments in 3D printers that use FFF (Fused Filament Fabrication) or FDM (Fused Deposition Modeling) [4]. This substance is known to be among the hardest plastics and is reasonably priced.

b. *ABS:* Thermoplastic ABS (Acrylonitrile Butadiene Styrene) is frequently used as 3D printer filament. It is also a material that is frequently used in home or personal 3D printing and is compatible with the majority of 3D printers.
c. *Resin:* A popular material for 3D printing is resin. SLA, DLP, Multijet, and CLIP technologies are among the principal applications for it. Castable, strong, flexible, and other forms of resins are among the many varieties that can be utilized in 3D printing [5].
d. *PLA:* Renewable resources like sugarcane or cornstarch are used to make PLA, or polylactic acid. The term "green plastic" is also used for it. Primary and secondary schools are the main users of it because of its ease of use and safety. FDM desktop printing also employs it.
e. *Gold & Silver:* These days, gold and silver can be 3D printed. These filaments are made of strong materials and are powdered. Typically, the jewelry industry uses these materials. These metals are printed using the SLM (Direct Metal Laser Sintering) or DMLS method.
f. *Stainless Steel:* Stainless steel can be printed using laser sintering or fusion. This material can be applied to two different technologies. SLM or DMLS technologies may be used. Stainless steel is ideal for usage in miniatures, bolts, and key chains since it emphasizes strength and intricacy [6].
g. *Titanium:* The lightest and strongest material for 3D printing is titanium. It is employed in the Direct Metal Laser Sintering procedure. The primary applications for this metal are in high-tech industries including space exploration, aviation, and medicine [6].
h. *Ceramics:* One of the most recent materials to be utilized in 3D printing is ceramic. Because it is resistant to breaking or warping even in the presence of severe heat and pressure, it is more durable than plastic and metal [12]. Additionally, unlike plastics, this kind of material is resistant to wear and corrosion unlike other metals. Binder jetting technology, stereolithography (SLA), and digital light processing (DLP) are the main applications for this material.
i. *PET/PETG:* Polyethylene terephthalate, or PET, is another commonly used material similar to nylon. Processes involving thermoforming employ this material. To make engineering resins, it can also be mixed with other materials like glass fiber. PETG is used in 3D printing. PET has been transformed, and the letter G stands for "glycol-modified." This leads to the formation of a filament that is easier to use, cleaner, and less brittle than PET. You can use this filament with FFF or FDM technology.
j. *HIPS:* Plastic filaments called HIPS, or High Impact Polystyrene, are used in FDM printers to create support structures. In terms of use, it is similar to ABS. The capacity to dissolve is the only distinction. Limonene is a liquid hydrocarbon in which HIPS is fully soluble.

ADVANTAGES OF 3D PRINTING

a. *Ease of Access:* Previously, this technology was exclusively available to professionals and techies. Now a days this technology is easily accessible for any places like hospital, industry and educational institution.
b. *Economical:* Due to its simplicity, this technique is incredibly cost-effective. There is less need for labor. There is no scrap involved in this operation.
c. *Enhanced Welfare & Quality of Life:* 3D printing technology can be used for a wide range of applications including lifestyle, education, healthcare, the military, and automobiles, 3D printing holds the potential to improve people's quality of life and welfare.
d. *Environment Friendly:* Since 3D printing generates less waste than traditional methods, it is also seen as environmentally friendly.
e. *Innovation in medical technologies:* This technology has ability to print organs. This is example of advanced healthcare.
f. *Personalization:* This technology is helpful to create any complicated product. This technology is able to fulfill customer's requirement.

DISADVANTAGES OF 3D PRINTING

a. *Manufacturing Armaments:* It has ability to print potentially harmful items like knives, toy guns, and other items that can be used as weapons is a significant drawback.

b. *Scan & Fraud:* Identity documents, credit cards, and automobile keys may all be scanned and printed using 3D printers.

c. *Copyright issues:* This technology is more widely available, there is a greater possibility of fake products and chance of unethical work.

APPLICATIONS OF 3D PRINTING

a. *Aeronautics & Space travel:* 3D printing makes it possible to fabricate tools, equipment, and entire structures in space and on other planets on demand as mankind seeks to increase its presence there [6]. Airframes, avionics housings, and other sophisticated aircraft components can be produced on Earth via 3D printing. In general, 3D printing can minimize the cost of space flight, which will assist to ensure human presence in space for a long time.

b. *Custom clothing:* The quantity of waste that is produced by discarded clothing is a well-known issue in the fashion business. Custom clothing may be made by means of 3D printing, which can help reduce waste. Customers can get more of what they want with less waste if they can print apparel according to their measurements and style preferences on demand [7].

c. *Custom fitted personal products:* The typical body type or size is taken into consideration when designing a significant number of everyday products. Doors, seats, wardrobes, keyboards, tables, and other items are made to fit the average person in a given area. This can cause discomfort and incapacity for a large number of people who don't fit into the criteria of the "average build." Everyone's ergonomics, comfort, and safety can be improved with personalized solutions made possible by 3D printing [7].

d. *Emergency structures:* Many people may become homeless for an extended period of time as a result of natural disasters like hurricanes, wildfires, and tornadoes. By producing homes, hospitals, and other structures far more quickly than it would take to build them using conventional methods, 3D printing can assist affected families from discomfort [8].

e. *Pharmaceuticals:* Drugs with varying sizes and forms can be produced by 3D printing, which can also be utilized to distribute active and inactive components throughout the body in different places. This makes it possible to customize the distribution characteristics of 3D-printed medications to meet the requirements of individual patients. Although just one medication, Spritam®, a levetiracetam made by Aprecia Pharmaceuticals, has been made via 3D printing, this technology could eventually allow for the on-demand, local production of more medications [9].

f. *Implants:* The 3D printing of implants permits the building of more specialized items for patients. Quick fabrication of parts with complex geometry improves patient outcomes. Implants that can be 3D printed include knee replacements, heart valves, maxillofacial implants, and dental implants. Entire organs may soon be 3D printed, which could significantly enhance the future prospects for transplant candidates [10].

g. *Prosthetics:* The creation of prosthetics has been transformed by 3D printing. Custom, fitted prosthetics can be made more easily and effectively when 3D printing methods and procedures are improved [11]. With CAD (computer-aided design) software, prosthetics may be rapidly designed and 3D printed. A 3D-printed prosthetic can be readily adjusted in CAD and replicated if any flaws are discovered. Prosthetics printed using 3D technology can therefore improve patient results, comfort, and happiness.

h. *Replacement Parts:* The capacity to quickly produce replacement parts is another use for 3D printing technology. As a result, customers may benefit greatly from shorter lead times and a reduction in the need to travel to pick up items. With the help of 3D printing, companies and customers can get the most out of their purchases and devote more time to further urgent concerns.

i. *Educational Materials:* Students can receive real products that can be used for learning through 3D printing. To improve learning, 3D printed objects such as biological reproductions or topographical maps can be used. Hence, 3D printing has the potential to stimulate innovation, improve education, and promote teamwork [12].

CONCLUSION

All phases of the creative process, from early idea design to final manufacture, can benefit from 3D printing. While selecting a 3D printer, it's important to keep in mind that every application has different requirements. To identify the perfect 3D printing capacity for your business, you must ascertain your unique requirements for utilizing 3D printing throughout the entire planning phase to production process. This will boost customer satisfaction and product quality while cutting down on time to market, streamlining and lowering manufacturing costs, and improving product performance. More use cases could be available for multiple systems than for just one.

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