Additive Manufacturing VS Traditional Methods

Dhriti Mabian

Abstract

Additive manufacturing is the process of creating an object by building it one layer at a time. It is the opposite of subtractive manufacturing, in which an object is created by cutting away at a solid block of material until the final product is complete.

Technically, additive manufacturing can refer to any process where a product is created by building something up, such as molding, but it typically refers to 3-D printing.To create an object using additive manufacturing, someone must first create a design. This is typically done using computer-aided design, or CAD, software, or by taking a scan of the object someone wants to print. Software then translates the design into a layer-by-layer framework for the additive manufacturing machine to follow. This is sent to the 3-D printer, which begins creating the object immediately.

Introduction

Additive manufacturing processes, also known as 3D printing, utilize computer-aided design (CAD) files that are converted into stereolithography (STL) files. This conversion involves approximating the CAD drawing with triangles and slicing it into layers, each containing the information for printing.

These processes have found significant applications across various industries, including aerospace, where the ability to manufacture lighter structures aids in weight reduction. Additionally, additive manufacturing has revolutionized medicine by enabling the production of customized medical devices and implants. Architects also benefit from 3D printing technology, which streamlines the prototyping and modeling phases of their projects.

The evolution of additive manufacturing technologies has been notable, with the Society of Manufacturing Engineers classifying several significant technologies as early as 2004, and at least four more emerging by 2012.

Despite its advancements, challenges remain. Studies have examined the strength of products manufactured through additive processes, highlighting areas for improvement. Notably, not all commonly used manufacturing materials are compatible with additive techniques.

Furthermore, accuracy issues persist, necessitating additional finishing processes.

Rapid Prototyping

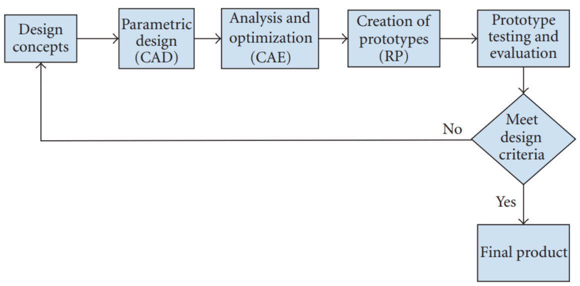


Figure 1: Product development cycle [2].

The inception of layer-by-layer three-dimensional object creation through computer-aided design (CAD) dates back to the 1980s with the introduction of rapid prototyping. Initially designed for modeling and prototyping purposes, rapid prototyping quickly evolved into an early form of additive manufacturing (AM). It streamlined product development by reducing time and costs, fostering greater human interaction, and expediting development cycles. Furthermore, rapid prototyping facilitated the fabrication of intricate shapes that were challenging to produce through conventional machining methods.

While not yet mainstream in manufacturing, rapid prototyping finds applications across diverse sectors. Scientists and students utilize it for rapid model construction and analysis, medical professionals for anatomical studies and procedural planning, market researchers for consumer perception analysis, and artists for creative exploration.

Rapid prototyping technologies have evolved to enable the production of finished products, particularly with advancements in plastic materials. Despite its growth, challenges persist, such as limitations in materials and size constraints compared to traditional manufacturing methods.

The amalgamation of computer-aided design (CAD), computer-aided manufacturing (CAM), and computer numerical control (CNC) technologies has made rapid manufacturing feasible, enabling the printing of three-dimensional objects.

Figure 3 provides an overview of various additive manufacturing processes, classified into liquid-based, solid-based, and powder-based categories. These processes, including stereolithography (SL), Polyjet, fused deposition modeling (FDM), laminated object manufacturing (LOM), 3D printing (3DP), Prometal, selective laser sintering (SLS), laminated engineered net shaping (LENS), and electron beam melting (EBM), play pivotal roles in the industry's future.

Despite its advancements, rapid prototyping is not universally applicable. CNC machining processes may still be necessary for certain applications, and material limitations persist.

Figure 4 illustrates survey data indicating widespread engagement with additive manufacturing technologies across manufacturers, service providers, and users, as reported by Wohlers.

Problem Statement

In our research, we delve into the realm of additive manufacturing materials for 3D printing tools, exploring a diverse array of options including thermoplastics, metals, ceramics, and composites, each offering unique properties and applications. Contrastingly, traditional methods employed in press tool machines, such as stamping, forging, and machining, serve as the backbone of manufacturing but pose limitations in design flexibility and lead time. We scrutinize the comparison between these traditional techniques and additive manufacturing, weighing factors like production speed, cost-effectiveness, and design complexity. Utilizing simulation techniques like static structural and modal analysis, we delve into the performance evaluation of components manufactured through both methods, gaining insights into their structural integrity and reliability. Additionally, we undertake a comprehensive material study, coupled with the design of punch and tag components, integrating CAD software to optimize geometries for manufacturability and performance across various manufacturing paradigms.

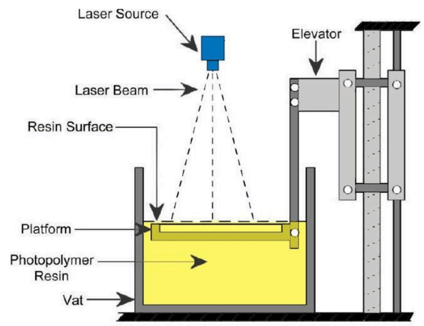
7 Types of Additive Materials

The 7 Categories of Additive Manufacturing

Media often uses the term "3D Printing" broadly, but Additive Manufacturing encompasses a diverse range of processes, each with distinct methods of layer manufacturing. These processes vary based on the materials and machine technologies employed. In 2010, the American Society for Testing and Materials (ASTM) group "ASTM F42 – Additive Manufacturing" established a set of standards that classify

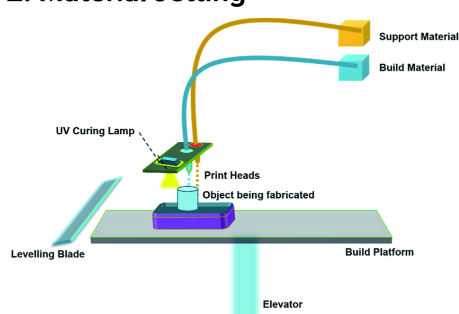
Additive Manufacturing into 7 categories

1. VAT Photopolymerisation



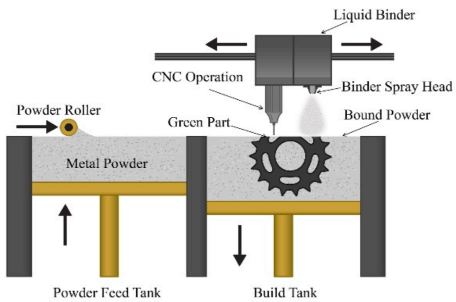
VAT photopolymerization involves a vat of liquid photopolymer resin, from which the model is built layer by layer. This method is particularly suited for intricate designs and fine details. The liquid resin solidifies when exposed to a light source, typically a laser or projector, enabling precise control over the shape of each layer.

2. Material Jetting



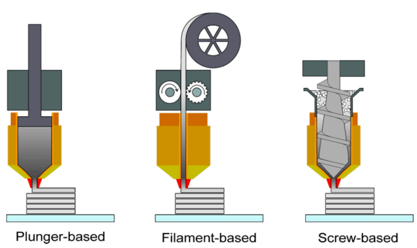
Material jetting is akin to the operation of a two-dimensional inkjet printer but in three dimensions. Material, usually a liquid photopolymer, is jetted onto a build platform using either a continuous or Drop on Demand (DOD) approach. This process allows for the creation of multi-material objects with varying properties in a single print.

3. Binder Jetting



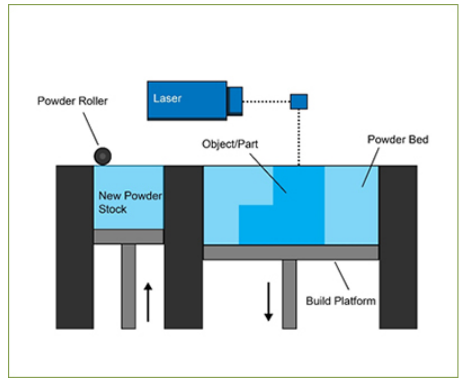
In binder jetting, two materials are utilized: a powder-based material and a binding agent. The binder, typically in liquid form, is selectively deposited onto a layer of powder. A print head moves horizontally along the x and y axes, depositing alternating layers of the build material and the binding material. This process is often used for rapid prototyping and large-scale production.

4. Material Extrusion



Material extrusion, exemplified by the popular Fused Deposition Modeling (FDM) technique, involves feeding a thermoplastic filament through a heated nozzle. The material melts and is extruded onto a build platform, where it quickly solidifies layer by layer. Both the nozzle and the platform can move, allowing for complex geometries to be built. FDM is widely used for its versatility and accessibility.

5. Powder Bed Fusion

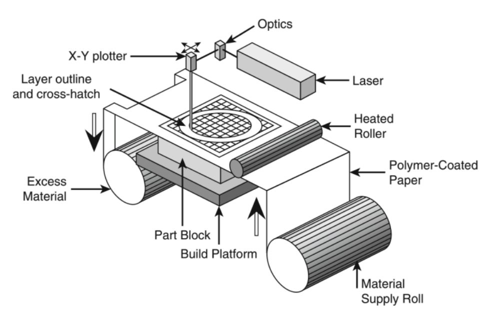


The Powder Bed Fusion category encompasses several commonly used printing techniques:

- Direct Metal Laser Sintering (DMLS)
- Electron Beam Melting (EBM)
- Selective Heat Sintering (SHS)
- Selective Laser Melting (SLM)
- Selective Laser Sintering (SLS)

These methods utilize a bed of powdered material, such as metal or plastic, which is selectively fused together layer by layer using a heat source, such as a laser or electron beam. Powder Bed Fusion is renowned for its ability to create strong, fully dense parts with intricate geometries.

6. Sheet Lamination

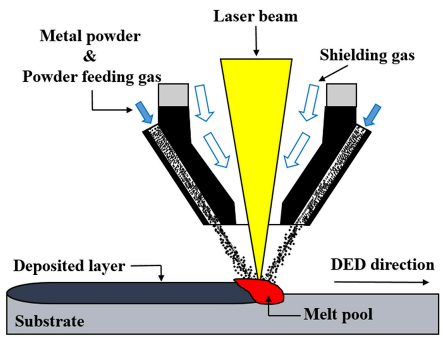


Sheet lamination processes include:

- Ultrasonic Additive Manufacturing (UAM)
- Laminated Object Manufacturing (LOM)

Ultrasonic Additive Manufacturing (UAM) involves metal sheets or ribbons bound together using ultrasonic welding, creating objects with excellent mechanical properties and fine details. Laminated Object Manufacturing (LOM) uses sheets of material, typically paper or plastic, adhered together and then cut to shape each layer. LOM is known for its cost-effectiveness and suitability for large parts.

7. Directed Energy Deposition



Directed Energy Deposition (DED) encompasses a variety of terms:

- Laser Engineered Net Shaping (LENS)
- Directed Light Fabrication (DLF)
- Direct Metal Deposition (DMD)
- 3D Laser Cladding

These methods are used for tasks such as repairing or adding material to existing components. Laser Engineered Net Shaping (LENS) utilizes a high-powered laser to melt and fuse metal powder. Directed Light Fabrication (DLF) uses a laser to fuse materials. Direct Metal Deposition (DMD) involves feeding metal powder into a focused laser beam to create fully dense parts. 3D Laser Cladding is used to fuse metal onto a substrate, commonly for repairing worn parts.

Additional Insights

- Advantages: Additive Manufacturing offers numerous benefits such as reduced waste, faster prototyping, complex geometries, and customization.

- Materials: Various materials are used, including polymers, metals, ceramics, and composites. Each material has unique properties and applications within Additive Manufacturing.

- Applications: These processes are utilized across industries, from aerospace and automotive to healthcare and consumer goods. They are used for prototyping, production parts, tooling, and even artistic creations.

- Industry Growth: Additive Manufacturing continues to evolve, with ongoing advancements in materials, processes, and software. This growth is driving innovation in fields like bioprinting for medical applications and aerospace manufacturing for lightweight, complex components.

- Challenges: Despite its advantages, challenges remain, such as post-processing requirements, material limitations, and the need for standardized quality control.

These categories and additional insights into Additive Manufacturing provide a comprehensive view of the diverse methods and applications within this innovative field.

Additive Manufacturing Technologies

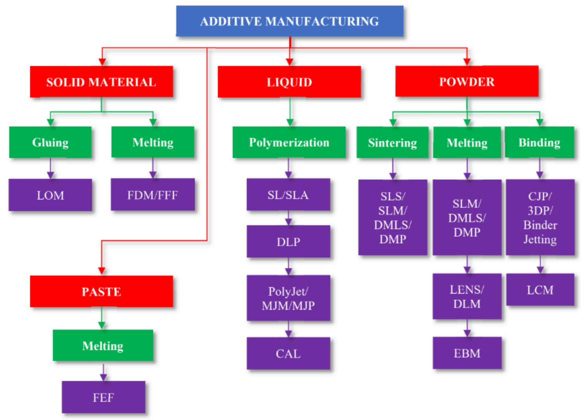


Fig. 1. Types of additive manufacturing processes [2, 5, 8-60]

The most popular methods of additive manufacturing are shown in Figure 1. The methods are

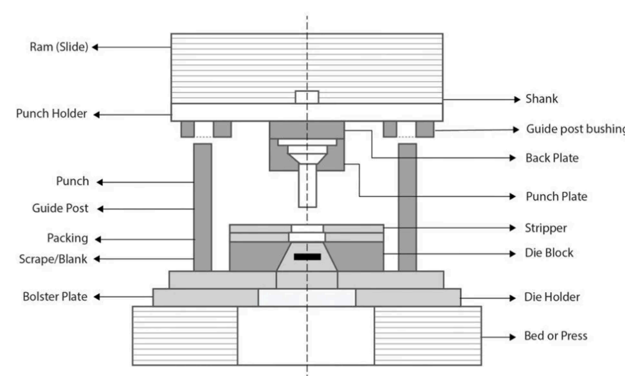
separated according to the input material and the type of process carried out. Input materials are:

liquid, solid material or powder. The use of liquids as input material results in the implementation of the photocuring process (polymerization using a light source). The use of liquids (photopolymer or photosensitive resin) as input material causes the use of photocuring process (using a light source for the polymerization process). For solid material, gluing/bonding or melting processes are used.

However, if the input material is powder, then binding, sintering and melting processes are used. Table 1 presents types of additive manufacturing processes, and Table 2 shows the possibilities of using AM processes for engineering materials.In accordance with the idea of additive manufacturing , the additive process is always preceded by a stage of Computer Aided . This software allows to design models with specific geometric dimensions. Process parameters and division into layers can be done in CAD software (special software provided by the device manufacturer) or in the machine software after transferring the file to the device. The designed model is saved using the .stl extension, which is recognized by most devices that perform most devices used for additive processes. Then the layer-by-layer manufacturing process begins (except by CAL method). The process is carried out up or down and it depends on the method used. At the end of the process, the supports are removed.

Optionally, finishing can be performed.CAD software (including dedicated devices that implement additive processes) allows selection of process parameters that allow the manufacture of a product with specific properties. Computer aided design in material engineering is necessary to design innovative materials that are already existing or completely new, whose model will have specific geometrical dimensions with a specific structure and properties. CAD software and various additions to this software (process and material simulations) and tools (neural networks, finite element methods, genetic algorithms, expert systems).

Material Selection:-



Life-cycle fatigue

Fatigue failure is defined as the tendency of a material to fracture using progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably below the normal strength. Although the fracture is of a brittle type, it may take some time to propagate, depending on both the intensity and frequency of the stress cycles. Nevertheless, there is very little, if any, warning before failure if the crack is not noticed. The number of cycles required to cause fatigue failure at particular peak stress is generally quite large, but it decreases as the stress is increased.

There are several steps running the fatigue test analysis. Firstly, load the maximum and minimum stress from FEA result. Second, load materials property of the product. Third, apply the modifying factor and fourth stress concentration factor must be obtained. Lastly, the result of fatigue life analysis will be obtained.

Types of Punch And Die which can be used :-

Material	Composition/Properties	Typical Applications
D2 Steel	Cold work, high carbon, high chromium type tool steel; deep hardening	Blanking dies, forming dies, thread rolling dies
D3	Cold work tool steel with high carbon and chromium content	Punches, dies
High Carbide	Steel with a high carbide content	Punches, dies
Chromium Steel	Steel alloy with significant chromium content	Punches, dies
High Speed Steel	Steel alloy with high hardness and wear resistance, retains hardness at high temperatures	Punches, dies

For Punch

Material	Composition/Properties	Typical Applications
HCHCr	High carbon and chromium steel alloy	General-purpose press tools, long-lasting applications
EN31	High carbon alloy steel with chromium and molybdenum	High-strength applications, heavy-duty tooling
D2 Steel	Cold work, high carbon, high chromium type tool steel; deep hardening	Blanking dies, forming dies, thread rolling dies
Mild Steel	Low carbon steel	Supporting plates

For Die

Material Properties for different plates:-

Sr.no	Description of Item	Material Selected
1	Punch & Die Block	D2 steel
2	Stripper	Cold rolled mild steel
3	Die Back Plate	Oil hardened steel
4	Punch Back Plate	Oil hardened steel
5	Guide Pillars & Bushes	Carbon Steel & Hardened ground steel
6	Punch Holder	Mild Steel
7	Top &Bottom Plate	Mild Steel
8	Allen Key Bolts	Mild Steel

RESULT AND DISCUSSION

The table below showed the output result value for punch analysis from the Finite Element Analysis. The result from the table above showed us the maximum values for stress, displacement, and reaction force. Generally, as can be seen from the table, pressure is different for those three materials. This is because the total blanking force is different for those materials because each material has its ultimate strength. Ultimate strength is a factor that affects the calculation and lifetime cycle.

Table- II: Results for a maximum value of the properties for three different materials used

	Aluminium	Brass	Copper
Force	6827.82kN	20kN	35.32kN
Pressure	922.63Pa	2702.7Pa	4772.972Pa
Stress	1471 Pa	4309Pa	7601Pa
Displacement	0.3779mm	1.107mm	1.955mm
Reaction force	98.83N	289.5N	511.3N