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A Review On 3D Printing In Pharmaceutical Industry

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Abstract

technique For the creation of technical components, 3D printing has proven to be a feasible because it is an additive process, unlike previous manufacturing methods. The advantages of 3D printing for industrial use include little material waste, simple manufacturing, minimal human participation, minimal post-processing, and energy efficiency. The pros and cons of various 3D printing techniques are covered in the study. There is a detailed explanation of various materials that work with each sort of 3D printing procedure. The report also lists the many contexts in which each process type is applied. There is also a separate section about industry 4.0. Despite the fact that significant advancements has been taken place in the realm of 3d printing, certain aspects still require attention including material incompatibility and material cost. Future studies could be done to improve the procedures and adapt them to work with a variety of materials. In order to broaden the application for 3D printed parts, there is a need for increased efforts in developing cost effetive printing technologies and compatible materials for these printers.

Key Words

3D printing, Arthroplasty, Orthopedics, *3DGraphy*, Bio printing, Metal printing

History

The idea of 3D printing (3DP) can be traced back to the early 1970s, credited to Pierre A. L. Ciraud who devised a method involving the application of powdered material. Each layer was solidified using a high- intensity beam. In this context, it was envisioned that materials such as plastic or metal could potentially be melted and utilized in the production process. In the early 1980s, Ross Housholder introduced the concept of sand binding using different materials in his patent titled "A molding process for forming a three-dimensional article in layers." Around the same time, Carl Deckard developed a method called selective laser sintering (SLS) which involved solidifying a powdered bed using a laser beam.

Stereolithography (SLA) was the first technology that Chuck Hull developed that was marketed. Using liquid resin that had been photopolymerized by through UV light. Towards the end of the 1980s, Scott Crump submitted a patent for fused deposition modeling (FDM), a process that involves the use of thermoplastic material for creating objects MIT scientist Emanuel Sachs and his colleagues patented "Three-dimensional printing techniques" based on combining the chosen powder regions with binding substance (3). Fig. 1 presents the most significant developments in 3D printing for pharmaceutical and biological applications.

Introduction

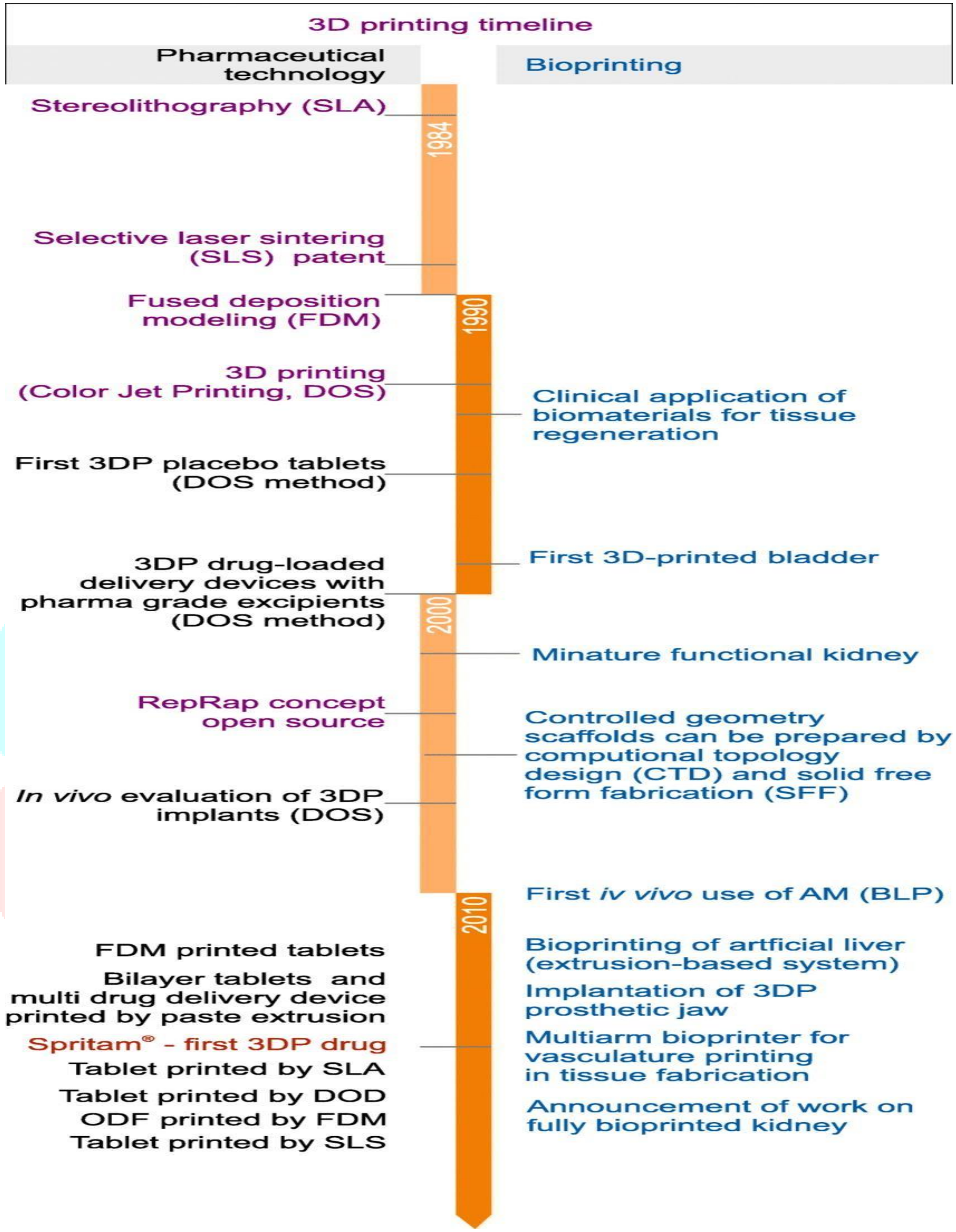
How do we manufacture things, or how do we go from raw materials into something that we want to use, buy, or consume in any form, is the very first question that comes to mind when we think of the manufacturing industry. Subtractive manufacturing is the initial method of production, where we start with raw materials and work our way up to the final product [1]. The following sort of manufacturing is known as forming, and it involves applying force to a block of material to cause it to change into its desired proportions. Casting is one of the manufacturing methods, classified as the third type, in which a solid substance is melted and transformed into a liquid state. Subsequently, the liquid material is poured into a mold to create the desired object [2].

The fourth method of production is additive manufacturing (AM), also known as 3D printing. In this process, parts are generated additively, layer by layer. Additive manufacturing (AM) and 3D printing encompass a wide array of techniques used to produce three-dimensional prototypes and structures from digital data [3].

The foundation of additive technologies is the computer-aided design (CAD) solid modeling component. This solid modeling data is utilized by additive models to build layers with incredibly small cross-sectional areas, enabling manufacturing of detailed and complicated shapes and surfaces that are exceedingly challenging to produce using traditional techniques.[4] If a device has all three of these characteristics—three-dimensional, additive, and layer-based— then it is considered a 3D printer. In order to generate the desired chemical, several substances are combined in an additive process. Let's use baking cupcakes as an example. To make the batter, we would add to create desired chemical, add the ingredients one at time to an empty bowl until we had the desired consistency. A large cake can be purchased and the top portion of it can be removed to create the shape of a cupcake. This is a subtractive procedure where we usually start with a larger part and remove everything that is unnecessary. Examples of subtractive manufacturing include laser cutting, CNC machining, and hand carving o lasercutting, CNC machining, wood carving, etc.[5]

We begin with the basic design of the part we wish to create in 3D printing, which is essentially an additive manufacturing method. The aforementioned design was produced using computer software that can be connected to 3D printers. A unique file type is then produced by this software and transmitted to the printer. After reading that file, the 3D printer builds the object by adhering one layer on top of another. To create a part in a 3D printing process, layers are used almost often. Instead of reading the pieces as an entire part, 3D printers read them as a single two-dimensional layer at a time. The functionality of the 3D printers in Fig. 1 depends on the fact that they are built to read Standard Type of file for tessellation language (STL).

Future-proofing features of 3D printing, such as minimal material waste, minimal post- processing, and extremely low costs even for producing complicated parts, make it a viable technology. The ability of 3D printing to reuse plastics, recycle, and reduce emissions are some of the other sustainable elements[6]. The method can also create designs with intricate and well- optimized geometries, which aid in creating lightweight components with higher strength to weight ratios. Consequently, 3D printing is used create designs that are sustainable.



Types of processes in 3D printing

AM techniques have been developed to meet the demand for printing complex models at high resolutions. AM technologies have advanced significantly as a result of rapid prototyping. The three main categories of AM technologies are sintering, melting, and stereolithography. Sintering involves raising the temperature of the material without melting it to create complex, high- resolution prototypes, melting involves using electron beams to melt the powders, and photopolymerization involves using an associate To prepare torque-resistant ceramic components at the highest temperatures, this laser is fired over a photopolymer resin vat [7]. AM has been broken down into seven processes, including VAT Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Powder Bed Fusion, Sheet Lamination, and Direct Energy Deposition, according to ASTM (American Society for Testing and Materials). In the sections that follow, we've gone into more detail about some of the key techniques, emphasizing their labor requirements, advantages and disadvantages, types of materials they employ, and possible uses for 3D printing ultraviolet laser.

2.1. Stereolithography (SL)

The 3D printing era began in the late 20s, and stereolithography (SL) was the first 3D printing technology to be commercialized. The first 3D printers were stereolithographic/SL devices, which were used to create 3D models, prototypes, parts, and patterns. Despite the fact that the field of 3D printing was the subject of numerous investigations in the 1970s, Charles Hull introduced and patented this technique in 1984 [8]

One must comprehend the SL process in order to define the word stereolithography. A CAD file is generated on the system and translated to an STL file format to start the procedure. The STL file type in question offers the geometric information a 3D printer needs to create an any thing. The ultraviolet (UV) curable photopolymer liquid, perforated table, laser source, and computer used to regulate the process are the four essential components that go into the formulation. 3D printers begin to function in such a way that the perforated table is submerged in the liquid tank after reading the STL file type. The perforated pores allow the liquid polymer to contact the table as the table descends. The UV laser strikes the upper surface of the photo liquid polymer as soon as the liquid touches the table, instantaneously hardening it. In order to produce a layer-by-layer geometry, this table is then moved downward once more. Starting with the base layer, each succeeding layer is fused. The final layer of the 3D printed object is finished. The component is submerged in another resin to separate the 3D printed model from the liquid polymer[9]. Following this procedure, the resin used for the layers bonds strongly, allowing the 3D printed model to bake in a UV curing oven. All the layers in this oven harden, get stronger, and achieve the appropriate surface polish at the predetermined temperature. Thus, the finished product is the result of all these procedures. Now that the name SL has been established, it may be used to describe a technique for 3D printing in which liquid photopolymer is transformed into 3D objectswith the aid of a stereolithographic (SL) machine.

Fused deposition modelling (FDM)

To remove the 3D printed model from the liquid polymer, a portion is submerged in another resin. Following this procedure, the resin's link between all the layers becomes very strong, and the 3D printed model is now ready to bake in a UV curing oven. All of the layers in this oven harden, get stronger, and attain the proper surface finish when the temperature is set. In the end, all of these procedures result in the finished product. We may now define the term "SL"; it is defined as a 3D printing technique in which liquid photopolymer is transformeThe component is submerged in another resin to separate the 3D printed model from the liquid polymer. Following this procedure, the resin used for the layers bonds strongly, allowing the 3D printed model to bake in a UV curing oven. All the layers in this oven harden, get stronger, and achieve the appropriate surface polish at the predetermined temperature. Thus, the finished product is the result of all these procedures. We can now define the term "SL." Stereolithography (SL) is described as a 3D printing technique in which liquid plastic into 3D objects with the aid of a stereolithographic/SL machine.

2.3. Powder bed fusion (PBF)

In a PBF process, a plate is constructed from a thin layer of powder, and an energy source—such as a laser or an electron beam—fuses the powder in accordance with the geometry of the component being manufactured [10]. Through the application of this technique, the laser can selectively dissolve powders in a layer-by-layer fashion, leading to the creation of three-dimensional sections. In Powder Bed Fusion (PBF) methods, the output is not continuous but distinct, as the pulverized material is spread over the previously affixed layer to ready it for the next layer's processing.

It's worth noting that each layer is connected to its adjacent layers. The finely powdered material is delivered through a hopper, and then a roller or brush evenly distributes it across the powder bed, creating a space for the platform. The ideal thickness of each sheet of unfolding powder is determined by the conditions of the procedures and materials utilized. Powder Bed Fusion (PBF) is referred to by various names, such as Selective Laser Sintering (SLS), Electron Beam Melting (EBM), Selective Laser Melting (SLM), Direct Metal Laser Melting (DMLM), and Direct Metal Laser Sintering (DMLS).

Selective laser sintering (SLS)

In the mid-1980s, Drs. Carl Deckard and Joe Beaman from the University of Texas at Austin developed this technique. Known as Selective Laser Sintering (SLS), it enables the construction of intricate geometries by consolidating successive layers of powdered material on top of each other through a rapid prototyping process.

Using CO2/nitrogen lasers and relying on the type of surface end and fusion required, layers are solidified. In this process, the powdered chemical compound is used to create the item The powder could be made of metals, thermoplastics, ceramics, or glass. This process is known as direct metal laser sintering (DMLS) if the powder being utilized is made of metal. The electricity is transferred from the first chamber to the second, where the actual manufacturing takes place, in SLS printers, which have two chambers. The temperature at which the powder is heated is below the melting point of a comparable substance. The powder is then leveled or smoothed at the top surface by creating layers using a leveler or roller.

Binder jetting (BJ)

Inkjet technology has been modified for use with binder jetting. The initial introduction of this procedure was credited to the Massachusetts Institute of Technology (MIT), where it was first introduced.This approach employs an inkjet to link the objects rather than lasers to do so. It builds up in layers to create a 3D project using inkjet 2D printing technology. In this procedure, a liquid binder is precisely deposited with the aid of a printhead that moves along two axes[11]. Like all other 3D printing processes, The process commences with the creation of a 3D drawing, which is then imported into the printer software

. Since a steady supply is necessary for printing, a dispenser guarantees that supply by putting the requisite powder in it.

The printing head applies a layer of powder with varying thickness, and subsequently, the binder is applied according to the specified requirements.

. The solvent holding the binder is dried using fluorescent or electric lamps before moving onto the next layer. The powder bed is then de-escalated and covered with a fresh layer. After the cycle is finished, the binder is next put in a furnace. Depending on the type of binder employed, variables like temperature and time are necessary. Before being employed, the metal and ceramic parts must go through sintering, in-filtration, heat treatment, or hot isostatic pressing. Nevertheless, the majority of metal and plastic components does not require any further processing and can be used directly after being printed by the printing systems.

Direct energy deposition (DED)

This 3D printing technique, in contrast to others, is used for maintenance and repair rather than component production. By melting the material as it is deposited, DED technologies facilitate the creation of materials [12]. The deposition head, which integrates an energy source and two powder feed nozzles, is the main piece of machinery utilized in the DED process. In this technique, a thin wire may also be supplied, in addition to the metal powder. A platform with inert gas tubing and the specific part that needs to be manufactured are sometimes also present. The deposition head, which deposits the laser beam and powder beam simultaneously, is a 4 or 5 axis machine. the DED procedure employs. The material is incrementally applied, one layer at a time, to the existing products using a centered heat source (electron beam or laser), mending and creating new material structures as it solidifies

Laminated object manufacturing (LOM)

LOM, known as Laminated Object Manufacturing, was commercialized in 1991 by Helisys Inc., now Cubic Technologies, a California-based company. It is a rapid prototyping method that creates models out of laminates made of paper, plastic, or metal, which are successfully epoxied together.. The model or item is then cut out using a laser cutter in the appropriate shape. Starting with a sheet bonded to a substrate using a heated roller, further layers are accurately cut and then attached one after the other, i.e. (forming followed by bonding) or vice versa (i.e. bonding followed by forming) [13]. As each layer is completed, the platform descends, the next sheet of metal is rolled into position, and then the platform returns to its initial position to receive the subsequent layer.

The procedure must be followed till the prototype is created. UAM, which combines lamination with ultrasonic metal seam joining and CNC cutting, may be a subset of LOM [14]. Comparatively, Table 1 below outlines the procedures, benefits, and drawbacks related to it.

Classification of materials used in various 3D printing processes

After exploring the different types of 3D printing, the next question that arises is about the materials utilized in these processes. Each material has its own viability, distinctive properties, and specific applications. Some common materials include plastics like PLA, ABS, and PETG, as well as resins used in SLA and DLP printers[15]. These materials find use in creating prototypes, consumer goods, functional parts, and various other applications.. The next sections, which are specific to each 3D printing technique, have elaborated on material issues based on these factors.

3.1. Materials used in stereolithography

As the name of the process suggests,, stereolithography is an optical manufacturing process in which UV rays are used to bind liquid monomers, also known as photopolymer resin, to form polymers (allowing them to cross-link together). The design is then maintained as desired by layering these polymers to form a solid surface. SL (Stereolithography) uses a UV laser in a process called photopolymerization to solidify liquid resin into rigid plastic.

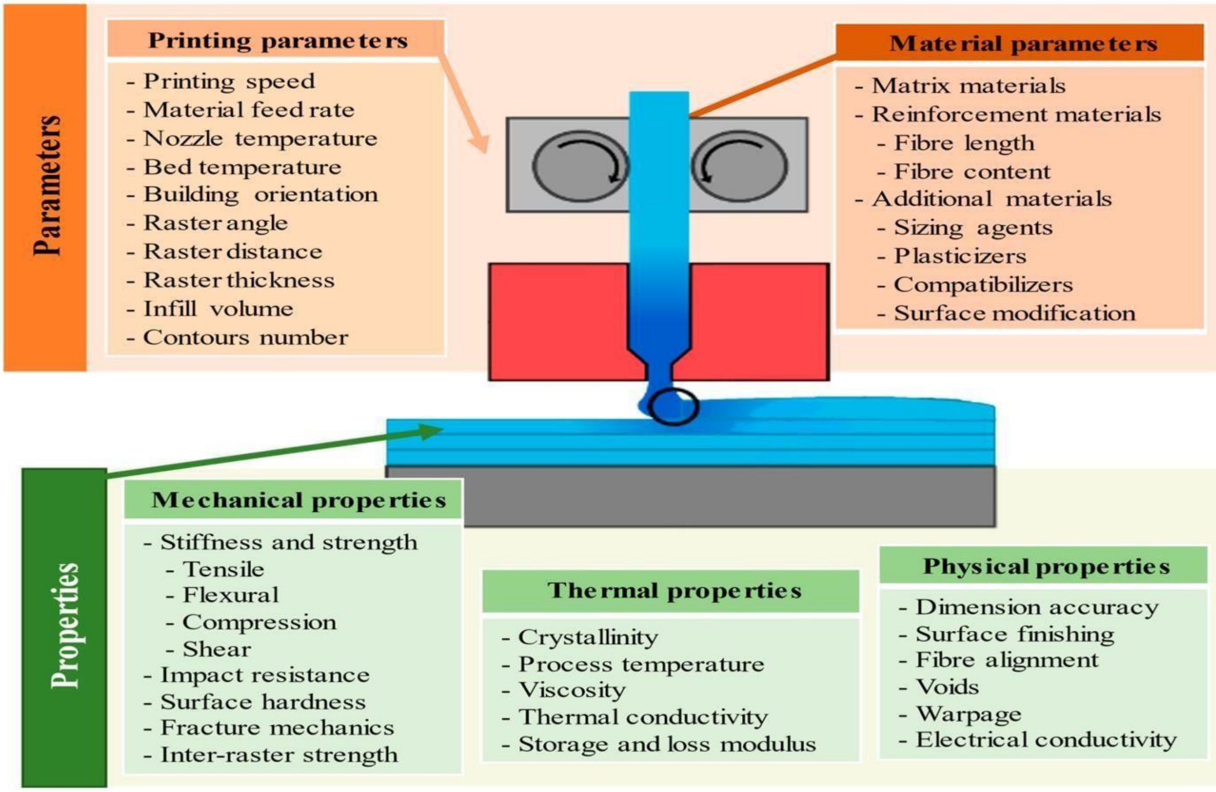
Stabilizers, flexibilities, monomers/oligomers, solvents, photo-initiators, reactive diluents, and other additives are used in stereolithography. Materials, their qualities, and uses are grouped together in Table 2 [16].

Table 2. Materials, characteristics, and SL technique applications

	Purpose	Soil Type	Method*
Subgrade stabilization	Improve load carrying and stress distribution characteristics	Clays of high PI	SA, SC, MB, C, CMS, LMS, SL
	Reduce frost susceptibility	Fine granular	CMS, SA, SC, LF
		Clay of low PI	CMS, SC, SL, LMS
	Waterproofing and improved runoff	Clays of low PI	CMS, SA, LMS, SL
	Control of Shrinkage and swell	Clays of low PI	CMS, SC, C, LMS, SL
		Clays of high PI	SL
	Reduce resiliency	Clays of high PI	Fine Granular
		Plastic silts or clays	Coarse granular
Base course stabilization	Improvements of substandard materials	Fine granular	Clays of low PI
		Clay of low PI	SC, SL
	Improved load carrying and stress distribution characteristics	Coarse granular	SA, SC, MB, LF
		Fine granular	SC, SA, LF, MB
	Reduction of pumping	Fine granular	SC, SA, LF, MB, membrane
Dust palliative	Improvement in dust palliative	Fine granular	CMS, SA, Oil or bituminous surface spray APSB

Materials used in fused deposition modeling

Among other distinguishing qualities, these materials are resistant to UV radiation, durable, translucent, and biocompatible. The continuous filament required for this popular AM method uses thermoplastic material as an input [17]. The characteristics, uses, and illustrative examples of several material classes are shown in Table 3



Materials used in selective laser sintering

This process involves sintering granulated material (often polyamide or nylon) using a laser as the power source. In a three-dimensional model, the laser is directed automatically to specific locations in space, effectively binding the material together to create a robust structure. This process operates in a manner similar to selective laser melting (SLM) but is carried out under distinct technical conditions

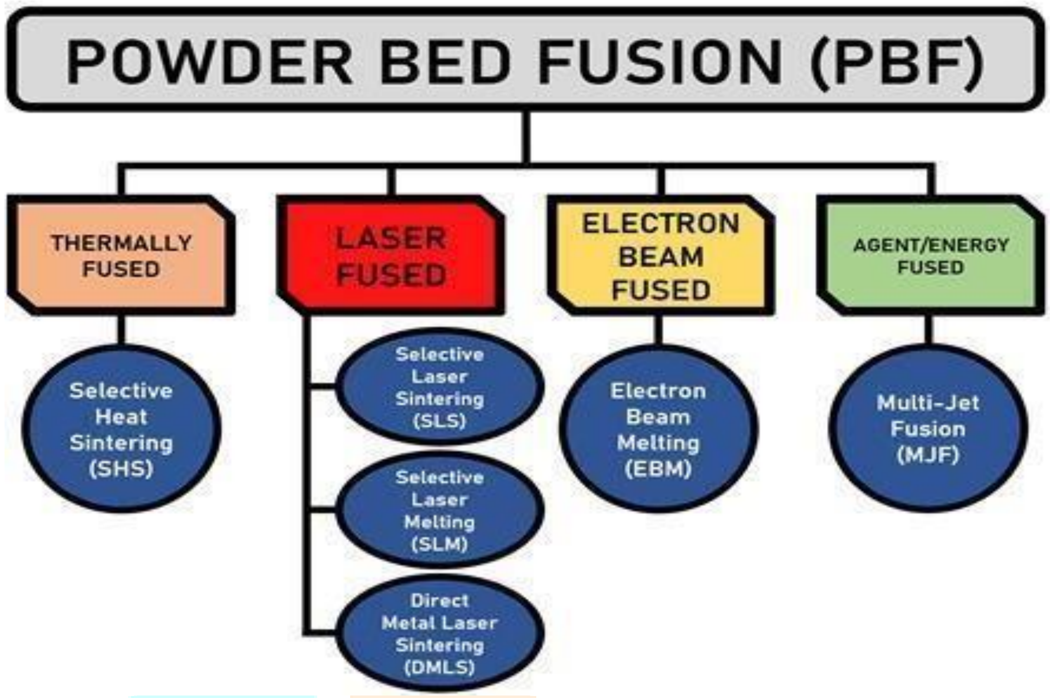
. In contrast, a liquid binder is typically used when using this laser on powders with lower melting or sintering temperatures. Table 4 presents a comparison between the materials used inpowder bed fusion processes, where SLM is typically appropriate for specific metals like steeland aluminum, while SLS finds application with a diverse range of materials, including polymers, alloys, and metal powders.

Material	Laser	Scan	Environment
Composition	Mode	Speed	Pressure
Density of the powder	Wavelength	Layer thickness	O_2 level
Morphology	Power	Impulse distance	Type of gas
Diameter of the granules	Frequency	Scaling factor	Preheating
Distribution	Pulse width	Operating surface	
Thermal properties			
Rheological properties			

Materials used in powder bed fusion

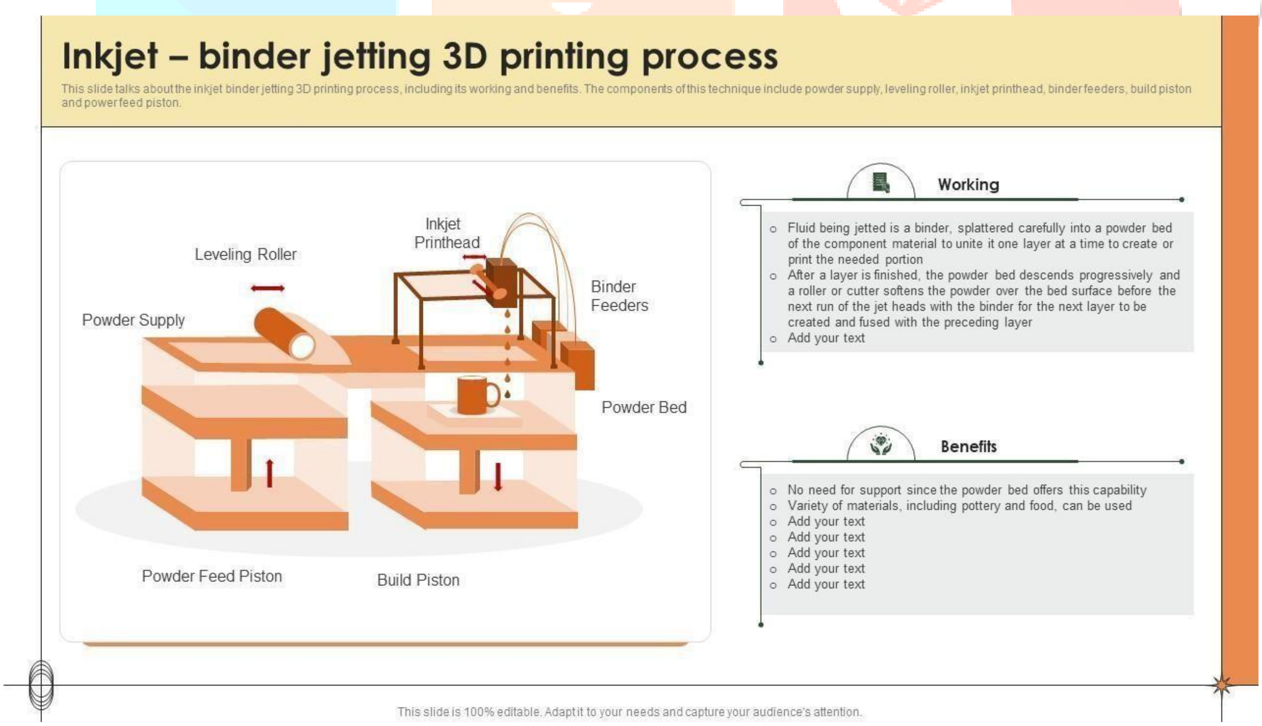
The technique uses securely bound, evenly dispersed, and quiet little powder particles in tiny layers on a platform [18]. PBF (Powder Bed Fusion) is among the rapid manufacturing methods wherein a thermal source, like a laser, initiates the partial or complete fusion of powder particles. The layer of powder is then smoothed by rolling it with a roller or blade re-coater. The combining process in the PBF method consists of two steps: melting and sintering. Some examples of PBF techniques include SLS (Selective Laser Sintering) procedure, Electron BeamMelting (EBM) method, and Selective Laser Melting (SLM) method.

The resources properties, and applications incorporated in PBF are mentioned belowin Table 5 and Table 6 [16].



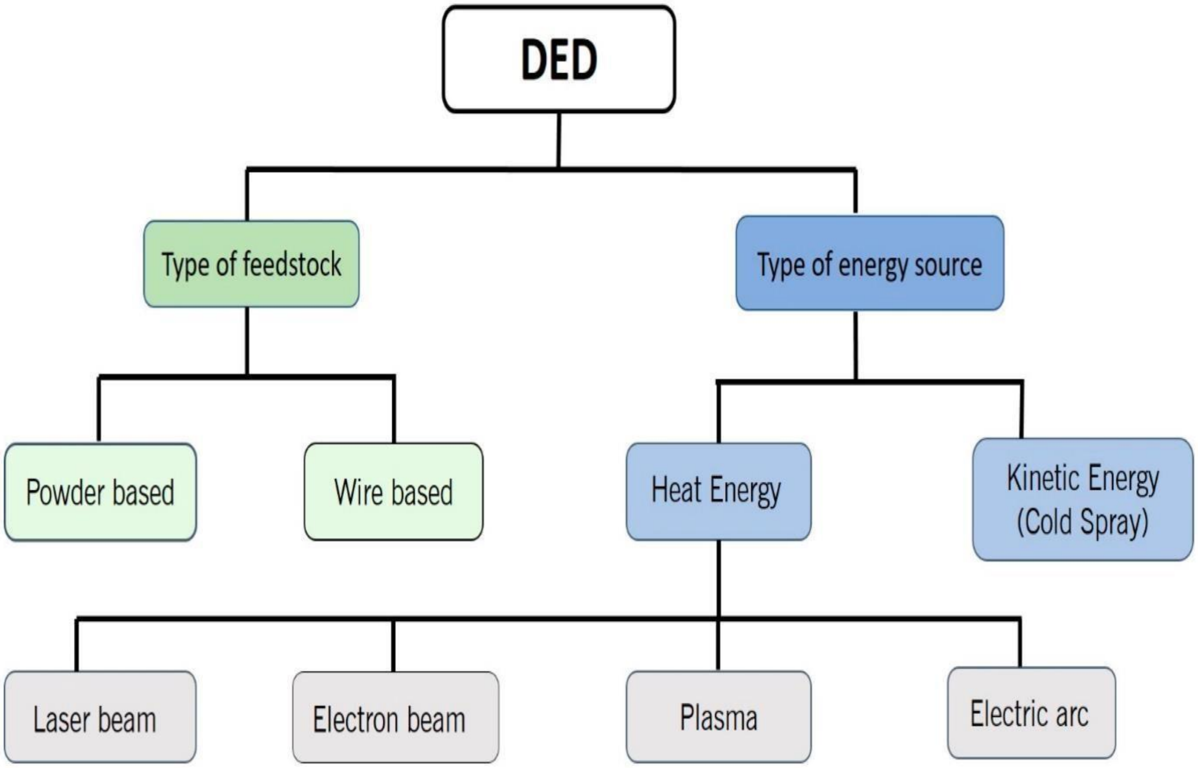
Materials used in binder jetting

Additionally known as "Powder bed and inkjet" and "drop-on-powder" printing, the binder jetAM technique. Table 7 below provides a summary of their material examples [19].



Materials used in direct energy deposition

The operating concept of a DED process differs fundamentally from a PBF process in that a steady stream of powdered material is deposited or laid down on the substance itself, as opposed to a layer of metallic powder that is pre-deposited, in this case [20]. The comparison of materials and their attributes is shown in Table 8 below.



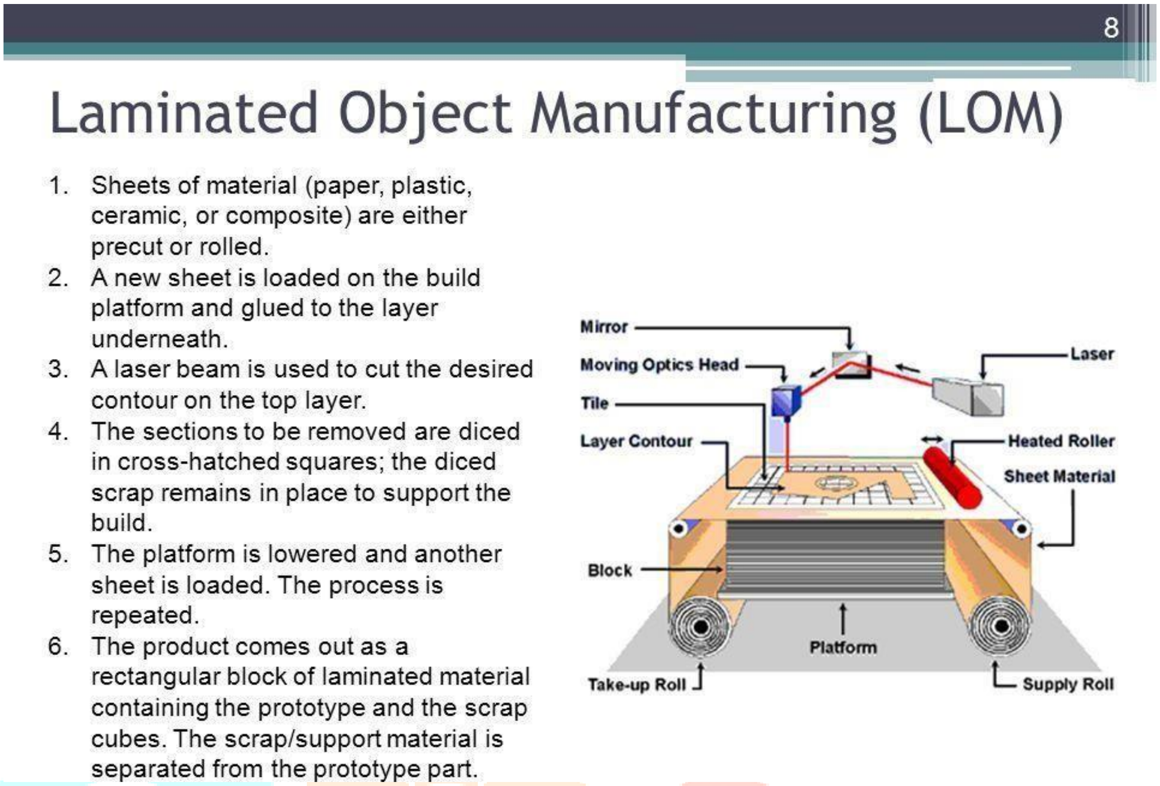
Materials used in laminated object manufacturing

The two primary categories of sheet lamination methods are as follows:

1. Laminated Object Manufacturing (LOM): This method involves using a laser to cut thematerial sheets.

2. Ultrasonic Additive Manufacturing (UAM): This method employs ultrasound to join thesheets together.

The summary of some of the materials, together with their characteristics and uses, is presentedin Table 9 below [21].



Applications of 3D printing

The manufacturing of things in the shortest amount of time with the least amount of waste is made feasible by each of the processes that have been mentioned so far. Additionally, the techniques make it incredibly simple to create complicated structures of the highest quality. With the aid of 3D printing, industries are being upgraded and revolutionized. Traditional production methods are gradually giving way to unconventional ones, including 3D printing. In-depth knowledge about the properties of different materials is essential when working with 3D printing. This understanding allows for the implementation of various modifications to traditional methods, utilizing the current knowledge of materials and processes.

We will briefly go through a few of the processes that have been applied in this section that have been covered thus far. Figure 2 displays all the applications discussed in the text[22].

Applications of stereolithography

Fabrication of heart valve scaffold

Tissue engineering of heart valves is demonstrated through a novel experimental technique that involves producing viable and functional heart valve tissue using autologous cells. A polymeric substance is employed to create a framework for the heart valve. SL is a crucial tissue engineering approach for the heart valve. It creates plausible tissues that can develop inside the human body similarly to real tissues. Utilizing X-ray computed tomography and other software, biodegradable and biocompatible scaffolds are constructed for the stereolithic models. These resemble humans and are readily absorbed by the human body. Currently, mechanical valves that cannot grow are used, which increases the likelihood that a body may reject them. Consequently, this novel method gets over these restrictions[23].

Fabrication of lithium disilicate glass-ceramic for dental applications

Natural teeth partially reflect, absorb, and relay light, giving them a certain amount of translucency. The preceding field's particularly pronounced and unfavorable lack of transparency in metal ceramics prompted the development of all-ceramic bridges. Glass and ceramic materials are frequently employed in the dentistry business for individualized and aesthetically pleasing restorations. Lithium disilicate is often treated using AM technology to produce exceptionally dense (>99 percent), full ceramic components that are suitable for use in dental restorations. By melting the SiO2-Li2O-Al2O3-K2O-P2O5 glass system and heating treatment samples to the glass's crystallization temperature, lithium disilicate glass-ceramic can be created. Excellent mechanical characteristics of the manufactured glass, such as high strength, make it possible to

Applications of fused deposition modeling

Drug delivery

The phrase "drug distribution" refers to methods, formulations, systems, and technologies based on nanoparticles that are used to effectively and safely distribute pharmaceuticals throughout the body as needed to produce the desired therapeutic effect while maintaining good health Fused deposition modeling (FDM)-based 3D printing provides notable advantages for producing customized tablets, such as streamlining manufacturing processes, improving inherent qualities, and offering diverse dosage forms. FDM is an economical 3D printing method that creates solid shapes through material layering using extrusion. Given its thermo-based nature, careful consideration of material choice is essential, considering the melting polymer rheology and heat transport characteristics.. Due to their low melting point, thermoplastic polymers predominate in FDM applications. Polyvinyl alcohol is the most popular polymer for FDM drug delivery systems [24,25].

Production of patterns for investment casting

Today's users' demands for high-quality, low-cost components that are deliverable quickly provide a significant problem that necessitates streamlining the operational parameters of the corresponding machinery. Industrial casting has successfully employed the FDM technology to make wax and wax shapes at competitive prices. A high-quality surface finish and precise dimensional accuracy are crucial in investment casting and component assembly. The surface condition exhibited by the master pattern is faithfully replicated by the mold.

it. As a result, the master pattern produced by FDM needs to have an excellent surface polish in order to produce decent castings. Styrene-acrylonitrile-butadiene is the most common non-wax material used to create casting patterns in FDM. With just slight adjustments to the foundry's standard procedures, the wax and Acrylonitrile Butadiene Styrene patterns produced using the FDM technology have both shown to be successful in burning off the ceramic shell. Investment casting uses wax gates and vents, which are manufactured as an integrated component of the pattern and joined by the foundry via an ABS pattern [26].

Applications of powder bed fusion

Direct metal laser sintering in order to fabricate lightweight robotic structural parts

Direct metal laser sintering, also referred to as laser powder bed fusion, is employed to fabricate lightweight robotic structural parts. This additive manufacturing process utilizes a laser source to melt and fuse various layers together, enabling the direct production of parts with a near-net shape.With only a few finishing stages needed, metals manufactured using near-net type processing technologies produce products that are nearly similar to the final size and shape. This method is used to create lightweight robotic components out of an aluminum alloy. The achievement of high hardness and strength, along with other fascinating mechanical properties, is attributed to the remarkably fine microstructure

The lightweight finger exoskeleton with joints was created in a single step of development. Additionally, it is formed with all the desired mechanical characteristics [27].

Fabrication of smart parts using powder bed fusion PBF technology

Energy device modules with built-in sensors or other intelligent parts can provide input on how the real-time system is operating and allow for on-the-ground monitoring. Conventional surface contact or cavity sensors have a higher risk of interfering with the normal operation of energy systems due to the complexity of component design required for sensor placement. However, utilizing additive manufacturing (AM) technology makes it feasible to adaptably embed sensors into structures without compromising their integrity or functionality. The layer-by-layer approach allows sensors to be positioned inside a part at any desired location, providing unparalleled access to previously unreachable regions within the part's volume. Researchers are also investigating challenges such as component registration and bond strength at interfaces caused by the stop-and-go process to enhance the manufacturing process for smart parts. By enabling embedded sensors to function in delicate sections of a part that are typically exposed to high temperatures, additive manufacturing (AM) technology has the potential to revolutionize the design of metal parts

Applications of direct energy deposition

Repairing stainless steel

Powder Bed Fusion (PBF), a popular 3D printing method, finds extensive use in manufacturing parts from 316L stainless steel. In situations where these PBF parts undergo severe degradation or wear during operation, traditional repair procedures can be beneficial. However, these methods come with some drawbacks, such as creating a significant heat-affected zone and repair flaws. In contrast, Directed Energy Deposition (DED) generates a smaller heat-affected zone, minimal dilution, and ensures strong metallurgical bonding. The restored region's microstructure is primarily made up of intricate dendritic structures because of the region's uneven nucleation. In addition, the micro-hardness of the deposition zone is higher than that of the original hot-rolled specimens and is similar to that of the PBF specimens [28].

Repairing automotive dies

Tungsten inert gas (TIG) welding has been extensively utilized for repairing dies used in car engine manufacturing. However, it only lasts for approximately 20.8 percent of the die's lifespan before requiringfurther repairs[29].

An additive reconstruction technique known as powder-blown DED is used to remove damaged sections and subsequently rebuild them. The original die and the DED-repaired die both had the same lifespan. The adoption of Directed Energy Deposition (DED) repair has resulted in a significant reduction of emergency repairs and unscheduled downtime on the production line. This technology has extended the operational lifespan of the restored DED dies, allowing them to function for the same number of cycles as the original die, thereby eliminating the need for frequent early maintenance.

Applications of selective laser sintering

Applications for rapid tooling

Rapid development has become a key enabler for reducing the time it takes for a product to reach the market and as a productivity-boosting strategy. One of the most popular methods for rapid prototyping is the SLS procedure. The modules are swiftly prototyped with the SLS methodology using a variety of methods. Copper polyamide is the material used to generate tooling inserts (they are less expensive than the other materials), although all nylon-based materials are utilized to create prototypes for manufacturing or parts with functional characteristics like hinges, chips, and other features. A small number of pre-production parts can be made using the same materials and manufacturing processes as the final production parts using the same SLS approach that was used to make copper polyamide tooling inserts. A thorough understanding of design characteristics is necessary for efficient application of the quick instrument method [30].

Selective laser sintering of biodegradable polymers for tissue engineering applications The possibility to use biological alternatives to restore destroyed or damaged tissues haspropelled tissue engineering (TE) forward. This branch of biomedical engineering is growing in complexity and importance. For anchorage-based cell types, temporary three-dimensional scaffolds are frequently utilized to control cell proliferation[31]. Computer-controlled manufacturing processes like Rapid Prototyping (RP) methods have been acknowledged as having an advantage over conventional manual-based scaffold manufacturing techniques because of their capacity to construct structures with complicated macro- and micro-architectures. Commercially available RP modeling materials are not biocompatible and are not suited for direct use in scaffold development, despite the vast RP processing capacity for scaffold assembly. Some of the biocompatible polymers in production are Poly Ether Ether Ketone (PEEK), Poly Vinyl Alcohol (PVA), Poly CaproLactone (PCL), and Poly L-Lactic Acid (PLLA), as well as a bioceramic called hydroxyapatite. To work with these materials, the SLS technique's parameters have been adjusted. Scaffold specimens produced by SLS are examined under a scanning electron microscope. The micrographs demonstrate their utility in the creation of TE scaffolds and the capability of the SLS approach to produce extremely porous scaffolds for TE applications [32].

Applications of binder jetting

Binder jet in pharmaceutical manufacturing

The pharmaceutical industry's most promising three-dimensional printing method to date is binder jet printing. The FDA changed the binder jet procedure in 2015 to make it easier to produce Spritam, the first tablet made via 3D printing, as a different method for mass production. Binder jet printing is anticipated to have a significant impact on formulation production over the coming ten years. Particularly with binder jet printing, producers can create oral dosage forms with a variety of release characteristics, from quick dissolving to platforms for controlled release. Even though it has many advantages, there are also downsides. [33]

Bone scaffold and implant application of binder jet process

Scaffolds are biocompatible three-dimensional structures that imitate the characteristics of the extracellular matrix (mechanical support, cellular activity, and protein production), and they operate as a support system for cell attachment and the development of bone tissue. Their conclusions are supported by data on chemistry, pore volume, pore size, and mechanical strength. Using the Binder Jet AM process, a hybrid made of tricalcium phosphate and stainless steel is employed in different volume fractions to create sections with different densities. The most widely used biomaterials for implants include metals and alloys, ceramics, and polymers. The most biocompatible and closely related to genuine bone in terms of characteristics are calcium phosphates. Their limited tensile strength and fracture toughness, however, prevent them from being used for bioimplants[34]. The following is the major manufacturing approach for the binder jet process: (a) The CAD file is divided into layers, and each layer produces an STL file. A piston covers the powder bed and lowers the part-in-progress so that the next powder sheet can be extended and selectively joined. This layer-by-layer process continues until the component is complete. (b) A thin spread of powder sprinkled over the surface of a powder bed marks the start of each layer. (c) A binder material selectively binds particles where the product is to be formed using ink-jet printing technology. (d)[35].

3D Printing and industry 4.0

The manufacturing sector will alter as a result of the fourth industrial revolution, often known as Industry 4.0, a German idea. In order to enable automation and build machines with the least amount of technical assistance from humans, it incorporates numerous concepts including inter- machine communication and the Internet of Things (IoT) [36,37]. 3D printing is a key element in the idea of Industry 4.0, especially in light of the technical features of it and the objectives of Industry 4.0. Furthermore, the importance of additive manufacturing in industry 4.0 has grown as a result of recent developments in the field of 4D printing that have made it feasible to manufacture smart materials. Although the idea of Industry 4.0 also calls for the digitalization of several businesses, 3D printing can be extremelyhe scenario of industry 4.0. The goal of Industry is to create an industrial environment where systems are autonomous and there is sufficient connectivity among workers, equipment, suppliers, and end customers. enough connectivity between the workers, equipment, suppliers, and end consumers. The various 3D printing-related materials, techniques, and technologies have been covered in the discussion above. Industry 4.0 goals will be more easily attained because to the numerous advantages of 3D printing, including digital data transfer, remote access, minimal human involvement required, ability to create complicated geometries and smart materials, less waste, and reduced post-processing requirements [38].

Conclusions

Due to its sustainability, 3D printing has the potential to displace existing technologies.

In addition to being affordable, 3D printing is also environmentally benign, which can assist to lessen the harmful consequences of industrialization on the environment.

The literature review led to the conclusion that several 3D printing methods have developed and are compatible with a variety of materials. Each 3D printing technology has a unique set of benefits and drawbacks. In addition to being able to handle elaborate and complex designs, 3D printed items require extremely little post processing.

FDM is the most widely used 3D printing process, yet it works best with polymeric materials. The technologies that rely on powder, like SLS, have a number of problems, include trouble moving and storing powders[39].

. Future recommendations

Future research can be done to enhance 3D printing technology, make it more effective, andmake it work with a wider range of materials.

On the mechanical qualities of the generated parts, the impact of different process parameters invarious technologies can be investigated.

By improving the user experience, productivity, and cost-effectiveness of the 3D printingprocesses, the applications of these components can be expanded

Declaration of Competing Interests

The authors affirm that they have no known financial or interpersonal conflicts that would haveappeared to have an impact on the research presented in this study[40].

References

1. T. Ngo, A. Kashani, G. Imbalzano, K. Nguyen, D Hui
2. Additive manufacturing (3D printing): a review of materials, methods, applications andchallenges
3. Comp. Part B, 143 (2018), pp. 172-196,
4. Recent progress on polymer materials for additive manufacturing5. Adv.

Funct. Mater., 30 (43) (2020), Article 2003062,

6. Additive manufacturing: technology, applications and research needs7. Front.

Mech. Eng., 8 (3) (2013), pp. 215-243,

8. 3D printing- creating a blueprint for the future of orthopedics: current concept review andthe road ahead!
9. Effect of fused deposition modelling process parameters on mechanical properties of 3Dprinted parts

10. Laser powder bed fusion additive manufacturing of metals; physics, computational, andmaterials challenges
11. Appl. Phys. Rev., 2 (4) (2015), Article 041304,

12. Selective laser sintering: A qualitative and objective approach13. JOM, 55

(10) (2003), pp. 43-47

14. J. Kruth, X. Wang, T. Laoui, L. Froyen
15. Lasers and materials in selective laser sintering 16.

Assembly Automat., 23 (4) (2003), pp. 357-371,

17. M. Li, W. Du, A. Elwany, Z. Pei, C. Ma
18. Metal binder jetting additive manufacturing: a literature review

I. Gibson, D. Rosen, B. Stucker, M. Khorasani

19. Binder jetting
20. Add. Manuf. Technol. (2020), pp. 237-252,
21. H. Chen, Y. Zhao
22. Process parameters optimization for improving surface quality and manufacturingaccuracy of binder jetting additive manufacturing process

23. Rapid Prototyping J., 22 (3) (2016), pp. 527-538,

I. Gibson, D. Rosen, B. Stucker

24. Directed energy deposition processes
25. Add. Manuf. Technol. (2015), pp. 245-268,

26. J. Park, M. Tari, H. Hahn
27. Characterization of the laminated object manufacturing (LOM) process28. Rapid

Prototyp. J., 6 (1) (2000), pp. 36-50,

29. J. Li, T. Monaghan, T. Nguyen, R. Kay, R. Friel, R. Harris
30. Multifunctional metal matrix composites with embedded printed electrical materialsfabricated by ultrasonic additive manufacturing
31. Comp. Part B, 113 (2017), pp. 342-354,

32. S. Corbel, O. Dufaud, T. Roques-Carmes
33. Materials for Stereolithography
34. Stereolithography (2011), pp. 141-159

35. J. Lee, J. An, C. Chua
36. Fundamentals and applications of 3D printing for novel materials37. Appl.

Mater. Today, 7 (2017), pp. 120-133,

38. F. Ning, W. Cong, J. Qiu, J. Wei, S. Wang
39. Additive manufacturing of carbon fiber reinforced thermoplastic composites using fuseddeposition modeling
40. Comp. Part B, 80 (2015), pp. 369-378,