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Review Article

An assessment of the materials used for additive manufacturing: Current trends and processing issues

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Additive manufacturing, often known as 3D printing, is a breakthrough industrial technology that employs computerized design files to layer products one by one. This study discusses the application of one such progressive manufacturing approach. AM is flexible, adaptable, highly configurable and can be tailored to suit the needs of most sectors of industrial production. An overview of the various materials appropriate with each 3D printing process has been presented. The literature reviewed has shown that issues such as incompatible material and the costs of materials are still to be addressed, even though 3D printing is becoming more widely used. There may be a broad range of materials that can be used to produce these parts and objects. These include combinations in form of composite products, hybrids, or functional graded materials such as metals, ceramics, and polymers. To accomplish this performance through anticipatory and replicative methods, a large amount of work is still needed at AM about its two major enabling technology namely AM materials and AM metrology. The positive aspect is that industry is extremely proactive in establishing AM as one of the most prominent manufacturing engineering methods.

Keywords: Additive manufacturing, Binder jetting, Challenges, Direct energy deposition, Fused filament fabrication, Laminated object manufacturing, Materials, Power bed fusion, Steriolithography, Selective laser sintering

1 Introduction

There are many other acronyms for additive manufacturing (AM), among which are layered, generative, fast, desktop, digital manufacturing, and so on. Additive manufacturing was originally commercialized in the 1980's and is continuing evolving at a rapid pace[1-3.] Additive manufacturing methods use three-dimensional model data to create a wide variety of structures and components including complex geometric shapes, using 3D printing. The procedure involves printing layers of materials, which are subsequently moulded into pairs. That layer-by-layer manufacturing facilitates a stunning degree of flexibility with the manufacture of curved, composite and hybrid structures which could not have been achieved on traditional production methods[4,5]. Additive manufacturing could have some potential benefits [6,7], including:

- Complete translation of design into components.
- Creation of parts with higher personalization, without additional tools or production costs
- The functional design permits the manufacture of complex internal features.
- Production of flexible and lighter components with a flat or lattice structure
- The possibility of directly producing the parts to their finished state or close to finished state.

In contrast, the accomplishment of 3D printing is judged by how well the created product performs its intended purpose, or marketability. AM's excellence and simplicity of use in translation Making forms and architecture into useable things is crucial.

In addition to these strengths, AM techniques lie under the category of Zero waste production methods. As waste and noise pollutions are reduced to a great extent their usage. It is possible to install AM machines in an office environment that is friendly to workers. The elimination of jigs and fixings is a major cost saving and a peculiar feature of AM[8-10]. Processing and nesting of parts at the same time A further dimension of efficiency is added to AM techniques by careful layout optimization[11]. These factors show that AM could potentially save considerable time and costs while increasing flexibility, quality, and variability at the same time[12-19].

It is worth noting that, despite significant progress in the field of AM methods, some degree of uncertainty remains to be found. Furthermore, there is

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a critical need for research and analysis in a few fields. AM materials are one of the most significant factors. AM material types, smart materials, and architectures have all been the subject of interesting study [20-23].

A summary of various aspects is intended to be provided in this review. AM materials highlighting the progress that has been achieved over the past two decades. The procedure begins with an explanation of how additive manufacturing technologies are categorized. Following that, the category of additive manufacturing materials to be studied encompasses plastics, metallics, ceramics, cermets, intelligent materials, and the author focuses specifically on their suitability for a range of advanced material techniques. Detailed discussion has been given on the various issues relating to materials as well as their processing through AM. Before concluding this article, a discussion of future prospects and a summary are provided.

2 Materials and Methods

2.1 Process types used in 3D printing

Able to produce detailed sharp prototypes, melting, using electron beam technology to melt powder and stereolithography process for which photopolymerization is used with an associated ultraviolet laser, Additive manufacturing technology depends on three key types of sintering in which material temperature rises to a degree not achievable by liquifying. This laser shall be discarded over the photopolymer Resin vat to enable torque resistant Ceramic parts to remain at maximum temperatures [24]. AM has been split into seven processes, namely VAT Photopolymerization, Material Deposition, Adhesive Jetting, Material Extrusion, PBF techniques, Sheet Lamination, and Direct Energy Deposition, as stated by the American Society for Testing and Materials [25].

2.1.1 Introduction to stereolithography

The beginning of the printing process has occurred with SL, an original 3D printer in the late twentieth century. The market's first ever printing process and the world's first 3D. The stereolithographic printing machines were configured to print 3D models,3D prototypes, 3D parts and replica. The techniques use photocurable polymeric resins as a printing medium. The photochemical process is used to cure these photosensitive materials. UV light can be used as the source of energy and cure by converting liquid phase into solid phases layer-by-layer, connecting polymers with each other. You may select amongst bottom-up and top-up stereolithography. For bottom-down SL, for individual printing of layer and an Ultraviolet source of light shall be focused on a vat of polymers, base table is lowered in steps which progressively move up to polymer resin. While the base plate is rising and falling, the Ultraviolet light source will be placed in the outermost layer of the resin.

There is a need to understand how the stereolithography process works to define this term Stereolithography. To open this process on your computer, a CAD file was created and will be transformed into the STL configuration. The geometric data that the 3D printer needs to make an object is supplied by this STL file type. Ultraviolet-curable photopolymer liquid, perforation table, source of laser and computer for controlling the operations are four basic working contributing to this formulation. Once a 3D printer has read the STL file type it will work to such a degree as to allow the perforated table to sink directly into the liquid reservoir. As it moves down, the wet polymer strikes the table through its perforation holes. UV light is directed on the overhead layer of a photo liquid polymer, immediately enhancing its hardness as soon as it encounters a table. This table would then move downwards so that a layer-by-layer geometry could be created, and each subsequent layer formed initiating with the foundation layer. Once the last layer finished, the additive manufactured product is dipped in a different resin to distinguish the additive manufactured model from the fluid polymer. In this process the bond between each layer in that specific type of Resin will become stronger, so a model printed upon it is now allowed to be cured with ultraviolet light. Inside this oven, all layers are hardened at the specified temperature and strength increases resulting in a desired surface finish.

2.1.2 Fused filament fabrication (FFF /fused deposition modeling (FDM)

Thermo-plastic filaments are employed in the process of "fused deposition modeling" or "fused filament fabrication," which involves pushing layers of the filaments together until a three-dimensional object is formed [26]. Wires will be used in the form of materials in this process. The wires are passing through the jet of the printer. The material will be hot extruded in the print jet, sending a small coating of molten material out of the tube. A spool of material shall provide a constant supply of materials. The extruder's going to deposit material which will be ignited later. slicer will operate within the profile created by the G Codes and M Codes formulated by the extruder program. The extruder then prints a next layer onto the preceding layer of the product after having printed one layer. Desktop printers are the preferred way to obtain FDM printers, which is very convenient. Most Fused deposition modelling printers uses plastics as their feedstocks whereas most models do not have metal wires at all. We need to uncover smaller statistics of the finishing process to generate components. Some schools make use of fused deposition modelling printers[27]. It is referred to as a fusion deposition model because the close-by layers melt into one another, whilst extruders complete it, and therefore 3D printers are responsible for modelling an item[28].

2.1.3 Introduction to powder bed fusion (PBF)

This method will allow a laser to vaporize the powder layer, which results in 3D sections. Powder bed fusion procedures unravel powdered material past the formerly bonded stratum, adjusting it for the operations of the subsequent stratum, leading to a disconnected rather than regular output (although each stratum is collateral to neighbouring stratum). Powder bed fusion procedures are classified as laser beam-based powder bed fusion (L- PBF) or electron beam-based powder bed fusion (E-PBF) depending on the source of heat[29,30]. Several advantages are offered by PBF technology mainly in terms of the development of very complex parts, a wide variety of material options, nesting of components that is particularly for polymers and so on[31-33].

2.1.4 Selective laser sintering (SLS)

In the mid-1980s, Dr. Carl Deckard and Dr. Joe Beaman of the University of Texas in Austin created this approach[34]. SLS (Selective Laser Sintering) is a rapid prototyping method that enables the creation of complicated geometries by hardening consecutive dispersed material layers above preceding ones[35]. To produce an object chemicals compound powder is used in this method. The powder can be a combination of plastic, ceramic, glass, metal and so on. In the case of powder produced from metal, this process is also termed as Direct Metal Laser Sintering. The Selective Laser Sintering System consists of two chambers, in which powder is transmitted from the initial chamber to a next chamber where actual production occurs. The powder is placed at a temperature which does not reach the melting point of the equivalent substance. The top surface of the powder is covered by a leveler or roller, which forms layers. There are finishing steps that need to be performed after production has been completed.

2.1.5 Binder jetting (BJ)

It employs the Inkjet technique. This approach was developed by the Massachusetts Institute of Technology (MIT)[36]. It's a straightforward method of operation in which building ingredients, most of which are powders, are spread through the platform by roller so that they may combine with substrate particles and create layers. A complete 3D component can then be built by repeatedly repeating the procedure of reducing the construction platform to fit the subsequent layer. However, most metals and polymers require no further treatment and are ready for use instantly as they emerge from the imaging systems[37,38].

2.1.6 Direct energy deposition (DED)

This method is used for repairs and maintenance, rather than manufacturing parts, as opposed to alternative 3D printing methods. The DED process makes it easier to produce materials when they are deposited by melting the material[39]. For the process of DED, a deposition head incorporating energy sources and two powder feed nozzles shall be used. It is possible to feed either metal powder or thin wire in this process.

2.1.7 Introduction to laminated object manufacturing (LOM)

Helisys Inc. (formerly Cubic Technologies), marketed LOM in 1991[40]. The parts are made in a printing technique called LOM, where sheet material is attached to each other. A laser is used to cut the required part of the sheet from the continuous supply of the sheet material, which is applied with some adhesives, external pressure, and heat, to stick to the sheet. The underside of the sheet is covered with an adhesive layer. The properties of the printed element may be changed by temperature changes, roller pressure fluctuations and other processes with separate application of both pressures and temperatures[41]. Due to the combination of lamination, ultrasonic metal seam joining, and Computer numerical control machining, UAM might be regarded as a subset of LOM[42].

2.2 Materials required for various 3D printing techniques

Unique materials must be employed for additive manufacturing, subject to the nature of the application and available resources. In particular, the material used is comprised of two phases: a liquid-phase and a solid-phase. Stereolithography (SL) employs the fluid phase, i.e., thermoset photocurable polymer material. The other is in the form of a solid that may be powdered or wired. Table 1 listed the different types of material, material form and printing technique for additive manufacturing.

2.2.1 Materials for stereolithography

The definition of "stereolithographic" itself defines that the method to produce polymers through UV light is used for liquid monomers, also known as photopolymer resins., and then they are arranged in such a way as to be able to interconnect themselves with each other. Then these polymers are formed, layer-by-layer, to ensure a replica that we want.SL uses the UV laser in a photopolymerization method called curating. Liquid resin to hardened plastic [43]. Table 2 listed the materials and features for stereolithography process

2.2.2 Materials used for the fusion deposition modelling

The materials are resistant to Ultraviolet radiation, hardness, permeability, and biocompatibility in addition to different characteristics. The additive manufacturing method is widely applied, requiring a continuous filament with thermoplastics as the base material [44]. Table 3 listed the materials and features for fusion deposition modelling process.

2.2.3 Materials used for selective laser sintering

A 3D model illustrates how granulated material, commonly nylon or polyamide, is sintered using a laser as the power source. In order to bind the material together to form a robust framework, the laser's beam is pointed autonomously at predetermined points in the area. Table 4 listed the materials and features for selective laser sintering process.

2.2.4 Materials used for powder bed fusion (PBF)

The method consists of fine layers of quiet minute particles of pow der, which are dispersed and tightly bound to the platform [45]. PBF is one of the fastest manufacturing methods, whereby heat sources such as lasers are applied to start fractional or entire mixing among particles in powder and then roll it overusing a roller or blade recoater; this allows for more smooth application of an entire layer of powder. The combination process in PBF is made up of melting

Table 1 — For additive manufacturing, categories of materials are available.

Material type	Material form	Printing technique
1 Plastics	1.1 Photo curable resin	1.1.1 Stereolithography (SLA)
	1.2 wire	1.2.1 Fused deposition modelling (FDM) OR Fused filament fabrication (FFF)
	1.3 Powder	1.3.1 selective laser Sintering (SLS)
2 Metals	2.1 wire form	2.1.1 Arc welding process 2.1.2 Direct energy deposition process
	2.2 powder	2.2.1 SLS method 2.2.2 SLM method
	2.3 sheets	2.3.1 LOM
3 Ceramics	3.1 Powder	3.1.1SLS technique
4 Cement type	4.1 Powder	4.1.1 Binder jetting method
	4.2 Cement slurry	4.2.1 Fused deposition technique (FDM) OR Fused filament fabrication (FFF)
5 Bio-ink	5.1 Resin form	5.1.1 stereolithography technique
	5.2 wire	5.2.1 Fused deposition modelling technique

Table 2 — Organizes the materials and their features, as well as their uses[44].

Materials	Properties	Applications/ Industries
DC 100	Less contraction and more precision	Patterns for jewellery are cast using this method
DC 500	Like wax in biological terms, it flames readily	To produce precise, lighter wire jewelry designs that are difficult to recreate using rubber moulding techniques
DL 350	Comparable to polypropylene in terms of flexibility and resistance to fatigue and other impurities	Utilized to make items for both commercial and everyday usage.
DL 360	Robust and readily apparent in nature.	Manufactures components for commercial and general-purpose uses that demand transparency.

Table 3 — FDM technique materials, characteristics, and application.

Material type	Materials	Properties	Applications
Thermoplastic Polymer	Polyphenylsulfone, Polycarbonates, Polytetrafluoroethylene, Polyether Ether Ketone, Recycled Plastics, Acrylonitrile Styrene Acrylate, Nylon 12, etc.[44]	Toughness and strength, high fatigue resistance, and high impact strength are all properties linked with this. They have excellent tensile and flexural strength, for example[44]	They are useful for aeronautical and aerodynamics applications because to their high heat resistance.
Polymer pattern Composites	GFRP, Carbon Fiber Reinforced Polymer[91]	Toughness, ductility, yield strength, and other qualities are compatible.	Application in construction
Ceramic Slurries and Clay	Alumina, Kaolin[92]		General-purpose applications, as well as applications in the dentistry area
Green Ceramic/ Binder Mixture	Zirconia, Calcium phosphate[93]	Chemical and corrosion resistance, robustness, durability, and resistance to heat Excellent frictional properties, low electrical and thermal conductivity, non-magnetic in nature, and so on[94]	To create piezoelectric components
Green Metal/ Binder Mixture	Stainless steel, Titanium, Inconel[95]	This results in qualities like as strength, lightness, and corrosion resistance, among other things.	To produce mechanical parts for tooling and fixtures, etc.

Table 4 — Illustrates an overview of the materials used in this method.

Laser	Material	Qualities	Application
CO_2/N_2	Polymers including Polyamides[96] Thermoplastic Elastomer (TPE)	As a semi-crystalline thermoplastic, it has a perfect sintering behaviour[96]	Making prototypes throughout the early design phase, vehicle components, hardware, and so on
Nd:YAG	Ceramics	Excellent robustness and hardenability, enhanced chemical and resistance to heat, and effective thermal & electrical, characteristics [97]	Applications in biomedicine, and metallurgy[98]
Yb-Fiber	Glasses including amalgamated silica as well as borosilicate.[99]	Chemical resistance, thermal stability, and so forth[99]	Medical and chemical fields, glass filters[99]

Table 5 — The materials, features, and uses used in PBF.

materials	features	uses
Titanium	Corrosion resistance and thermal expansion with excellent biological reliability, as well as outstanding durability and low density	Its uses include, but are not restricted to, design, medical, automotive, aerospace, marine, and jewellery fields, among others.
Aluminium (Al)	Thin metal having low density and high capacity for electricity, as well as alloying qualities and ease of processing	These components, which have complex geometry, are employed in aircraft engineering, the automobile sector, and prototype construction
Nickel based alloys	Good weldability and hardenability, as well as corrosion resistance and mechanical strength.	Aerospace engineering and other industries needing heat resistance have applications in tool manufacture.

and sintering [44]. Table 5 listed the materials and features for PBF process.

2.2.5 Materials used for binder jetting

The Additive manufacturing operation where powder bed and Inkjet are also used is called Binder jet "drop-on- powder" printing. Their material examples are summarized in Table 6 hereunder[44].

2.2.6 Materials used for direct energy deposition (DED)

The performing principles of direct energy deposition differs from that of powder bed fusion, where a high density and powerful laser is focused on the uninterrupted stream of powder contained within the material rather than upon its layer of metallic powder which has been redeposited[44]. The comparative examination of materials and their characteristics is shown in Table 7[46].

2.2.7 Materials for laminated object manufacturing (LOM) process

The following sections outline sheet lamination technology methods: The material is initially sliced with a laser, which is referred to as Laminated Object Manufacturing (LOM), and the subsequent step is where working sheets are combined using ultrasound methods, which is referred to as Ultrasonic additive manufacturing (UAM)[44]. Table 8 listed the materials and features for laminated object manufacturing process.

Table 6 — BJ technique materials, characteristics, and applications.

Materials	Qualities	Applications
Stainless steel	Heat and corrosion resistant, with higher tensile strength	Pumpand mining machinery components
Ceramic beads	incredibly permeable with improved thermal qualities	This is used to cast steel alloys and may also be used for printing cores that must withstand strong met allostatic pressures.
Inconel alloy	Adding strong mechanical characteristics and even more density to the product	These are frequently utilised in the aerospace sector to produce gas turbine blades, seals, and pressure vessels.
Iron	It has superior mechanical qualities and is extremely resistant to wear	Uses include the fabrication and maintenance of automobile components and machine tools.

Table 7 — DED technique materials, characteristics, and applications.

Materials	Properties	Applications
Titanium	Corrosion resistance, thermal expansion, and biological compatibility, as well as lightweight and excellent durability	utilized to fix automated work and aviation industries
Aluminium	A light metal having a high electrical conductivity and low density, as well as blending properties and processing ease.	fixing prefabricated parts and filling up gaps
Stainless steel	The heat and resistance to corrosion, as well as increased tensile strength.	Turbine engine repair and other equally complicated applications
Copper	Better surface smoothness, malleability, and ductility	Commercial purpose
Inconel, Ceramics	Better mechanical qualities and higher density	Aerospace and medical usage are two examples

Table 8 — LOM technique materials, characteristics, and uses.

Materials	characteristics	Uses
Polymer	Adhesive adhesion, good conductivity to heat	Making paper
Composites	High modulus, low density, good fatigue resistance, and so forth	Making paper
Paper	Good electrical conductor	Electronics manufacturing

2.3 Binding mechanisms in AM

The fact that the additive manufacturing parts are assembled in layers, which form a part of each other by some means must be seen clearly. The components, expansion, and effectiveness of which the bonding of the layers is crucial to determining the efficiency and success of any particular AM technique [47].

Figure. 1[48] depicts a broad classification of these binding AM processes into four types:

- Secondary phase assisted binding mechanism.
- Chemical induction binding mechanism
- Solid-state sintering mechanism
- Liquid fusion system

2.3.1 Secondary phase assisted binding system

Additive manufacturing technologies such as sheet lamination, SLS, and so on are based on the mutual use of layer attachment through the help of the tertiary phase[49]. This tertiary phase might be a granular, liquid, or coated material, or something else. Secondary stages are incorporated using nozzles, coatings, etc., and layers are predominantly linked by liquid phase sintering, evaporation, and hydration [50]. An adhesive binding agent is used for sheet laminations and jetted binders. Either by automated nozzles or embedded in a powder bed, Adhesives are introduced to the primary material's liquid in a dry condition. Liquid binders, on the other hand, are composed of a binding ingredient. In the case of sheet lamination, For the formation of layers that subsequently bind, coating must be formed direct by heating and applying salt or pressure on sheets.

2.3.2 Introduction of the chemical induction binding mechanism

In the event of chemical induction, other stages do not have to be achieved to bind. Material jetting, selective laser sintering, and other processes use the chemical reactivity of the material to link layers[51]. The direct manufacture of SiC ceramic components has been researched at the Fraunhofer Institute IPT (Aachen, Germany)[52]. There were no binder components utilized, and the laser-material contact durations were extremely limited, omitting the diffusion processes that occur in SLS. As the SiC particles are heated to extremely elevated temperatures, they partially disintegrate into Si and C.

2.3.3 Introduction of the mechanism of solid-state sintering

This sintering takes place at temperatures lower than the material's melting point and is described as a thermal consolidation process [51,53]. For ceramics, this

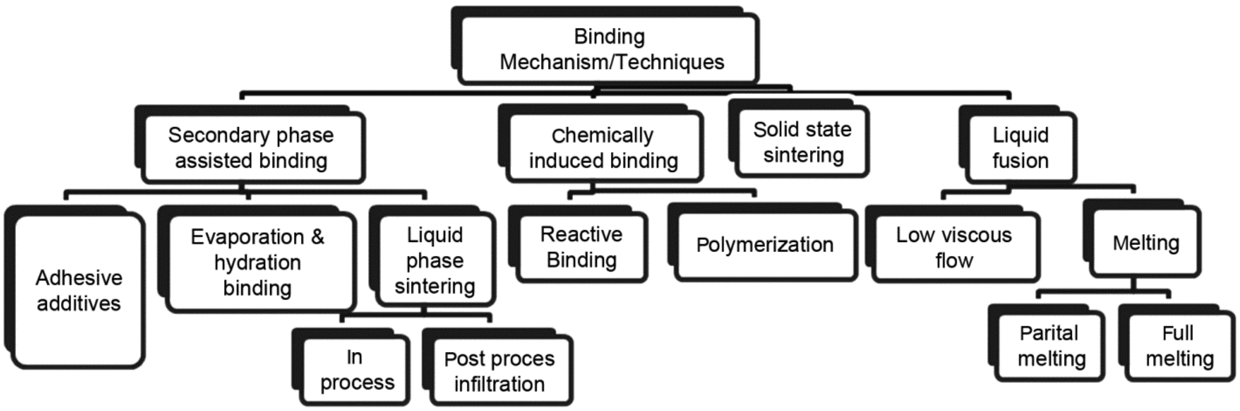

Fig. 1 — AM binding mechanism classification[48].

process is most suitable. Several physical and chemical events occur during solid state sintering. The neck is generated by atomic diffusion inside and grows over time. The fundamental benefit of Solid-State Sintering is that it can process a wide range of materials. All powder materials will consolidate by volume diffusion if the temperature is sufficiently elevated enough to provide the kinetic energy needed for vacancies to move through the boundaries of grains [54]. Researchers from the Baikov Institute of Metallurgy in Russia, the National Academy of Science of Belarus, and the University of Leuven in Belgium worked together to study the SLS of powdered titanium using 'soft' radiation of laser[55].

2.3.4 Introduction of the Liquid fusion mechanism

The operation of liquid fusion coupling is the main basis for most AM processes. In this process, the fluid viscosity of polymers is low and melt occurs in metals[56]. During low viscosity flow, succeeding layers merge upon deposition over prior ones. Wax droplets in the material jetting procedure, hot polymer deposition on a prior layer in PBF, and so on are a few examples.

2.4 Challenges in AM materials

Advances in additive manufacturing research, simultaneous application and evolutions have been observed throughout the modern world. The congeniality of raw material with additive manufacturing processes is a major issue. Restraints on the finishing of surface, accuracy in dimension, anisotropic behaviour etc. are other challenges encountered in Additive manufacturing materials. of the parts made. Another impediment is the lack of test facilities for specific components and materials created using the Additive Manufacturing Method. The large number of failures that occur when components are made using Additive Manufacturing technologies is one of the major issues.

2.4.1 Irregularity in AM parts

Several major additive manufacturing operations are constrained in terms of material qualities at the development stage compared to process parameters that need to be investigated further. In view of that lack of understanding, there is a very high incidence of defects. The existence of irregularity results in lesser mechanical and other characteristics of the manufactured components[57-61].

2.4.1.1 The Balling phenomena

A defect in which the elemental surface is not wet with liquid material, resulting in the occurrence of a scan-track, which increases roughness of surface, and a tendency to form beaded pores [62, 63]. As an unfavorable defect linked with direct metal laser sintering (DMLS), the balling effect is a complicated physical metallurgical process. Melt ball formation, sometimes referred to as balling, is a major barrier to inter stratum linkage that occurs when molten material solidifies as spheres instead of solid stratum [64]. During the stratum-by-stratum scanning process, metal balls form freely and independently. This leads to an uneven layer deposition and rough, bead-shaped terrain, which lowers the component's density and quality [65].

2.4.1.2 Porosity

The reasons for void Irregularity are recurrence of keyhole emergence, gas entrapment during atomization results in small holes, inadequate penetration of successive layers into the substrate, and so on [66,67]. Pores in an AM component can be either unneeded solid phase flaws that give rise to system failure or specifically engineered pore structures for uses. In

AM-produced components, this sort of porosity is divided into two types: lack-of-fusion (LOF) porosity and gas porosity. The LOF porosity is caused by a poor selection of processing settings. Vanden broucke and Kruth displayed optical micrographs from a Ti-6Al-4V parametric investigation.[68].

2.4.1.3 Cracks

Cracks are another common error in items manufactured applying the fusion method of additive manufacturing when metals melt and solidify fast during these procedures. [69]. Since the temperature of each layer, namely the substrate, hardening, and deposited, varies according to the rate of contraction, cracks are particularly prominent along the grain line [70]. Internal cracks are prevalent faults in AM components that are caused mostly by thermal stresses. These imperfections have a substantial influence on part performance and limit the use of AM products[71 -74]. The primary variables influencing the incidence of fractures in components are AM process parameters. Further- more, the orientation of the grains dictates the direction of the crack's propagation [75].

2.4.2 Size restrictions

The greatest volume of the component that can be manufactured using a certain additive manufacturing technology must be restricted by the size of the production volumes for that AM machine. A more appropriate approach would be to manufacture high volumes of parts in the segments and subsequently assemble them, which results in increased time requirements.

2.4.3 Production rate

However, today's AM approaches are more adapted to flexible task order automation. Large-scale production, on the other hand, remains a challenge, and traditional technologies are most appropriate for such purposes [76 ,77].

2.5 First-time investment

Raw material costs are also costly, and their conformity and availability are limited [78-81]. Substantial efforts are devoted to research with a view to reducing material costs relating to the AM process. In principle, the need to invest in industry grade AM equipment requires a large capital investment.

3 Results and Discussion

3.1 Critical analysis and future outlooks

For conventional and additive manufacturing techniques, improving materials' properties is still a field of re- search. Considerable work has been done on material for AM. Some of the main constraints on AM materials continue to be anisotropy, mass modification, micro structural controls, composition control, variety and so forth. One such issue is the availability of basic materials for various types of AM fabricators. The characteristics of smart material and composite materials are another major challenge. For example, shape memory alloys, especially NiTi SMAs, are one such example.

Nevertheless, to achieve its real effects, there are several challenges. This is largely because of numerous differences and representations between AM methods, research in this area has been fragmented. As a result, AM techniques are hard to replicate because of this. The main factors for industries to adopt the manufacturing process are repeatability and consistency.

3.2 3D printing applications

For product production in the shortest possible time with minimal waste, each of the procedures covered so far has an important role to play. Moreover, this process facilitates the creation of complicated structures with incomparable quality at an enormous speed. Industry is being revitalized and redefined using 3D printing.

3.2.1 Uses of 3D printing in stereolithography

As a result of its precision, speed, and capacity to generate complicated shapes, stereolithography has found several uses in a variety of sectors. Some typical applications of 3D printing in stereolithography include:

3.2.1.1 Manufacturing of heart valve scaffold

An alloy of polymers shall be used to create a heart valve scaffold. An integral technique known as "SL" is the tissue engineering of the heart valves. It's made into viable tissues that can grow in a person's body, as is the case for genuine tissue. Stereolithographic models are made from X-ray computed tomography and other software for the synthesis of bio-degradable and bio-compatible scaffolds. They're same as humans, and they are easy to accept by the body. Non-living mechanical valves that cannot develop are now employed, which increases the likelihood of a body rejecting them. As a result, this innovative approach bypasses these constraints[82].

3.2.1.2 Uses of ceramic for dental applications

Natural teeth, which give rise to some degree of transparency, partially refraction, absorbs and transmitting lights. In previous areas, there was a marked and unfavorable lack of translucency in metal ceramics leading to construction of all ceramic bridges. The principal material used for custom restoration of the teeth in dentistry are glass and ceramics. Lithium disilicate glass-ceramic is created by melting the SiO2-Li2O-Al2O3-K2O-P2O5 glass system and heating treatment samples to the glass's crystallization temperature. The generated glass has outstanding mechanical properties, including high strength, making it possible to print and unbind crowns and bridges repeatedly, particularly in the area closest to the teeth[83].

3.2.2 The Uses of fusion deposition modelling (FDM)

FDM has various benefits, including low cost, simplicity of usage, and variety. Here are some popular applications for FDM 3D printing:

3.2.2.1 Drug delivery

Nanoparticle based practices, formulate, systems, and technology for the safe transport of medicinal products into the body to achieve a desired therapeutic outcome while maintaining good health are referred to as "drug distribution". A major advantage of FDM based 3D printing is that it simplifies the manufacturing process, increases inherent properties, and introduces a variety of dosage forms to manufacture individual tablets. polyvinyl alcohol for fusion deposition modelling of the drug delivery systems is a widely applied polymer[84, 85].

3.2.3 The Uses of powder bed fusion (PBF)

PBF is often used with metal and polymer powders and has various benefits, including high accuracy, complicated geometries, and the ability to make functioning end-use components. Here are some of the most common applications of Powder Bed Fusion in additive manufacturing:

3.2.3.1 Direct metal laser sintering (DMLS) to produce light-weight robot structural parts

Additive manufacturing technique, direct metal laser sintering, by using a source of laser to make approximately net shaped components directly by computer aided design data by melting different layers together. To produce robotic lighter components, this method is applied in an aluminium alloy. The tiny finger exoskeleton with joints was created in a single development step. It is also formed with all of the desired mechanical qualities[86].

3.2.3.2 Manufacturing of intelligent parts using PBF

It will allow the flexible deployment of sensors into structures without losing structure or function, through smart parts manufacturing using additive manufacturing technology. The layer-by-layer passage makes it possible to place sensors in the part at every desired location, enabling unprecedented access to areas that have not yet been accessible within a volume of parts. AM approach will revolutionize metal component design by allowing integrated sensors to provide functionality to delicate parts that often come into contact with elevated temperatures[87].

3.2.4 Applications of direct energy deposition (DED)

Compared to other additive manufacturing processes that use powders or liquid resins, DED feeds a solid material, often in wire or powder form, into an energy beam, which then layers the desired product. Here are some of the most common applications of Powder Bed Fusion in Additive manufacturing.

3.2.4.1 Repairing 316L stainless steel

PBF, also known as 3D printing technology, is often employed to produce 316L stainless steel parts. Traditional repair methods may be helpful, where these PBF components are impaired or worn out at the time of operation. However, these techniques have several disadvantages including the formation of an area in which heat and repair damage are likely to occur. Compared with that, DED has a robust metallurgical bond, low dilution and minor heat affected area.

3.2.4.2 Reworking automotive dies for Automobile industries

Tungsten inert gas welding has long been employed in the restoration of dies with Tungsten inert gas used in the construction of car engines, although it has only a life of 20.8% of the actual die duration before needing to be fixed again. The need for an emergency repair and unplanned interruption in the flow of traffic has been reduced due to DED repairs. Using this invention, the restored DED die can now be continued for as long a cycle as the original[88].

3.2.5 The Uses of selective laser sintering

Selective laser sintering has various benefits, including the capacity to make complicated shapes, functional components, and materials in a variety of materials. Here are some examples of how Selective Laser Sintering is used in additive manufacturing:

3.2.5.1 Uses for rapid tooling

The SLS technique can be applied to copper polyamide tooling inserts. Technical knowhow of design character- istics is required to effectively use the rapid instrument process[89].

3.2.6 The need of Binder jetting

Binder Jetting is an additive manufacturing 3D printing method that includes putting a liquid binding agent over a powdered material layer by layer to build up the final 3D parts. Binder Jetting offers several unique advantages and finds specific applications where its characteristics are beneficial:

3.2.6.1 Binder jetting uses in pharma industry

The advantage to manufacturers is that they can manufacture oral form with a large variety feature, e.g., dissolving rapidly as well as continuous droplet platforms, mainly by way of the use of binder jet printing. Despite its good features, there are certain drawbacks[90].

4 Conclusion

a. In the case of Additive manufacturing processes, materials play a crucial role. At present, a wide range of AM raw materials is used for polymers, ceramics, composites, metals, alloys, functional grades, smarts, and hybrids.
b. It can be concluded that several items have been identified based upon the literature examined. The technology of 3D printing is evolving with various materials that are suitable for it. There are various advantages and disadvantages to each of the 3D printing technologies.
c. Based on the research, it is possible to infer that a variety of 3D printing methods have emerged, each of which is compatible with a distinct material. Each 3D printing process has its own set of pros and downsides. The following areas of research are important for the study of AM materials the development of custom applications specifically for home use, the production of a Material Database, etc.
d. Understanding the physics that drives the binding processes associated with materials corresponding to various AM methods is required to comprehend the process dynamics.
e. Fusion deposition modelling is the preferred technology of 3D printing, but it can also be applied to polymeric materials. Various challenges, such as logistics and storage of powders, have been encountered using powder technologies like SLS.

Conflict of Interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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