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A Review on Additive Manufacturing Processes

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Abstract

Additive manufacturing is a new and rapidly developing method in the business world. "Additive manufacturing process" refers to the process of creating products from layers of material. High speed printing or 3D printing is another name for this process. This manufacturing method uses no tools and can produce highly accurate products in less time. A rigid part can be formed and used in this way. Stereolithography (STL) files are created by converting computer aided design (CAD) files used in the additive manufacturing process to these files. Drawings created with CAD are approximated with triangles and divided into sections in the process, each section containing information about the different operations to be printed. Relevant production processes and applications are discussed. They can be used to make lighter models that will save money and benefit the airline industry. Jobs in both architecture and medicine changed due to increased production. However, a lot of work and research still needs to be done before the production of additional equipment can take place in production, because not all common equipment can be used successfully. Accuracy must be improved to eliminate the need for processing steps. The continued rapid growth since launch and the positive results to date give us hope that increased production will play an important role in future production.

Keywords: Additive manufacturing (AM), 3D printing, STL, CAD, polymer, prototyping.

INTRODUCTION

Rapid prototyping, a technique created in the 1980s for modeling and prototyping, is the first means to construct 3D projects using computer-aided design (CAD). Technology is developed by experts to implement their ideas [1]. One of the key components of additive manufacturing (AM) is rapid prototyping (Figure 1) [2]. Prints and graphics can be produced using this. This product's ability to design all complex systems that need to be installed, which saves time, money, human contact, and the completion of the production process, is another significant advance [2, 3]. The manufacturing sector hasn't gotten it yet, though. Instead, it is utilized by medical professionals, scientists, artists, instructors, and students. Researchers and students can create and analyze models using rapid prototyping to reach conceptual and scientific understanding [4]. Unlike customary. Due to the quality of plastic materials, rapid prototyping in general, there are two types of additive manufacturing (AM) processes: (i) one-step processes, also known as "direct processes", which involve one-step fabrication to complete geometry and base material; (ii) the multistage process, also known as the "indirect" process, in which the desired product is produced by various processes; the former provides the necessary

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support for the latter . Most indirect multi-step processes used in additive manufacturing (AM) methods for ceramic molding use sacrificial binder components to produce ceramic particles [3–6]. Glue is usually removed by adding a "shell" in the oven.

In other cases, the CNC machining program is still required, so quick changes are still not the best option. The size may exceed the length of additional printers available [8]. Little information is available for rapid prototyping. Obviously, not all materials in general can be printed, but at least metals and ceramics can be printed [9,10].

ADDITIVE MANUFACTURING PROCESSES

Fused Deposition Modelling (FDM)

The thin plastic (about 0.25mm thick) is fed into a machine where it is melted and extruded to start the printing process. For this model, Polycarbonate (PC), Acrylonitrile Butadiene Styrene (ABS), Poly phenyl sulfone (PPSF), PC-ABS blend, and PC-ISO (a PC of medical grade) were used as the materials [11]. The main advantage of this method is that, compared to other additive manufacturing methods, it does not require any additional work, no resin treatment, tools and materials are cheaper and therefore more expensive (2.5 z-axis resolution) lower (0.25 mm), so full work is required if a smooth surface is required [12,13]. Another problem is the long-term construction of large products and equipment, which can take a long time. To save time, some models are available in two variants: one with increased power, the other with reduced power [10-14]. Figure 2 shows the basis of fused deposition modeling [10]. FDM technology has attracted attention due to its rapid development and low cost [12-14]. This easy prototyping and proof-of-concept model is the power of technology (Figure 2). Poor material quality, high roughness, and limitations in the use of different thermoplastic materials are just some of the disadvantages of FDM. The resolution of FDM is 50-200 m [14,15].

Stereolithography (SLA)

Stereolithography (SLA) and related processes are based on the principle of reduced photo polymerization. As shown in Fig. 3, light (usually ultraviolet light or electro-optical) is used in the resin layer or monomer to initiate a chain reaction. Once completed, a process called radicalization causes the monomers to instantly convert into polymer chains [16]. The coating cures after polymerization to hold the finished coating in place and adjust the coating process to the application [12-16]. Initially, a CAD model is transformed into an STL file, and the object containing the data for each layer is "sliced" out of the STL file [17]. The chosen method has an impact on each layer's resolution and thickness. It is intended to serve as support for hanging constructions and an anchor platform. After that, a UV laser is used to cure the unique coating (Figure 3). The platform is lowered when the layers are complete, and once the procedure is complete, the residual components are removed and used once more [18]. Micro stereolithography is a contemporary variation of this method that has been created with better resolution. Layers less than 10 m thick can be used to do this [18,19]. The basic components of the stereolithography setup are shown in Figure 3 [18].

For ceramic molding, only DED and powder bed fusion are stepwise processes [7].

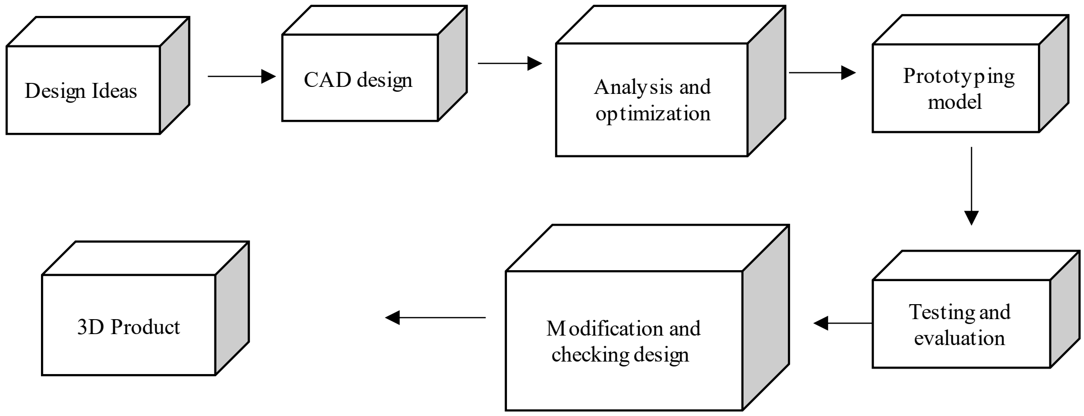

Figure 1. The cycle of product development [2].

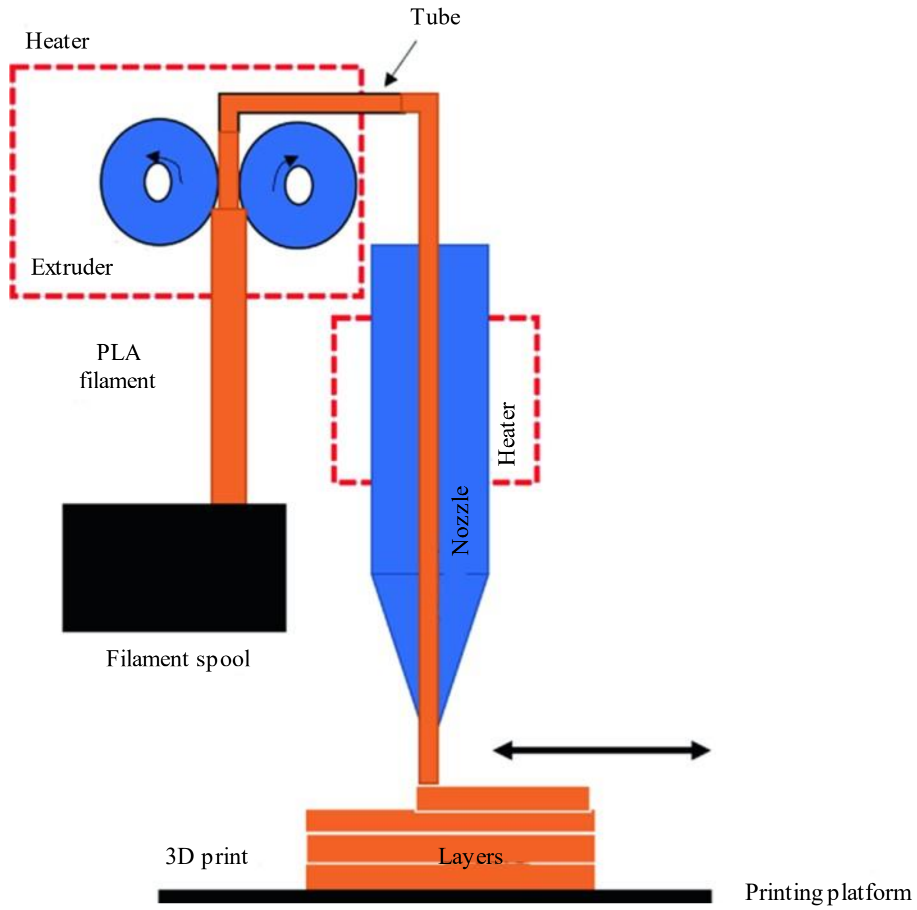

Figure 2. Fused deposition modelling (FDM) process [10].

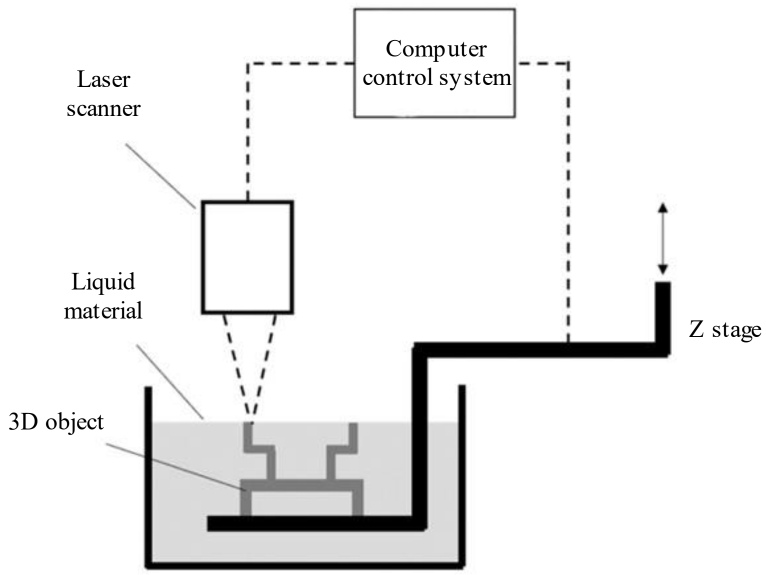

Figure 3. Stereolithography (SLA) Process [18].

UV curing is the process of employing ultraviolet light as a disinfectant to turn liquid monomers or polymers into stiff polymers [20]. The method is based on a straightforward photo polymerization method. Ceramics and other materials can float [18-21]. Compositions can be made from a variety of components. Multi-material stereolithography is the name of this technique [21]. All resin must be drained and replaced with new material when the process reaches a layer that needs to be replaced to print a different document [21,22]. Since the resin may only be printed in layers, this must be done even if the original is reused. The plan needs to be detailed in the plan [20–23].

Laminated Object Manufacturing (LOM)

The first additive manufacturing technique is LOM. A laser or mechanical cutter is used to repeat the cross-section of layers of material (often metal, plastic, and paper). Layer by layer, continue mixing until the result is finished [24]. Layer-by-layer object creation is made possible by the additive object manufacturing (LOM) method, which combines manufacturing and technology [24,25]. The thing becomes a form in this way [25]. Pressure, heat, and thermal bonding layers are used to affix the layers together. CO2 lasers manufacture the appropriate pieces for each layer using data from 3D models in CAD and STL files [25, 26]. Low cost, no requirement for support or post-machining, no phase shift or deformation during the process, and versatility are all benefits of the method [26]. Some drawbacks include limited content, the need for mechanical equipment for equipment and orientation, and difficulties producing complicated lumens manufactured waste that was wasted by the makers (Figure 4) [25]. Structures made of paper, composite material, and metal can be created using this method [24-27].

Electron Beam Melting

It turns out that SLS and electron beam melting (EBM) can coexist. This approach is still relatively new, but it is evolving quickly. In this procedure, a high voltage electron laser beam (often between 30 and 60 KV) melts the powder [27]. Oxidation issues are avoided while making metal items under high vacuum. Apart from that, the technology is very similar to SLS. EBM also can use several kinds of metal precursors. Given that the entire procedure is completed in high vacuum, the factory provides a potential setting for this technique [27, 28].

Selective Laser Sintering

A carbon dioxide laser is used to sinter, or melt, the powder during the 3D printing procedure. In fact, the heat within the house causes the material to melt [29]. According to the manufacturer's instructions, the laser fuses the powder in certain regions of each layer. The piston controls the bearing material to minimize the layer thickness once a layer is complete [27-29]. Plastics, metals, metal alloys, metals and polymers, and metals and ceramics are examples of materials that can be employed in this way [29,30]. Two examples of useful polymers are acrylic styrene and polyamide (nylon); they have nearly identical qualities as injections [29–31]. In composites or additives, it can be mixed with glass fiber polyamide. Copper and other metals can be used to fortify them. A CO2 laser beam is used in the technique outlined to choose the design using SLS powder-based 3DP technology (Table 1) [32].

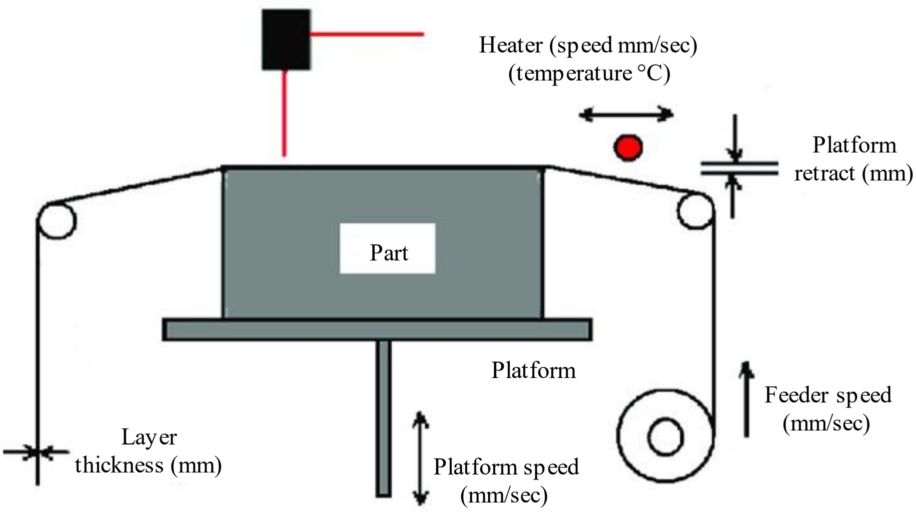

Figure 4. Laminated object manufacturing (LOM) Process [25].

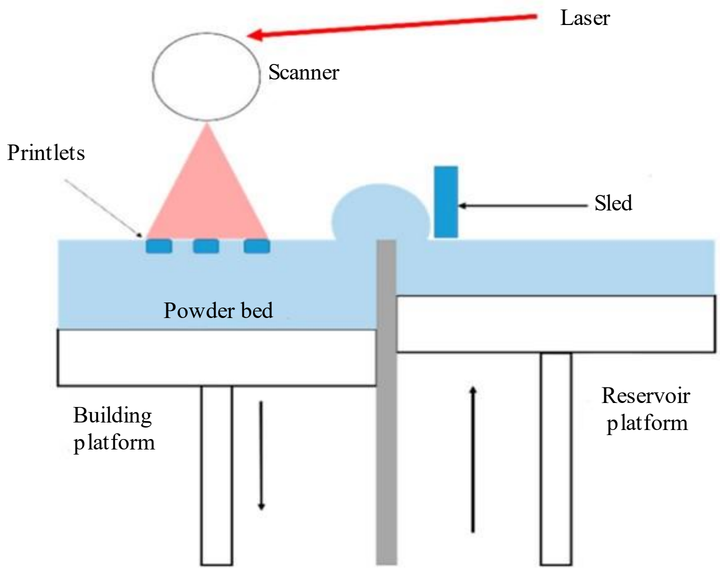

Figure 5. Selective laser sintering process [32].

Table 1. Process parameters during SLS [32].

Process parameters	**Values**
Temperature powder bed	168
Temperature Chamber	145
Laser source	Diode laser-2-4 W-435 nm
Laser speed	590 mm/s
Focus diameter	0.28 mm
Layer thickness	150µm
Hatch distance	0.5mm
Type	Sintratec Kit

Table 2. Working parameters in SLS process [32].

Scanning speed	**(SP)**	**110-140 µm**
Laser Powder	(P)	250-400 W
Exposure Time	(ET)	70-105 µm
Point Distance	(PD)	40-65 µm

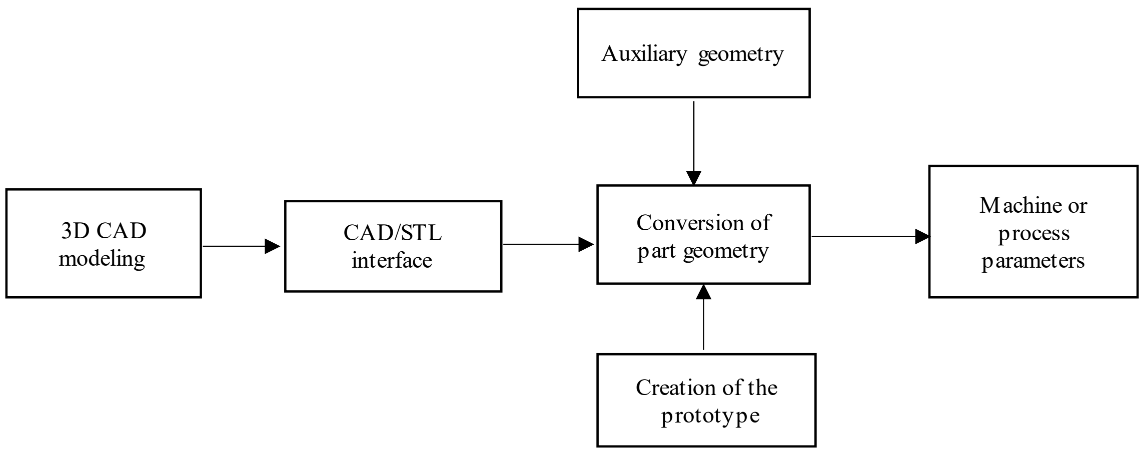

Figure 6. Rapid prototyping data flow [35].

The initial data for machines in use is two-dimensional (2D) slice data (Table 2) [32]. The laser beam's direction is then adjusted to shine onto the powder layer that has been deposited on the tray (Fig. 5) [32]. The powder is heated by a laser beam and then mixed to create a layer. To generate things utilizing CAD data, it also moves the X and Y axes [32].

3D Printing

The process of making 3D items from the image of a 3D model or other electronic data is called 3D printing, also referred to as additive manufacturing (AM) [33]. Hideo Kodama of the Nayoga City Institute of Commerce is credited with creating the first physical product to be printed through digital design. High speed technology is now widely used in many fields that concern human economy such as science, engineering, medicine, military, construction industry, fashion, education and computer industry (Table 2). Often associated with the word "3D printing", the plastic extrusion process was developed in 1990 and was named "Fused Deposition Modeling" (FDM) [32-34]. Since the beginning of 2010, the concepts of 3D printing and additive manufacturing have become two concepts for AM technology; one of them is end use, public and media etc. sourced from AM Enterprise products [34, 35]. It is used indiscriminately by producer groups, additive manufacturing machine manufacturers and international control organizations (Figure .6) [35]. The only two indicators are that each system includes the automatic management of additional business processes and is integrated throughout the 3D office [35,36].

MATERIALS USED IN ADDITIVE MANUFACTURING

Materials, especially engineering materials, are important in additive manufacturing. To produce sound, the material must be molded into a list, have adequate properties, and have good performance properties [37]. Generally, free modeling and optimization is used to improve performance and create new applications [38].

Acrylonitrile Butadiene Styrene [ABS]

3D printing is one of the most used and developed products to date. The product is light, flexible, strong and easy to compress, making it ideal for 3D printing. It has lower extrusion strength than PLA, another popular 3D filament [38,39]. This feature facilitates the extrusion of small areas. The disadvantage of ABS is that it must heat and cool [39]. While ABS printing typically operates at temperatures between 210 and 250°C, the glass transition temperature is approximately 105°C [40]. Another drawback of this product is that the printing process generates strong fumes that can be harmful to breathe for both humans and animals. As a result, 3D printers should be in a space that has good ventilation [39–41].

Poly Lactic Acid [PLA]

Poly lactic acid (PLA), a biodegradable polymer made from corn, is another popular product among 3D printing enthusiasts. It is a thermoplastic made from self-degrading recycled materials [42]. Therefore, PLA materials are more environmentally friendly than other types of plastic. Another important feature of PLA is that it is biocompatible with the human body. PLA has a harder structure than ABS and melts at a lower temperature (180 to 220 degrees Celsius) [42,43].

Polymers

However, some additive manufacturing processes may be unstable and require routine physical maintenance. The two primary additive manufacturing (AM) processes are the extrusion of thermoplastic polymers and powder bed fusion [43]. Amorphous thermoplastics are typically considered extrusion materials, for example in FDM, while semi-crystalline polymers are used in powder fusion sintered objects. Due to their melting characteristics, amorphous thermoplastics are employed for product extrusion [44]. Well-known polymers like "PLA" or Poly lactic Acid and "ABS" or Acrylonitrile Butadiene Styrene soften over a broad temperature range and create polymers suited for extrusion through 0.2-0.5mm diameter nozzles for viscoelastic materials like FDM technology [44,45].

Metals and Alloys

There are several uses for additive manufacturing right now, including the production of iron, titanium, aluminum, and nickel alloys [46]. Powder bed fusion and directed energy release are two powder-based manufacturing processes used to create high-quality metal products. Metal alloys are employed in numerous industries, particularly in the automotive and aviation sectors, as they are the first materials to be processed [47]. Additionally, purer metal is incorporated into the soil. In actuality, the finest materials for implantable medical devices are titanium alloys, particularly Ti-6Al-4V [46,47]. Due to their high strength, light weight, corrosion resistance, and ease of welding, aluminum (Al) and its alloys are perfect for a variety of applications in the construction, automotive, aerospace, and defence industries. Due to their outstanding machinability, Al Si-based alloys, particularly AlSi10Mg, AlSi12, and A357, are frequently employed in different alloy combinations used in the SLM process [48].

Table 3. Additive manufacturing methods and their principle, applications, and resolution [51,52].

S N.	Additive manufacturing processes	Principle	Significance (when to use	Specific applications	Resolution
1.	Fused deposition modelling	Material extrusion	models for proving concepts and basic prototyping	scaffolds, artificial limbs, vehicles, and drug delivery tools	50–200 μm
2.	Laminated object manufacturing	Sheet lamination	Flexible material choices and reused support materials	Paper architectural models and one-time use sand casting patterns	It depends on laminate thickness but typically it is 50μm
3.	Stereolithography	Vat photo polymerization	Adaptable material choice and practical prototyping	Vacuum casting master patterns, sacrificial patterns, molds, dies, casting for jewelry, casting for assembly parts, and the production of dental models are all examples of metal casting tools	10 μm
4.	Direct energy deposition	Laser or electron beam melting	Big, low-complex components	Marine propulsion, ballistic material tooling repair and reconditioning, aircraft parts, refractory metal components, and	250 μm
5.	Selective laser sintering	Powder bed fusion	simultaneous production of several components	Automotive design, aerospace parts, gaskets, seals, hoses, Jigs, fixtures, tools, parts with snap fits or living hinges, and flame-retardant components	80–250 μm

Ceramics

In general, there are two types of additive manufacturing (AM) processes: (i) one-step processes, also called "direct processes," which involve one-step fabrication to complete geometry and base material; and (ii) the multistage process, also called a "indirect" process, in which the desired product is produced by a number of processes; the former provides the necessary support for the latter. Many indirect multi-step processes utilized in additive manufacturing (AM) techniques for ceramic molding create ceramic particles using sacrificial binder components [48–50]. By including a "shell" in the oven, glue is typically eliminated. Only DED and powder bed fusion are sequential methods for ceramic molding (Table 3) [51,52].

APPLICATIONS OF ADDITIVE MANUFACTURING

With the advancement of production technology, 3D printing products have left all research and development behind and started mass production. These important programs generate and present ideas that have never been done before [51,52]. The enormous potential of additive manufacturing has revolutionized manufacturing processes in the following five areas:

Medical

The rapidly evolving medical industry uses advanced technology to support professionals, patients and research teams. With a variety of rigid, flexible, hazy and transparent high-strength and bio compatible 3D printing materials, doctors are changing designs more than ever before. Additive manufacturing opens the door to incredible discoveries and life-saving solutions using surgical-grade materials, workflows, prototypes and prototypes. was good [53]. Examples of applications that have revolutionized their respective industries include orthopedics implant devices, per-operative CT scan models, dental instruments, specialized saw and drill guides, homes, and specialized tools [51-53].

Energy

Success in the electronics industry depends on the ability to quickly customize purpose-built products that can withstand challenging situations. By using additional materials to create efficient, lightweight, bespoke components and materials, solutions can be given for all needs and functions [52, 53]. Some of the important applications occurring in the oil, gas and energy industries include rotors, turbine nozzles, testators, down hole equipment and structures, flow measurement sites, mud models, liquid/water flow meters, pressure gauge parts, pump manifolds and controls. valve material [53,54]. It's impossible to foresee what huge energy firms will be able to accomplish with additive manufacturing without considering the creation of corrosion-resistant metal alloys in unique places that may need to operate underwater or in other severe settings [54].

Aerospace

Historically, additive manufacturing has been used by businesses in the aerospace industry. Because the product must withstand weight, these parts have some of the best performance in the industry. Designers and manufacturers of commercial and military aviation platforms should consider aircraft products made of high-performance materials. Using 3D printing it is possible to create simple materials, good designs and powerful products. Weight loss is one of the most important aspects of manufacturing in the aerospace industry. This has been achieved by combining design and using minimal materials. Modern ideas and practices in the aviation industry are on the rise due to the efficiency gains brought to large organizations [53-55].

Consumer Products

The amount of time it takes to develop and sell an idea is crucial for graphic designers, marketing teams, and other creatives. When producing listings, this is occasionally used to simulate the final product's appearance and feel to communicate concepts to stakeholders. Manufacturers of consumer items are turning to 3D printing to speed up design and re-engineering [53-55]. Complex client items with practical functionality can be made with 3D printing at an early stage of the PDCL (Product Development Life cycle). Sporting products have in the past benefited from prompt shipping. High-performance architectural designs, portable gadgets and models, entertainment goods, and clothes are some other beneficial applications [55,56].

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Transportation

In other words, adapting to a demanding environment, like a hot, high-speed one, involves living quickly. Transport must be outfitted to endure rigorous testing to decrease redundancy [56]. The transportation sector is only now starting to investigate the potential of printing and the car, thanks to a choice of high-quality materials, cutting-edge manufacturing techniques, and the capacity to create incredibly high-quality graphics [53-56]. The ongoing development of 3D printing may potentially create new opportunities for mass customization and end consumers. Restoring components to restore old autos is one of the most efficient uses of technology today [55,56].

DISCUSSION AND CONCLUSION

This article examines the iterative nature of manufacturing in addition to rapid prototyping with the support of speeding up the design process and shortening the time between production and marketing. Information needed for further manufacturing processes can be obtained from CAD files, which are then converted to STL files. During this process, the drawing created with CAD is approximated with three-dimensional images and divided into sections, each containing information about the different processes to be printed. In addition to the description of additive manufacturing processes and practices, a study of the manufacture of products using these additive manufacturing processes is also provided. Additive manufacturing is poised to play an important role in the manufacturing industry of the future, as technology has been steadily and continuously expanded since its use and results have been achieved so far. The ability to build lighter models has made supplemental materials popular in the aerospace industry because reducing weight is one of the goals of aircraft and aircraft manufacturers. Additive manufacturing can help the auto industry by matching hard-to-find items like classic cars. Thanks to advances in additive manufacturing, it is now possible to create precise grafts independent of the complex structure of the bone and to obtain the correct bone structure before surgery. Additive manufacturing allows designers to create complex shapes they envision for public projects, using 3D printers. Research on the long-term viability of products produced by additive manufacturing processes is also reviewed. Studies comparing the methods of metallic and non-metallic materials were reviewed and the strengths of the products produced by different methods were compared.

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