Chapter 8

Additive manufacturing in the automotive industry

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Abstract

The market for materials derived from renewable resources has grown in recent years, driven by factors such as the need to decrease carbon emissions, lower fuel expenses in the automobile sector, address environmental contamination, and mitigate the risk of oil depletion. In the automotive sector, utilising components derived from sustainable sources not only mitigates emissions, but also decreases expenses, conserves fuel, and enhances vehicle weight efficiency. The automotive sector is a globally competitive industry. Continuously, fresh marketplaces and diverse designs are arising with the aim of enticing clients, necessitating the adoption of novel production methodologies to accommodate the automotive sector. Biocomposites are utilised in the automobile sector because of their biodegradability, lightweight nature, ease of manufacturing, and high specific strength. The utilisation of additive manufacturing in automobile parts production is advantageous due to its rapid production capabilities, minimal equipment requirements, and suitability for the fabrication of biocomposites. The paper provides examples derived from contemporary scientific findings and industrial applications. The additive manufacturing (AM) method facilitates both prototyping and the design and production of final products. AM enables the production of diverse profiles while minimising resource usage. Additive manufacturing offers a substantial competitive edge in this industrial sector by offering production flexibility and the ability to create customised vehicle components as needed.

1. Introduction

Recently, the additive manufacturing method (AM) has gained prominence as a promising technology capable of substituting both new and classic methods. The field of additive manufacturing has garnered

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significant attention as a study issue, and new advancements in this area are revolutionizing the technology, elevating it from a mere prototype method to a fully-fledged production process. AM printed components, subassemblies, and prototyping play a crucial role in every product development process. AM, or Additive Manufacturing, is a prime illustration of these technologies, as it completely transforms the process of creating new things and manufacturing final goods [1]. Contrary to conventional manufacturing techniques like CNC machining, the AM filament deposition method (FDM) allows for the production of a part with little material waste, eliminating the requirement for tools, cutters, milling machines, and similar equipment. Additionally, it eliminates the need for chemical post-treatment and curing, which are typically necessary for alternative selective laser melting (SLM) techniques. The filament deposition method, which is the most often used polymer additive manufacturing technique, has previously demonstrated successful application in producing carbon fiber polymer composites with a high degree of orientation in the printing direction. Research has demonstrated that this method can be employed to create composite systems with regulated anisotropic characteristics [2]. Although the approach is modern, its initial implementation may be traced back to the 1980s. Although the AM process was once limited to prototype production from the 1980s to the 2000s, it has now expanded its utility beyond just prototyping. The AM approach, now in use, has significantly reduced the time it takes to bring finished products to market by offering long-term strategic and economic benefits. In addition, although additive manufacturing (AM) has made tremendous advancements in recent decades, its use is primarily limited to fast prototyping due to constraints in material characteristics, production speed, and part size [3].

Fiber-reinforced composites provide a combination of low weight, cost-effectiveness, and high strength-to-weight ratio. Utilizing natural fiber in additive manufacturing can enhance material characteristics, hence decreasing the fabrication time for functional components in comparison to conventional subtractive technologies. Furthermore, it may be feasible to manufacture intricate biocomposites with complex shapes [3]. Extensive research has been conducted on the utilization of the Additive Manufacturing technique in the manufacturing of composite materials, particularly in the fabrication of composites reinforced with carbon fibers [4]–[12]. Nevertheless, research on composites reinforced with natural fibers is limited but has shown a recent upward trend. Through the integration of bio-based sustainable polymers with natural reinforcements, it is possible to create novel materials that are both renewable and serve as alternatives to petroleum-based polymers [13]. Many commercially available polylactides (PLA), for instance, exhibit brittleness and possess low thermal breakdown temperatures. The composite material concept offers a strategy for producing renewable materials that can achieve or surpass the performance of routinely utilized petroleum-based engineering polymers [14]. Composites derived from sustainable resources are being substituted for industrial composites due to significant factors such as global warming, environmental pollution, greenhouse gas damage, and the potential depletion of oil. Biocomposite materials are composite materials that contain at least one component derived from natural sources. Biocomposites refer to many types of materials, including natural fiber-reinforced petroleum-derived plastics, natural fiber-reinforced biopolymer matrix composites, and synthetic fiber-reinforced biopolymer matrix composites [14], [15]. Multiple publications exist on the incorporation of continuous fibers into a PLA matrix as a demonstration of producing biocomposites using the AM process. Matsuzaki et al. [16] created continuous fiber composites using PLA-based carbon and jute fiber, which are natural biodegradable materials, by a process including molten filament and in-nozzle impregnation. By employing this method, the authors successfully accomplished the production of new-generation composite materials without the need for molds. The production process involved impregnating continuous fibers and polymer filament through the heated nozzle of the printer. Automobile makers are increasingly utilizing biocomposites. They primarily contribute substantially to weight reduction. Biocomposites are currently being used in automobile parts such as the front door console (weighing between 1.2 and 1.9 kg), rear door console (weighing between 0.8 and 1.6 kg), and trunk console (weighing between 1.5 and 2.5 kg) of popular car companies like BMW, Ford, Renault, and Volvo. Starting in 2021, the European Union will implement a new standard for the average emissions of new cars, which will be set at 95 grams of CO_2 per km. This emission level is equivalent to approximately 4.1 liters of petrol or 3.6 liters of diesel fuel consumed every 100 km. Utilizing green composites will effectively decrease CO_2 emissions by diminishing the fuel consumption of cars [17]. In addition, the manufacturing process of natural fibers consumes less energy compared to synthetic fibers. Nova-Institute, located in Hürth, Germany, conducted an analysis revealing that the manufacturing of one metric tonne of glass fiber results in the emission of 1.7-2.2 metric tonnes of CO_2 equivalent. In contrast, the combined impact of four natural fibers (flax, hemp, jute, and kenaf) amounts to 0.5 metric tonnes. A study conducted in India found comparable results for jute, kenaf, hemp, and flax fibers, determining that the carbon footprint associated with the manufacturing of natural fibers was 20-50% lower than that of glass fibers.

The automotive industry will face some restrictions in the world, especially in the European Union (EU) countries, in the coming years. One of these limitations pertains to international accords aimed at decreasing greenhouse gas emissions. Following the climate summit held in Paris in 2015, world countries pledged to decrease their greenhouse gas emissions. During the second global climate summit in Glasgow in 2021, 197 countries reaffirmed their commitment to a cooperative framework aimed at mitigating carbon emissions. The second limitation is that the European Union, in collaboration with the Association of European Automobile Manufacturers, has established a target for the average emissions of new cars across the EU at 95 g CO_2 km^{-1}, effective from 2021 [18]. In order to achieve all goals in the automotive industry, lightening vehicles as well as using clean energy has an important place. With the use of biocomposites, lightweight vehicles that burn less fuel are produced and natural materials with a much lower carbon footprint are used. In addition, the fact that in the directive published by the EU (2000/53/EC), it was decided that 85% of the materials used in vehicles should be recyclable and this rate should be increased to 95% by 2015 [19], increases the importance of the use of biocomposites. Beyond these, the possibility of running out of oil can also be considered a constraint. Considering that the rate of depletion of petroleum resources is approximately 100,000 times faster than the rate of nature's renewal, the importance of using natural resources will be understood more clearly [20].

2. Biocomposites

Biocomposites are extensively utilized in several industries including automotive, plastic construction, and aircraft industry [21]. The reinforcement fibers utilized to enhance and fortify the strength of the composite structure predominantly consist of synthetic materials such as carbon boron, glass, kevlar, and aramid. These fibers offer exceptional performance while maintaining a low density. Over the past decade, numerous investigations have focused on producing composite materials using polymer matrix and reinforcement elements derived from natural and renewable resources. The primary objective of these investigations is to create novel composite materials that do not pose environmental concerns post-use. This will be achieved by employing reinforcements with high biodegradability instead of artificial reinforcements with low biodegradability while emphasizing the use of renewable resources. Biocomposites are formed by blending bio-based fibers and other bio-based materials with plastic resins, resulting in the production of novel and environmentally friendly products. Bio-based materials are derived from sustainable sources such as wheat straw, corn husks, and leftovers of soy and corn processing. These biocomposites are utilized in injection molding and additive manufacturing applications to efficiently produce intricate automobile components in an environmentally friendly manner with speed and precision [22].

Research indicates that the mechanical properties of the polymer (pure resin) are enhanced through fiber reinforcement, leading to a significant improvement in impact resistance. When comparing natural fiber composites to composite structures made of high-performance fibers, it is evident that the strength values of natural fiber composites are inferior. Therefore, it is advisable to use these items in simpler applications rather than in regions that demand high mechanical performance. Consequently, materials like aramid, carbon, and glass are recommended. Instead of being positioned as a substitute material for reinforced composites, it has been asserted that they can be utilized in indoor applications capable of bearing low and medium loads, as well as in outdoor applications such as roofs, automobile interior components, and drainage panels. Various types of natural fiber supplements include flax, hemp, cotton, jute, wood fiber, sisal fiber, ramie fiber, and coconut fiber. Table 1 provides the mechanical characteristics of various plant-based natural fibers and synthetic fibers.

Table 1. Mechanical properties of some fibers

Fiber	Density (g cm^{-3})	Strain (%)	Tensile Strength (MPa)	Young's Modulus(GPa)
Cotton	1.5-1.6	7.0-8.0	287-597	5.5-12.6
Hemp	1.2-1.4	1.5-6.9	223-930	14.5-53
Jute	1.3	1.5-1.8	393-773	26.5
Flax	1.5	2.7-3.2	345-1035	27.6
Sisal	1.5	2.0-2.5	511-635	9.4-22.0
Wood	1.5	-	1000	40.0
E-glass	2.5	2.5	2000-3500	70.0
Aramide	1.4	3.3-3.7	3000-3150	37.0-63.0
Carbon	1.4	1.4-1.8	4000	230.0-240.0

2.1. The application of biocomposites in the automotive industry

Biocomposites offer several benefits when used in automotive applications. Composites are often lightweight substances, which leads to a decrease in vehicle fuel consumption and the release of greenhouse gas emissions. Biocomposites has superior acoustic and thermal qualities in comparison to synthetic composites, rendering them very appropriate as potential materials for vehicle interior components. Furthermore, biocomposites has numerous prospective uses within the automotive sector. Their inherent qualities make them very suitable for producing non-structural interior components, including timber flooring, seat cushions, seat backs, headliners, interior panels, dashboards, and thermo-acoustic insulation. Ongoing academic research is currently being undertaken on biocomposites, notwithstanding the absence of current implementation in structural part manufacture. Wood fibers are commonly used in the automobile sector for wood-plastic composites, whereas natural fibers including flax, hemp, jute, and sisal are utilized for natural fiber-reinforced composites [23], [24], [25]. These reinforcements can be applied with both thermoplastic and thermoset matrices. Various thermoplastic matrix choices are accessible, including biodegradable polyesters such as PLA, PHB, PBS, and natural polymers like bio-PC. The majority of these thermoplastic biopolymers are derived from the process of fermenting starch and glucose. Regarding thermosetting matrices, available choices encompass conventional resins containing bio-derived components sourced from natural oils and bioethanol (e.g. bio-epoxy, bio-polyester, bio-polyurethanes) [21]. Over the past decade, there has been a demonstration of the potential of lightweight, inexpensive natural fibers as alternatives to glass fiber and mineral fillers in automobile interior or exterior components. European automotive manufacturers have increased investments in the production of car door panels, seat backs, headliners, dashboards, and interior trim parts from natural fiber-reinforced thermoset or thermoplastic composite materials. The main reasons for the use of natural fibers such as kenaf, hemp, linen, jute, and sisal in the automotive industry are factors such as providing lightness, reducing costs, reducing CO_2 emissions, recyclability, and reducing dependence on foreign oil resources. With all these advantages, we can call natural fibers "sustainable" or "environmentally friendly" fiber sources. Although America has not yet made the necessary regulations considering the automotive scrap requirements, European and Asian countries have put forward strict principles on this issue [26]. In Europe, automotive manufacturers required 80% of car parts to be recyclable in 2006. In 2018, approximately 6.1 million vehicles became unusable within the borders of the European Union. As shown in Figure 1, more than 95%

of automotive parts or materials in the EU in 2018 were reused or salvaged. Figure 1 shows the graph of vehicles that have reached the end of their life, have finished their useful services, and have been treated as waste, broken down or disposed of in another way. During the dismantling phase, spare parts of the vehicle can be separated and reused for the repair of vehicles in service. The remainder of the dismantled vehicle will be recycled, used for energy production (energy recovery process), or ultimately disposed of.

Glass fiber-reinforced composites exhibit drawbacks including their elevated density (40% greater than natural fibers), challenging machinability, limited recyclability, and potential health hazards associated with glass fiber particles. In contrast, the environmental and economic benefits of natural fibers outweigh those of glass fibers. As an illustration, the total energy expenditure for producing flax fiber is 9.55 MJ/kg, but the energy requirement for producing glass fiber is 54.7 MJ/kg [28].

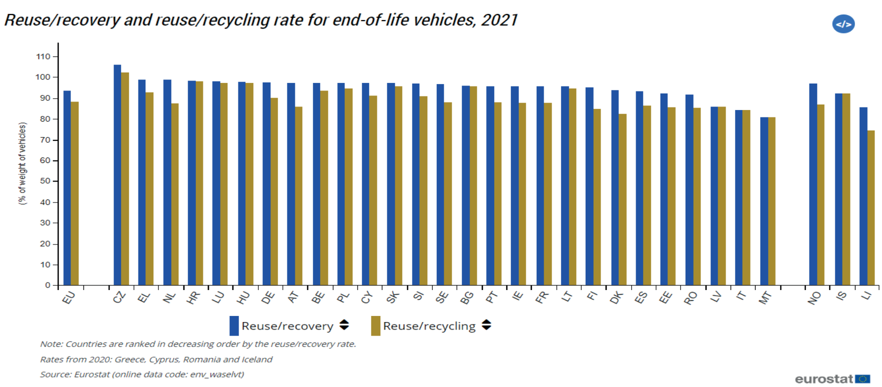

Figure 1. Reuse/recovery rate and reuse/recycling rate of parts or materials in the automotive industry in European Union countries [27]

In general, natural fibers are used in the reinforcement of automobile parts;

- Reduction in cost
- Production processes are safer than those of glass fibers.
- It has good thermal and acoustic insulation properties
- Less reliance on foreign oil sources,
- They recycle and these fiber sources are "sustainable" or "environmentally friendly"

• High fiber volume fractions of low-density fibers in natural fiber-reinforced composites reduce the weight of the finished product as seen in Table 2

• Reduction in CO_2,

• Moreover, the interiors of automobiles with natural fiber reinforcement are physically safer than glass fiber parts because no sharp-edged surfaces are formed in the event of a collision [29].

In recent years, European companies such as Dieffenbacher (Germany), BASF (Germany), and Rieter Automotive (Switzerland) have led the way in the research of natural fiber-reinforced composites. In 2005, Rieter won first place in the "JEC Composite Showcase" competition with its success in the production of banana plant fiber reinforced composites, which saved more than 60% of energy [30]. In North America, to give a few examples, Delphi Interior Systems, Visteon Automotive, Kafus Biyo-Composites/ Flexform Technology and Cargill Ltd. companies have actively focused their research on such composites. In addition to all these developments, with the development of bio-based polymers, the use of 100% natural materials in the automotive industry will be inevitable.

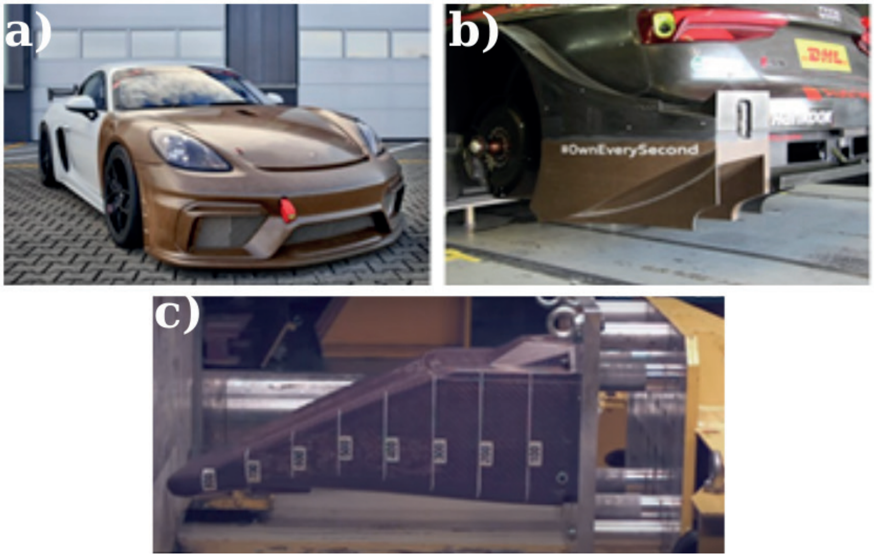

***Figure 2.** a) Porsche Cayman 718 GT4 CS MR with a natural fiber-reinforced composite body (September 2020) b) Natural fiber-reinforced composite "Shoebox" used by Audi motorsports (2020) c) Natural fiber-reinforced "crash box" crash test (October 2020)*

In 2019 and 2020, significant developments have been made regarding the use of natural fiber-reinforced composites not only in automotive interior parts but also in body panels and areas exposed to impact during a collision. In 2019, Porsche manufactured the doors and rear wings made of carbon fiber-reinforced composite from natural fiber-reinforced composite for the first time in the Cayman 718 GT4 CS model used in motorsport, thus using natural fiber-reinforced composite parts in mass production for a vehicle used in motorsports. Another development is that in the Nürburgring race held on 24-27 September 2020, Porsche used a hood made entirely of natural fiber-reinforced composite on the Cayman 718 GT4 CS MR model (Figure 2a). Another important development is that a crash test of the natural fiber reinforced "Crash Box" part was conducted for the first time in October 2020 (Figure 2c). Another important development is that the part called "shoebox", which is made of glass fiber reinforced composite in the vehicles used in races by BMW sport and Audi Sport is manufactured using natural fiber reinforced composites (Figure 2b). [31]. All these new developments prove how important such composites are, especially in the automotive industry, and that natural fibers are gradually replacing synthetic fiber reinforcements today.

2.2. Additive Manufacturing in the automotive industry

3D printing or additive manufacturing AM is the creation of a three-dimensional object from a CAD model or digital 3D model. It can be done by processes in which material is deposited, combined, or solidified under computer control, where the material is added together (such as fusing plastics, liquids, or powder grains), typically layer by layer. AM technology has made a significant contribution to the automotive industry, from rapid prototyping to increasingly widespread production of final car parts and structural production of almost the entire car. It is known that natural fiber-reinforced biocomposites produced by AM and used in automotive parts will function as well as the currently used petroleum-derived plastics. However, there are some challenges in meeting the quality and safety standards expected from auto parts produced with the AM technique. Sustainable, relatively fast, and accurate production of complex automotive parts is possible with the AM printing method, as with the plastic injection method. Although it is not yet possible to buy a fully AM-printed car from a dealer today, AM printing has been prominent in the prototyping of auto parts and part development processes for many years. The initial technology for manufacturing parts was selective laser sintering or binder sputtering. These methods have helped designers and manufacturers create more aesthetic parts [32]. Additionally, AM printing has enabled a wide range of manufacturing applications, adding tremendous value to supply chains. New, flexible materials have made it possible to produce high-precision, functional parts that can replace final parts and offer high performance [33].

The AM approach provided a platform for creative designers and engineers to actualize daring concepts through the utilization of technology. Car components manufactured using the filament deposition technique exhibit reduced weight, leading to enhanced vehicle performance, improved fuel efficiency, and decreased energy use. Large companies such as Mitsubishi Chemical or BASF, which care about using filament deposition technology in the automotive industry, produce many automotive parts with the AM method. Long gone are the days when rapid prototyping was the primary use of AM technology in the automotive industry. By 2029, the AM market is predicted to generate as much as $9 billion in revenue. Volkswagen, BMW, and Ford respectively stand out in using AM printing technology to produce final automobile parts [34]. The parts and accessories market in the automotive industry is predicted to reach approximately 17 Billion USD by the end of 2025. According to Machine Design, the automotive industry's consumption of AM materials is expected to reach approximately $530 million by 2021 [32]. One of the most commonly used AM technologies currently in the automotive industry is FFF (Fused Filament Fabrication). Its advantage is the possibility of using many different materials whose properties are similar to plastic. With the use of AM, the required parts and details can be created, which allows companies to become independent from external suppliers and facilitate their production processes, as well as ensure production continuity, which is very important today. Bocar, a company engaged in the manufacture of fire trucks, uses the AM technique to create plastic subassembly prototypes. In collaboration with 3DGence, it has prepared a 1:1 scale extruded collector model. Figure 3. Thanks to the professional 3DGence INDUSTRY F340 printer, the element creation process was shortened by several months. Precast casting eliminates the need for manual welding of elbows, pipes, and flanges. In this way, hydraulic systems are more sensitive and the failure rate is reduced.

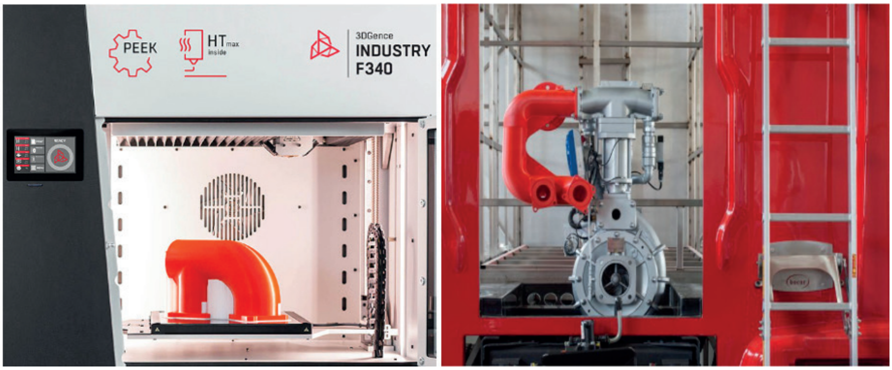

Figure 3. Extruded collector model [35]

The latest engineering solutions available on the market, including AM printing, were applied in the construction of the race car (Figure 4). Among other things, the casing of the battery pack was printed from a flammable material on a 3DGence INDUSTRY F340. In addition, this use of the AM technique enabled the creation of other parts and models, including molds of aerodynamic elements, from which we were able to independently prepare the necessary components for the racing car [36].

Figure 4. Example of a racing car produced with the AM technique

Formula Student is an annual engineering design competition in which student teams from all around the world compete to develop and race formula-style automobiles. Teams are judged based on their business plan, design concept, cost report, and race performance, particularly power, efficiency, and durability. This year, the team added a Form 3 SLA 3D printer to their toolbox in order to save time and money and build parts that would not be possible otherwise:

1. Prototypes: They print prototypes for various parts, such as anti-roll bar assemblies or HV Battery stakeholders.

2. Carbon fibre part moulds: The team printed a dozen moulds to make carbon fibre parts that couldn't be created any other way.

3. End-use parts: Approximately 30 final parts for cars have been printed directly with the AM technique, from button holders and steering wheel shifters to sensor connectors of hoses and cooling systems (Figure 5).

Figure 5. Carbon Fiber Molding and End-Use 3D Printed Parts for Formula Student Race Cars

One proof that AM is at a stage of dynamic development is the growing interest in it from large and well-established companies that were previously dealing with completely different topics. Companies have started to cooperate with printer and filament manufacturers and are developing solutions for both operating materials and software. They mainly focus on introducing AM printing in the aerospace and automotive industries. Only the best ones remain on the market, those that can deliver devices at affordable prices, and thus new projects can actually be realized. It is beneficial to evaluate the changes in the AM market today and get ahead of your competitors with the opportunities offered by technology.

Jorge et al. [37] showed that, according to the experimental results of their study, samples obtained with 20% wood flour showed lower mechanical properties, while those obtained from 30% of test samples became very brittle. They reported that mechanical properties such as torsional strength were higher in the test samples obtained by injection molding compared to AM FDM. TGA results of samples to understand the thermal behavior of composites showed that optimum temperatures were suitable for processing composites via AM. They claimed that composites could potentially be applied in the design of auto parts due to their biodegradability and mechanical strength.

2.3. Prototyping

In the automotive industry, the AM method is a widely used method for prototyping. Due to its ability to perform rapid prototyping, the 3D printing method and the prototype have become almost synonymous. With the AM method, prototypes of many parts, from very simple parts to dashboards and even scale models of the vehicle, can be produced quickly. Rapid prototype production with high precision and features close to the real product before mass production is important for the efficient operation of the factory. Using additive manufacturing (AM), it is possible to produce prototypes that are extremely persuasive, representative, and functional in just one day. Moreover, the cost of creating these prototypes is significantly reduced compared to traditional manufacturing techniques [33].

3. Manufacturing Methods in Additive Manufacturing

AM, like any other manufacturing process, necessitates good materials (including high-quality 3D printers with good resolution and high-quality software) that adhere to strict specifications and consistently produce major elements [38]. Traditional manufacturing techniques necessitate seriously elegant supply chain management, a significant business advantage to be robotized, the AM printing process necessitates robotization, and are reliant on CAD programming to print items using a variety of materials, radically reducing the measure of supply chain management. When everything is said and done, AM printing does not require any expensive dies, tools for machining, structures, or punches, and is cost effective. Depending on the source, AM print production procedures vary. Depending on the applications of the components, any of the strategies can be used. The classifications of AM print production techniques are shown in Figure 6 [39]. Figure 6 depicts the classification of several AM approaches.

Powder-Based Systems

Powder-based additive manufacturing (AM) is a technique where a powdered substance is fused together to create solid, functional components.

Bonding can be achieved through the use of heat, which causes the powder material to undergo partial or complete melting and fusion. Alternatively, bonding can be facilitated by introducing a coupling agent to the powder. The powder-based system is a method used in 3D printing for production. The manufacturing process utilises standard and traditional inkjet printheads to produce components. The powder bed exhibits porosity and undergoes condensation during the solidification process, leading to dimensional alterations or potential failure [40], [41].

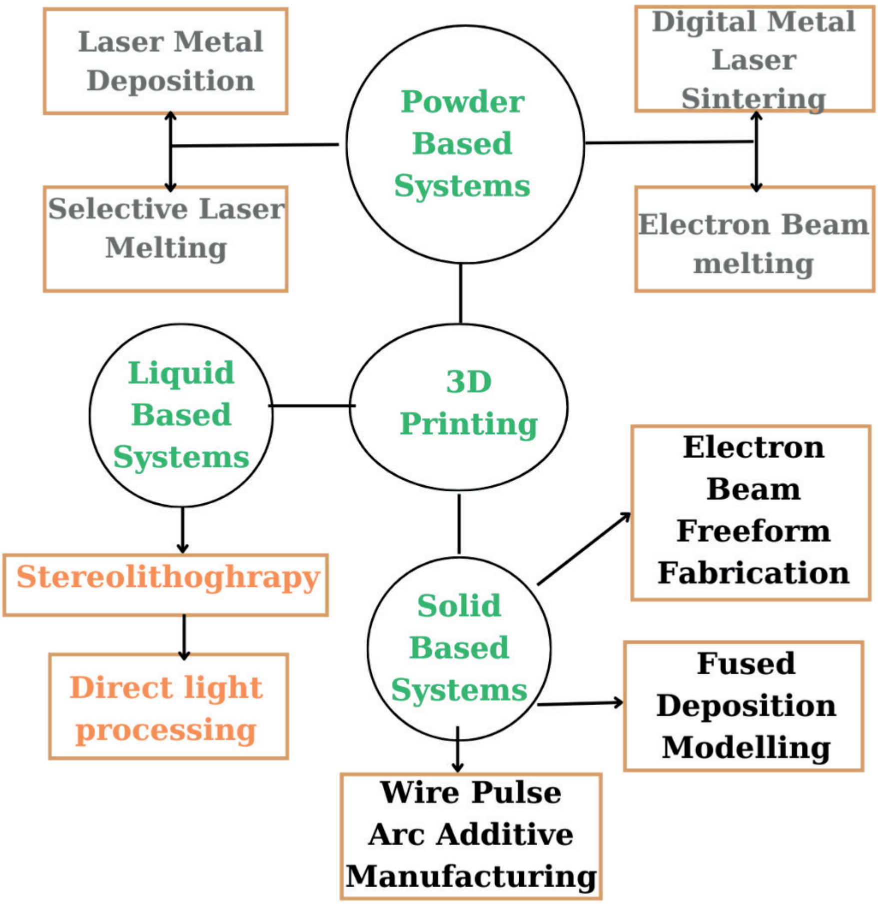

Figure 6. Classification of additive manufacturing

Laser Metal Deposition (LMD)

LMD, short for Laser Metal Deposition, is an additive manufacturing method that use a laser beam to convert a metallic base material into a molten pool of dissolved metal. This procedure entails injecting metal powder into the substrate by use of a gas flow.

Direct laser metal sintering (DLMS)

Direct laser metal sintering (DLMS), also known as direct laser metal forming (DLMF) and selective laser melting (SLM), is a process where a powerful laser beam is focused onto a bed of metal powder, causing the metal particles to fuse together in a predetermined shape [42].

Selective Laser Melting

Selective laser melting (SLM) is a technique that involves using a laser beam to heat metallic powder materials to their melting temperature, causing the powder layer to fully melt. Notably, SLM does not require the use of binders or fluxing agents in the metallic powder materials [43].

Electron Beam Melting (EBM)

Electron beam melting (EBM) is a recently developed additive manufacturing (AM) method that use a computer-controlled electron gun to create solid 3D objects directly from metal powder [42]. Electron beam melting (EBM) is an advantageous method of additive manufacturing that offers distinct benefits in the production of intricate metal components of superior quality. It is particularly helpful in industries that prioritise precision, performance, and the use of lightweight materials [38].

Laser Metal Deposition (LMD)

The pieces are fabricated utilising the material in its solid state, regardless of its prior liquid state, save for powdered material. Diverse configurations of solid materials, including rolls, laminates, wires, pellets, and more. It has the capacity to exist in that particular form. The initial solid-based additive technology comprises wire-pulsed arc additive manufacturing, fused deposition modelling, electron beam manufacturing, and laminated object manufacturing [44].

Liquid-Based Systems

Stereolithography is the technical term for liquid-based rapid prototyping. The primary methodology employed in liquid-based systems entails the production of components utilising a photocurable semi-liquid resin, which is subjected to irradiation by a laser beam to induce photopolymerization. Consequently, the process of polymerization induces the transformation of a substance into a solid state following a specific duration of laser exposure. Typically, in liquid-based additive manufacturing (AM) systems, parts are created by immersing them in a container filled with a light-sensitive liquid resin. This resin, which is capable of hardening or solidifying when exposed to light, particularly in the ultraviolet (UV) spectrum, is used. The light causes the resin to solidify close to the surface, resulting in the formation of a thin, solid layer [45], [46].

Wire Pulse Arc Additive Manufacturing (WPAAM)

Wire arc additive manufacturing (WAAM) is a method of additive manufacturing that utilises metal wire as the raw material. This wire is melted using an electric arc to create a complicated 3D item by depositing layers one at a time. When compared to laser or electron beam-based additive manufacturing (AM) technologies, the WAAM process requires a significant amount of heat input. This is because the electric arc used in WAAM has a comparatively low energy density, resulting in low melting efficiency [47].

Stereolithography (SL)

Stereolithography (SL) is the method of solidifying layers of polymers that are responsive to UV light. Stereolithography is an additive manufacturing technique that enables the production of items from a CAD file, similar to other creative manufacturing methods. In order to produce three Objects using stereolithography, it is necessary to carefully control liquid tar so that it undergoes photopolymerization and solidifies [48].

Fused Deposition Modeling (FDM)

Fused Deposition Modelling (FDM) is a widely utilised technology in additive manufacturing (AM) that involves the extrusion of thermoplastic materials from a nozzle tip. These materials are heated to a semi-molten state and then deposited onto a substrate, resulting in a three-dimensional structure [49].

Electron Beam Freeform Fabrication (EBFF)

Presently, there is ongoing development of a cross-cutting process known as EBFF, which generates conceptual metal pieces. This technique can be employed to fabricate intricate, consolidated components using a layer-by-layer material method. However, it is more efficient in terms of speed when utilised to add intricate features to pre-existing castings, forgings, or plated goods. EBFF employs a powerful electron beam that operates within a confined region [38].

Direct Light Processing (DLP)

DLP, an acronym for Digital Light Processing, is an advanced 3D printing method used to quickly manufacture photopolymer components. SLA and DLP devices share similarities, although they diverge in their curing techniques. SLA machines utilise a laser to track and cure one layer at a time, while DLP machines use a reflected light source to cure the entire layer all at once. The use of DLP technology allows for the simultaneous solidification of the entire layer [50].

4. Conclusion

Consequently, the automobile industry is experiencing a steady rise in the manufacturing of biocomposites. The use of additive manufacturing techniques in the creation of composite materials for the automobile industry is increasingly prevalent due to its ability to guarantee precision, cost-effectiveness, and efficiency. The manufacturing business has had a substantial metamorphosis in recent years, primarily attributable to the advent of 3D printing technology, sometimes referred to as additive manufacturing. This groundbreaking manufacturing approach has provided opportunities for inventive applications that offer potential cost reductions, more design flexibility, and increased effectiveness. Over the years, 3D printing has transitioned from being a specialized industrial process to becoming a widely used technology with diverse applications. The automotive sector also reaped the advantages of this manufacturing technique and actively promoted the production of diverse components, particularly composite parts.

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