



JOURNAL ON COMMUNICATIONS

ISSN:1000-436X

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Additive manufacturing concepts for automotives parts and its extensions – Review

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Abstract:

Modern technologies in general have had a significant impact on the universe in our quickly expanding globe. To produce diverse automobile subassemblies utilizing 3D printing technologies, additive manufacturing is the recommended technology. The manufacturing parts for automobiles are produced using 3D printing, an environmentally friendly method of layer-by-layer material deposition. The goal of this paper is to use a survey approach to gather information about additive manufacturing for automotive parts from a variety of well regarded indexed journals. Additionally, a brief explanation of the various techniques for carrying out 3D printing procedures for vehicle parts Likewise examining the relative merits of several techniques in terms of price, accuracy, and surface quality. Choosing the best inexpensive approach based on price and other factors

Keywords: 3D Printing, Additive Manufacturing, Cost, Accuracy, Automotive parts, optimal method

1. Introduction

Three-dimensional (3D) printing, often known as additive manufacturing (AM), is a manufacturing technology that allows the manufacture of objects by layering prints that are guided by digital 3D models. Additive manufacturing helps to produce complex contour shaped parts very easily using scanned laser tomography as compared to conventional method of manufacturing. Consequently, additive manufacturing (AM) is a resource that gives designers the ability to produce complex or custom models in a single step without the limitations of traditional manufacturing, such as high material waste, the difficulty of manufacturing complex shapes, and the requirement for specialized tooling. Using AM (Additive Manufacturing) part count can be reduced by minimizing the assembly costs and time.

Polymers, ceramics, and metals are just a few of the materials that AM (Additive Manufacturing) technology may work with. Researchers and companies are becoming more interested in metallic materials among these materials. In addition to the aforementioned advantages, metal additive manufacturing (MAM) may also have some environmental advantages, such as reduced waste, improved quality, lower pollutant emissions, and the ability to produce parts as needed. Rapid prototyping, invented in the 1980s for making models and prototype parts, was the first method of layer-by-layer construction of a three-dimensional object using computer-aided design (CAD). This technology was developed to aid in the implementation of engineers' visions. One of the earliest methods of additive manufacturing (AM) is rapid prototyping. It enables the production of printed parts in addition to models. Time and cost savings, more human engagement, a shorter product development cycle, and the ability to generate nearly any shape—even ones that would be challenging to machine—are just a few of the significant advancements this technique brought to product creation.

1.1. Classification of Additive manufacturing

In this section various types of additive manufacturing techniques are listed below as shown in fig 1.

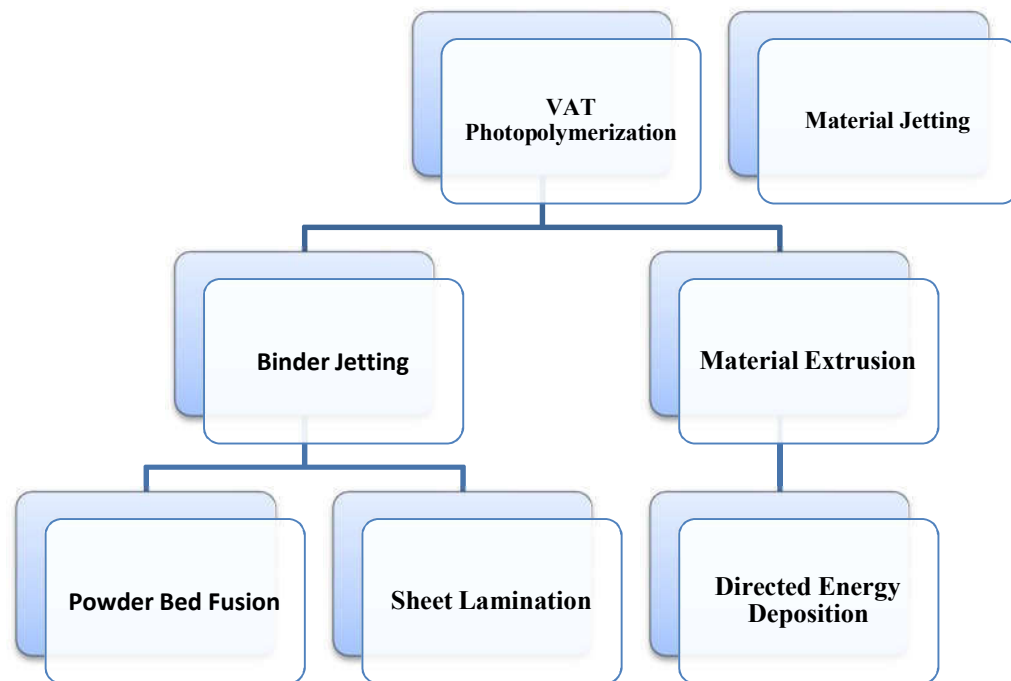


Fig. 1. Classification of Additive Manufacturing Methods

1.VAT Photo polymerization :

VAT Stereo lithography is another name for photo polymerization. The name VAT photo polymerization refers to a method of additive manufacturing that uses a vat of liquid photopolymer resin. Vat polymerization can quickly produce structures while offering a high level of accuracy and a beautiful finish, even though resin can be fairly expensive.

Despite its advantages, vat polymerization manufacturers are only allowed to use photo-resin ingredients and must carry out a significant amount of post-processing. Before they can be used, the printed objects must be taken out of the resin and thoroughly cleaned.

2. Material Jetting:

Material jetting builds objects by layering materials, much as binder jetting. Material jetting, on the other hand, melts wax-like materials and accurately deposits droplets onto the build platform, as opposed to building adhesive over a bed of powder. The item assumes shape as the layers are added. Due to its low cost and exceptional accuracy with high-quality surface finishes, material jetting is widely used by manufacturers. Unfortunately, the only materials that may be used for material jetting are wax-like polymers, which can be delicate. Additionally, since each droplet is built separately, items take longer to construct.

3. Binder Jetting:

One of the most popular forms of additive manufacturing is called binder jetting, often known as material jetting or inkjet powder printing. The only difference between this technique and your standard office printer is that it prints three-dimensional objects. Binder jetting shoots glue into a powdered material rather than ink onto a sheet. With each pass, the print head moves both vertically and horizontally, adding a fresh layer of construction material.

Due to its low entrance barrier and the low cost of its constituent parts, binder jetting is one of the most affordable additive manufacturing technologies. Additionally, it can produce objects in full colour and more quickly than most other additive manufacturing techniques.

4. Material Extrusion:

Extrusion of material functions similarly to a hot glue gun. A coil of material feeds into the printer. The substance is heated and melted at the nozzle's tip. The liquid substance is then applied to the construction platform in layers, where it can cool and solidify to form the object. Material extrusion has limits, while being the most affordable additive manufacturing technique. You can only use plastic polymers since the heating components lack the strength to melt high-density materials like metal, which makes them unsuitable for several applications like tooling and fixturing.

5. Powder bed fusion:

The process of powder bed fusion, also known as electron beam melting (EBM), begins with a sizable bed of material that has been powdered, usually composed of sand, metal, plastic, or ceramic powders.

A laser or electron beam is utilized to selectively fuse the powder together. The working area is moved downward after a layer of material has fused, and a new layer is then added on top using the same procedure. PBF produces items with a high degree of complexity, which makes them more durable than those made by some other methods of additive manufacturing. It is challenging to keep the workplace tidy because a bed of powder is needed. If you need to use powdered materials, this method is not the greatest choice for small areas.

6. Sheet Lamination:

A form of additive manufacturing called sheet lamination, also known as ultrasonic additive manufacturing (UAM) or laminated object manufacture (LOM), involves stacking thin sheets of material and joining them via ultrasonic welding, bonding, or brazing. The item assumes shape as the layers are added.

7. Direct Energy Deposition:

To produce three-dimensional objects, directed energy deposition (DED) applies welding techniques. A laser or electron beam or other concentrated energy source melts the substance, which is commonly metal wire or powder. Following a precise pour onto the construction platform, the liquid substance instantly solidifies to form a layer. Up till the print job is complete, this process is repeated.

1.2. Materials used in Additive Manufacturing:

Currently, the primary types of materials utilized in 3D printing are:

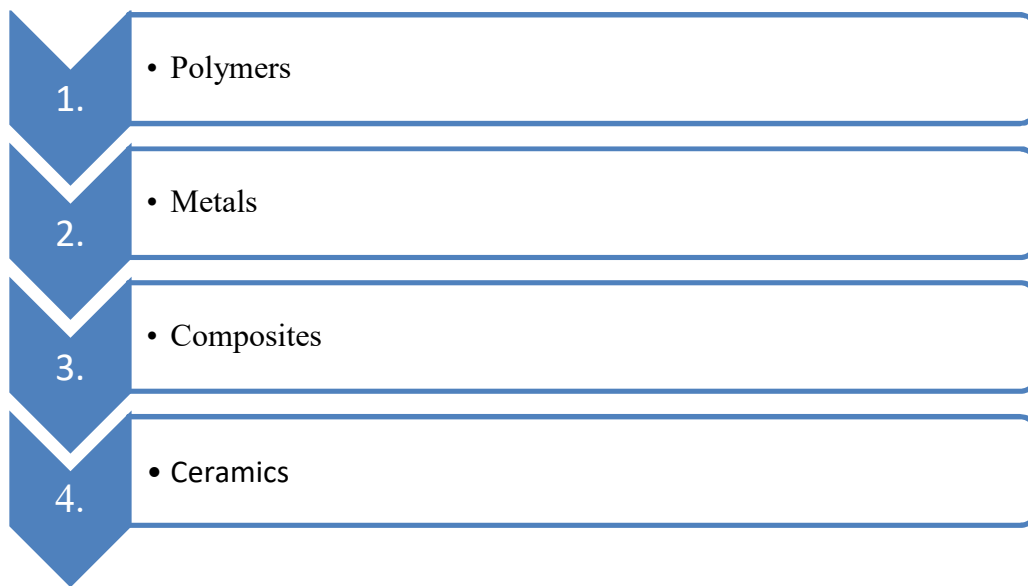


Fig .2. List of Materials used in Additive Manufacturing

- i. **Polymers:** Stereo lithography, the first 3D printing technology, uses a vat polymerization technique to cure resin and create polymer pieces. Even today, polymers are a common type of material for 3D printing, but they have advanced much from the early, brittle materials. Thermoplastics like PLA and ABS are among the materials used in filament-driven systems the most frequently, although high-performance materials like PEEK and PEKK are also gaining popularity in this sector. In powder bed fusion methods, nylons and TPU have become popular. Thermoset materials have traditionally been used in vat polymerization, but they are now also starting to be made accessible for extrusion and selective laser sintering. Typically, polymer materials come in the form of solid filament, pellets, liquid resin, or powders.
- ii. **Metals:** Aluminum, titanium, stainless steel, Inconel, and cobalt chrome are some of the most often 3D printed metals. Blue-light laser technology has made it possible to 3D print copper, a material that has previously been challenging to do so. Other techniques, like as binder jetting, may be more effective for printing reflective metals like copper. An alloy that works for one type of metal 3D printing might not work for others. Metals for 3D printing are often offered as wire or powder, although they can also be combined with other substances. In more recent "bound metal deposition" (BMD) techniques, "green" parts are constructed using filament or rods made of metal powder embedded in polymer, which are subsequently fired in an oven to take on their final dimensions and acquire metal characteristics, much like in metal injection molding (MIM). For procedures like this, metal powder can also be given in the form of a paste or suspended in resin.
- iii. **Composites:** A growing trend in 3D printing is composites, which blend many types of materials. The composite may be produced through 3D printing, or the process may start with

a material that already contains an additive. From short-run injection moulds to composite layup tools to finished products, polymers reinforced with chopped carbon and glass fibres are employed in a variety of applications, providing a cost-effective alternative to more expensive metals. Some 3D printers allow you to lay continuous fiber reinforcement either concurrently or intermittently with the 3D printed form, while others use sheets of reinforcement material fused with polymer layers. In some situations, polymer composites like this one can be produced robust enough to replace metal while frequently reducing weight significantly. Another class of materials finding new applications through 3D printing is metal matrix composites (MMCs), which combine a metal alloy with another material, such ceramic.

- iv. **Ceramics:** Ceramics have a low absorption and are challenging for laser-based printing methods. However, extrusion, material jetting, and photo polymerization-based methods have been created. Similar to the above-discussed procedure for bonded metal deposition, the 3D printing step frequently uses a ceramic slurry or material mixture to create a green object that can later be sintered.

2. Literature Review:

In this section literature review is focused on metal additive manufacturing in automotive and aerospace applications as described below:

Shahir Mohd Yusuf et al [2019] Metal additive manufacturing (AM) has developed from its origins in the research stage to the creation of a broad range of useful commercial applications. Particularly at this time, metal additive manufacturing (AM) is widely used in the aerospace sector to construct and maintain a variety of parts for both civilian and armed forces aircraft as well as for spacecraft. First, the sorts of AM technologies that are frequently employed to create metallic parts are described. The evolution of metal additive manufacturing in the aerospace sector from prototypes to the production of propulsion systems and structural components is then discussed. The development of metal additive manufacturing (AM) within the aerospace sector from merely prototyping to the production of propulsion systems and structural components is also addressed. Additionally, existing unresolved problems that hinder metal additive manufacturing from being produced in large quantities in the aerospace sector are explored. These problems include the creation of standards and qualifications, sustainability, and supply chain development.

Ana Vafadar et al [2021] Additive Manufacturing (AM), commonly known as 3D printing, has recently become more prevalent in a number of industrial fields as a result of the benefits it offers in terms of increased functionality, productivity, and competitiveness. Although the spectrum of applications for metal additive manufacturing (AM) technologies has expanded recently and these technologies have practically limitless potential, industries have had difficulty adopting them and adjusting to a volatile market. Despite the substantial research that has been done on the properties of metal AM materials, a thorough grasp of the procedures, difficulties, requirements, and considerations related to these technologies is still necessary.

As a result, the objective of this study is to give a thorough analysis of the most popular metal additive manufacturing (AM) technologies, a look at metal AM advancements, and an examination of industrial

uses for the various AM technologies across several industry sectors. This study also identifies current constraints and issues, such as production volume, standards compliance, post-processing, product quality, maintenance, and material variety, which prohibit industries from fully utilizing metal additive manufacturing prospects. In order to help enterprises choose an appropriate AM technology for their application, this article offers a survey as the standard for future industrial applications and research and development projects.

Markus Johannes Kratzer et al [2021] Due to its flexibility in design, functional integration, and quicker product development cycles, additive manufacturing (AM) is gaining importance across a range of industries. Components made with additive manufacturing may need additional processing procedures like heating and surface treatment before they can be used in a variety of applications. Both for the execution of the printing process and for the succeeding steps, there are a sizable number of alternative processes accessible. As a result, the design of the complete production process chain has a wide range of potential combinations. Decision support methods and systems have previously been established in research to make choosing a procedure in the area of AM easier. However, they do not take into account the full process chain, which includes post-processing. In order to maximize output in terms of economic criteria and fully utilize the technical capabilities of AM components, a wider perspective is required. In most instances, consideration is not given to the particulars of the automobile industry in terms of selection criteria or an underlying database of materials and procedures.

Mostafa Yakout et al [2018] A layer-based manufacturing technique called additive manufacturing is used to create parts directly from 3D models. Key technologies for metal additive manufacturing are reviewed in this paper. It focuses on how crucial process variables affect the microstructure and mechanical characteristics of the finished product. Aerospace alloys including titanium (TiAl6V4 [UNS R56400]), aluminum (AlSi10Mg [UNS A03600]), iron- and nickel-based alloys (stainless steel 316L [UNS S31603], inconel 718 [UNS N07718], and invar 36 FeNi36 [UNS K93600]) are among the materials that are taken into consideration.

Vladimir C.M. Sobota et al [2020] This article discusses the key considerations in choosing additive manufacturing (AM) technology as a means of producing metal parts. AM builds items by layering on material based on 3D models. Currently, there is a lot of interest in AM since it is believed that AM will increase the competitiveness of Western manufacturing firms. To determine the variables influencing the choice of AM technology, a literature review is done. Based on relative factor weights, these criteria are ranked in order of importance using expert interviews and the best-worst technique. A comprehensive picture of AM technology selection is provided by categorizing and further mapping elements relating to technology, demand, environment, and supply. Market demand was deemed to be the most important factor, despite the fact that it is now absent.

Validity restrictions are brought on by the make-up and size of the expert panel as well as how some of the elements were framed in relation to prior research. To separate the selection criteria for various AM implementation projects, additional research is encouraged.

Matteo Strano et al [2021] Rapid tool manufacture for plastic molding, sheet metal forming, and blanking has always been a crucial and significant objective for applied research, and many different production techniques have been suggested throughout the years. Extrusion-based additive manufacturing (EAM), such as fused filament fabrication (FFF) or comparable technologies, has not been frequently regarded among these techniques and needs to be further investigated. EAM is typically viewed as a low-cost, low-quality, low-performance class of additive manufacturing (AM) that is best suited for creating purely cosmetic prototypes rather than practical parts.

Maximilian Kunovjanek et al [2022] The use of additive manufacturing (AM) is still not widespread in most supply chains. However, a number of industries, from consumer goods to aerospace, are looking into its potential to support the digital value chain. In light of these advancements, the research community has offered numerous arguments in favour of the use of AM in supply chains. By methodically assessing pertinent literature according to industry sector, purpose, and supply chain area using the SCOR framework to provide quick access to crucial material, this article contributes to the scientific conversation. The review covers 1004 articles, 141 of which were given a full-text analysis and coding for each argument. Results showed the most common AM trends for supply chains, as well as perceived advantages and difficulties, and potential applications.

Dimitrios Chantzis et al [2020] A major component of an automotive OEM's business strategy is sustainability. Particularly in the realm of vehicles, attention has intensified, and big manufacturers have already made large investments. However, lightweight design as well as alternative propulsion technologies is also necessary in order to properly address the sustainability dilemma in the car sector. For internal combustion and electrified vehicles, respectively, the relationship between vehicle weight and fuel consumption and range makes weight reduction a top priority. The development of improved steel and aluminum-forming methods over the past few decades has led to a significant decrease in the weight of vehicle components. One of the oldest methods for producing modern steel and aluminum alloys is hot stamping. The method offers parts with high strength and little spring back, low forming loads, and good formability. Advanced tooling designs are necessary due to the high temperatures of the formed materials across several cycles and the extensive cooling needed to guarantee desired component characteristics. Tools are typically made using casting and machining, however due to the design flexibility it provides, additive manufacturing has recently attracted a lot of attention. The state-of-the-art hot-forming tooling designs are thoroughly reviewed in this study, along with the future direction of additive manufactured (AM) tools.

Neng Li et al [2021] Metal matrix composites (MMCs) laser additive manufacturing research has advanced significantly. On five different types of MMCs, recent efforts and developments in additive manufacturing are presented and reviewed. The design of the material, the pairing of reinforcement and metal matrix, the synthesis principle applied during the manufacturing process, and the resulting microstructures and characteristics are the key points of emphasis. Then, a future development trend is predicted, including: A strengthening phase formation mechanism and reinforcement principle; a material

and process design that actively achieves expected performance; a novel structure based on the unique characteristics of laser AM MMCs; and simulation, monitoring, and optimization of the laser AM MMCs manufacturing process.

Alessandro Busachi et al [2017] Given its capacity to delocalize manufacturing close to the point of use, "Additive Manufacturing" (AM) is a promising technology that will significantly benefit providers of Defense Support Services. Due to its potential for disruption, interest in the technology is growing. AM encompasses a broad range of strategies that can turn a 3D file into a physical object by depositing material in successive layers. AM is still being developed and is regarded as a young technology. Due to this immaturity, there is a large degree of uncertainty surrounding important indicators like time and cost. These metrics serve as important selection criteria for assessing additive manufacturing (AM) and contrasting it with traditional manufacturing. Due to this immaturity, there is a large degree of uncertainty surrounding important indicators like time and cost. These metrics serve as important selection criteria for assessing additive manufacturing (AM) and contrasting it with traditional manufacturing. This review paper investigates the state of the art in AM and attempts to inform the reader about the various AM methodologies with a close attention to those technologies that are most relevant to the defense support services industry. The study is organized as follows: first, the various AM technologies are given, along with their economic implications; second, cost modeling methodologies are examined; and third, a discussion is held.

Roberto Citarella et al [2021] With the introduction of additive manufacturing (AM) techniques used in the fabrication of structural components, structural design methodologies and optimization techniques that take into consideration the unique properties of the fabrication process are now necessary. While AM techniques provide for unheard-of geometrical design freedom and can significantly reduce component weight (e.g., through reduced part count), they also have an impact on fatigue and fracture strength due to residual stresses and micro structural characteristics. This is brought on by flaws, distortions, anisotropy, and stress concentration effects, the impacts of which still need to be researched.

Kaufui V. Wong et al [2012] Stereo lithography (STL) files, which are used in additive manufacturing methods, are created by translating computer-aided design (CAD) files into stereo lithography (STL) files. In this procedure, the CAD-created drawing is approximated by triangles and divided into sections containing the details of each layer that will be printed. The pertinent additive manufacturing techniques and their uses are discussed. They are used by the aerospace industry because it is possible to produce lighter structures to save weight.

Devarajan Balaji et al [2022] Metal additive manufacturing (MAM) does not need any introduction to be used in a variety of engineering and technology fields. The application of additive manufacturing, specifically for aerospace components, is covered in detail in this article. With the help of a patent landscape analysis, the opening section of this article introduces the most cutting-edge MAM technologies now available. In this article, the aerospace manufacturing cycle has been examined beginning with the

design phase and continuing with the selection of the process parameters. Understanding the manufacturing cycle is the first step in any manufacturing process. The decision of assessment parameters, whereby the surface texture analysis of components manufactured using additive manufacturing is covered, is the instant result of printing.

Mario Enrique Hernandez Korner et al [2020] Over the past 30 years, the research trend in additive manufacturing (AM) has developed from patents, design advancements, layer-by-layer materials, to technologies. But there are some obstacles in the way of this evolution, including the adoption of additive manufacturing (AM) in production; the latter's productivity restrictions, and the sustainability of the economy and society. To fully utilize the capabilities of AM, these obstacles must be removed. This study's goal is to conduct a comprehensive assessment of the bibliometric data on these hurdles in two study areas: business model innovation and sustainability in additive manufacturing from an Industry 4.0 perspective.

Review summary:

Based on the above review information it was observed that metal additive manufacturing (MAM) concepts is focused in the literature survey. Key important study is done on the following areas like automotives and aerospace.

3. Current status of additive manufacturing in Automotive Industry – Overview :

Additive Manufacturing (AM) has Been Heavily Used within the Automotive Sector to Overcome the Capital Versus Scope Trade-Off and Improve Performance. Additive Manufacturing (AM) has been Used for a Long Time by High-Volume Automotive Oems and Suppliers to Improve Overall Manufacturing Capabilities and Cut Costs. AM can create prototypes without developing tools, shortening design processes and cutting costs. Today, AM is used by both OEMs and suppliers to improve current processes: to support decision-making during the product design phase, to establish quality during the preproduction phase, to create customized tools, and to shorten the overall time to market.

Accelerating the product design stage of new product development: Before choosing the final design, organizations go through multiple iterations in the product design stage. The ability to inexpensively generate several variations of a product is one of additive manufacturing's biggest benefits. This allows vehicle manufacturers to use physical models to improve their product ideas.

For instance, a well-known tyre manufacturing firm uses AM to quickly produce prototypes throughout the design phase, and after testing the feel and touch of several options, selects the best design. Interestingly, the prototypes help the business by offering brand distinctiveness in addition to tailoring choices based on OEM needs: When sharing new goods with their OEM clients, the corporation has an advantage over rivals who might only have access to design specifications and blueprints.

Rapid prototyping improves quality: Automakers can test for quality ahead of actual production schedules by employing AM to manufacture prototypes long before the final production. Due to AM's design versatility, businesses may create and test a wide range of prototypes. For instance, GM's design, engineering, and manufacturing functional areas use selective laser sintering (SLS) and stereo lithography

(SLA) extensively in preproduction and design processes, and its rapid prototyping department creates test models with more than 20,000 components.

Custom tool fabrication is important to automakers because it helps the assembly line produce reliable, high-quality products. AM enables the creation of specialized tools to increase factory floor productivity. For making the hand tools required in testing and assembly, BMW, for instance, used AM in direct production.

Lowering the cost of tooling in product design: Prior to production runs, some automobile components receive tooling and investment castings.

4. Future directions for AM (Additive Manufacturing) in fostering performance and expansion:

Future automotive business models are likely to involve OEMs closely collaborating with a smaller, more tightly knit supplier base and supporting quicker refresh rates for vehicles with cutting-edge features. OEMs can implement this strategy by strengthening their relationships with so-called "tier 0.5" suppliers and continue to streamline their supplier base. Currently, it takes years for a car to reach the market from basic design to final manufacture. With AM, manufacturers can lengthen the growth and maturity phases while dramatically cutting the product life cycle's development phase.

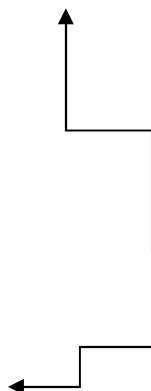
lowering production and assembly costs through part simplification Design restrictions imposed by conventional manufacturing methods might multiply the number of parts needed to make a component. The length and complexity of the assembling process both grow as the number of parts does. Complex designs that eliminate the need for many parts can be produced by AM.

5. Where is AM (Additive Manufacturing) going now and in the future?

Dashboards and cooling vents in some vehicles are currently produced utilizing additive manufacturing. It is likely that more products could be produced using additive manufacturing (AM) thanks to recent advancements in process and materials technology and a wider use of the technology.

Figure 3 displays a non-exhaustive list of the items that are currently made using additive manufacturing (AM) and those that may be manufactured in the future.

Manufacturing Processes (Applications: Investment casting, specialized tooling, and prototyping)





Exhaust Emissions (Applications: Emissions)

Fig.3. Illustrative example of Additive Manufacturing in Automotives

When the number of part production increases additive manufacturing is the only tool to simply the make the part using various additive manufacturing techniques. Additive manufacturing simplifies the part production method by reducing the manufacturing part cost by simplifying the design.

6. Driving factors and obstacles to Additive Manufacturing adoption in the automotive sector:

Future AM (Additive Manufacturing) applications in the automobile sector's success will mainly depend on how AM (Additive Manufacturing) technology develops over the next few years. Four barriers and two drivers that we have identified could potentially influence the adoption of AM (Additive Manufacturing) in the future.

Driver 1: More AM-compatible materials

A greater number of qualities can be included into finished products because to the wide variety of materials available. Due to the restrictions on the materials that may be employed, AM applications have traditionally been constrained.

Contrary to conventional manufacturing, which today employs a wide range of materials including metals, alloys, and composites, additive manufacturing (AM) has not been around long enough to experience the same advancements.

Driver 2: Higher-quality AM produced goods and less post-processing

The majority of AM systems can generate parts with some variability from time to time from thermal stress or voids. Lower repeatability is the outcome, which presents a problem for high-volume businesses like the automobile sector where quality and dependability are crucial.

7. Conclusion

In this article the extensive literature is focused on additive manufacturing concepts in automotive applications. Additive Manufacturing plays a vital role in prototype development, simulation and testing. AM concepts helps to reduce the complexity in manufacturing parts using 3D Printing approach as compared to conventional manufacturing methods. In this work metal additive manufacturing is

considered using suitable methods like laser sintered fused deposition method. Hence in this work attempt has been made to conduct survey on additive manufacturing applications in automotive areas using metal additive manufacturing technology.

The future direction of additive manufacturing in automotive industry is also illustrated in section 4, 5 and 6 respectively.

As a whole any part manufactured by additive manufacturing reduces the cycle time of part development and improves the accuracy.

Future extensions: The future extension of additive manufacturing is continued to focus on biomechanics field of area as extended survey .

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