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POTENTIAL APPLICATIONS OF ADDITIVE MANUFACTURING TECHNOLOGIES IN THE VEHICLE INDUSTRY

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Abstract: One of the most competitive fields on the planet is the automotive industry. New-market and innovative designs regularly arise, necessitating the development of new manufacturing methods to keep up with the automotive industry. Additive manufacturing offers a significant competitive advantage in this industry, serving as a disruptive strategy by increasing production flexibility, reducing product development time, and providing optimal automotive components and bespoke vehicle products on demand. Additive manufacturing on soft assembly tools or specialised tools to make automotive components enhances automotive production. Additive Manufacturing's freeform capability allows for the design and direct fabrication of optimised automotive components aimed at improving vehicle performance, as well as tailored assembly tools to boost productivity. Another related technological advantage of additive manufacturing is the ability to create lightweight components with the help of generative design algorithms. Furthermore, the time to market for Additive Manufacturing parts has fallen dramatically, allowing mass customisation to become a reality. The strong downward trend in fuel consumption offers new automobile design, performance, and compliance with regulations. Considering the actual example switch from the conventional combustion engine to other motion systems, Additive Manufacturing is a critical enabler technology for modern automobiles. This paper provides an overview of Additive Manufacturing applications in the automobile sector, focusing on the technical and economic benefits of this manufacturing technology.

Keywords: *Additive Manufacturing (AM), Automotive, Potential Application*

1. INTRODUCTION

Additive manufacturing (AM), often known as 3D printing, is a type of production in which materials are added layer by layer. Joining substances together by binding them together layer by layer to construct intricate 3D structures is called. As the name implies, Additive Manufacturing's a way of producing lighter and stronger 3D designs by including raw material rather than removing it [1]–[5]. 3D printing is a method of manufacturing three-dimensional physical models using 3D computer-aided design (CAD). Directed energy deposition, Vat photopolymerisation, sheet lamination, material jetting, binder jetting, powder bed fusion, and material extrusion are the seven different types of AM, as shown in *Figure 1* [6]. The 3D printer interprets the digital supply parameters obtained from the Stereolithography (STL) file format and converts them to G-codes utilising slicing tools [7].

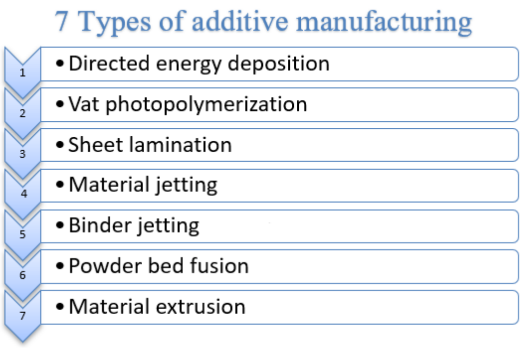

Figure 1
Classification of additive manufacturing [6]

Complex structure design and production and customisation, reuse, and improvement are all possible with this printing process. This needed cutting-edge processes like Stereo Lithography (SLA), which uses lasers to decompose photopolymer resins layer by layer. Selective Laser Sintering (SLS) is a sintered material coating method that uses a laser as a source of energy and focuses it on points in space defined by a three-dimensional object. Fused Deposition Modelling (FDM) is a process that involves heating and depositing a flexible thermoplastic filament from a long-coiled wire onto an object.

Digital Light Processing (DLP) is a method of printing three-dimensional (3D) structures created in 3D CAD software by projecting the material one layer-by-layer. It is employed in a variety of embedded systems, including medicine, automobile, and the military.

Selective Laser Melting (SLM) fuses metallic powders with high-power density lasers. Electron Beam Melting (EBM) is a prototype technology in which powder is deposited in thin layers before heated and melted. Laminated Object Manufacturing (LOM) is a cheap and fast way to make objects. The material is coated with an adhesive layer, then melted by a feeder roller before being sliced into the required shapes.

Unlike conventional manufacturing methods, which had a variety of limits on product design, AM's adaptability allows producers to fine-tune lean production tactics by minimising waste created by material removal. 3D printing has attracted the public's and specialists' attention in various fields, including automotive, aviation, industry, medicine, and food supply chain management.

AM is a truly breakthrough technology that is developing in the manufacturing branch, as leading industries switch from traditional to modern production. In AM, three-dimensional 3D printing is utilised to switch engineering design files into fully functional and durable constructions composed of sand, metal, and glass. Once the materials in one layer have already been linked by adhesive or heat, the second layer is built, and the bonding process is repeated. It allows for the creation of formerly impossible geometries. For various automotive, commercial, and creative purposes, full-form parts are made straight from CAD data. AM is an eco-friendly production method. AM produces product samples rapidly, which is becoming increasingly beneficial since it lowers the conventional trial-and-error process, allowing newer innovations to access the market faster. It may also make customised metal things fast to replace worn or broken industrial parts.

2. APPLICATION OF AM IN THE VEHICLE INDUSTRY

Complex geometries can be costly to make using typical manufacturing procedures or extremely difficult to produce with a particular technology. Reconstruct and redesign geometries that are less expensive and lighter than origin structures can be easily created using AM technology. These approaches make it widespread in the automotive industry. It was the second most important one in the US in 2014 [8]. In 2018 SmarTech released an Additive Manufacturing in Automotive report, and *Figure 2* shows an exponentially increase in the market with an expected of $12.4 billion US in 2028. [9]

Making the lightest practical vehicle while keeping safe is a primary priority in the automotive industry which will be more friendly to the environment. Also, AM plays the leading role in many sectors like spare parts and supply chain, tooling for automotive, customisation components, and topology optimisation and Design for AM (DfAM).

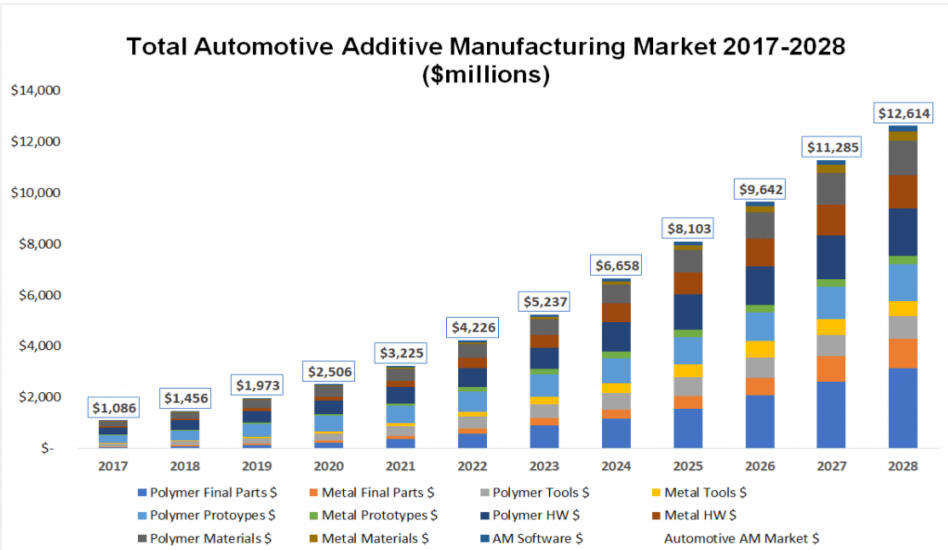

Figure 2
Total Automotive Additive Manufacturing Market 2017–2028 [9]

2.1. Growing potential of additive manufacturing on automobile components

The implementation of AM processes to develop automotive components was limited by material properties, like mechanical, thermal, and chemical behaviors under operation or surface finishing on beautifying components [10]. To increase the mechanical properties of materials, fiber reinforcements have been applied [11]. Recent advancements in carbon-fiber-reinforced filament materials have given the FDM technique a significant competitive advantage. AM equipment manufacturers have taken several methods to the length of the carbon fiber injected within the filament [12]. *Figure 3* highlights some of the existing and potential applications of additive manufacturing on automobile components [13].

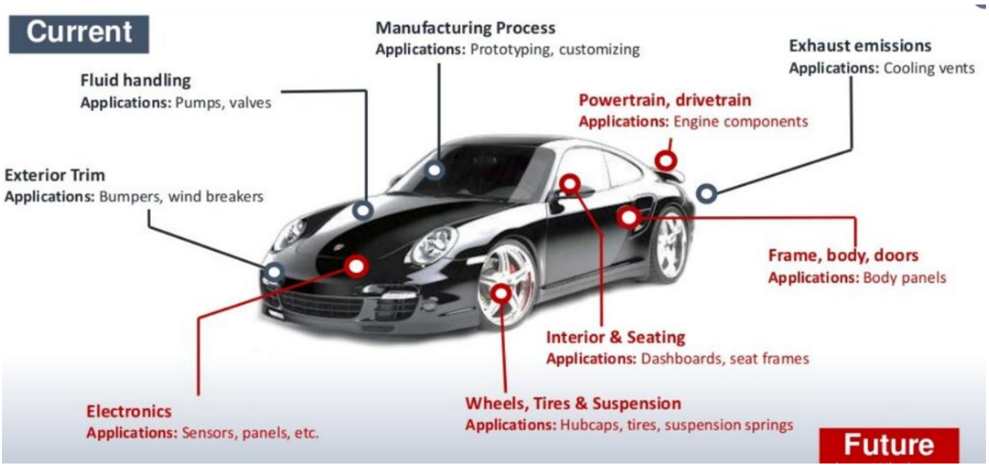

Figure 3

Some of the existing and potential applications of additive manufacturing on automobile components [13]

2.2. Effect of AM on environment

Stereolithography and laser sintering are the most common AM technologies used in the automotive industry. The key benefits of employing additive methods include weight reduction while still providing high-quality products. The reduced weight has an impact on the energy demand of a vehicle [14]. It also extends vehicles' lifecycles by allowing replacement parts to be produced faster, improves reliability, and has a modular design that allows product upgrades [15]. Electricity for machine tools, production resources (such as cutting tools), and waste all have an impact on the environment (e.g., chips, cutting fluids) [16]. Lower production weight, transportation, material losses, enhanced functionality, and the ability to print spare parts are all advantages of adopting AM technology. Potential drawbacks include increased power consumption in manufacturing and a slow printing process [17].

2.3. Stamping tooling

The demand for automobile components produced by the stamping process has risen substantially over the previous few decades, producing more than 100 million parts per year. Examples of stamped parts in the automobile sector include bumpers, chassis components, rocker rail, roof rail, and tunnels. The sheet thickness of these components can range from 1.0 to 2.5 mm [18]. AM, a technique that allows for nearly unlimited design freedom, can transform the design and manufacture of hot stamping dies. Design techniques such as topology optimisation can result in dies that employ the least amount of material while maintaining structural stability and thermal efficiency [19]. Leal et al. [18] used 3D-printed inserts in a body panel stamping tool in maraging steel DIN 1.2709, which indicated performed similarly to the traditionally manufactured inserts, but with a shorter lead time and less internal process logistics. Asnafi, N., Rajalampi, J., Aspenberg, D. et al. [17] also used AM technology in the U-bend forming tool and the results showed that AM improves the material usage and lead time significantly.

2.4. Spare parts and supply chain

As logistic operations expand in size, they get harder and harder to handle. Therefore it is crucial to assess resources to reduce risk and enhance efficiency. Distributed production of spare parts closest to the end customers may offer great benefits, including shorter supply lead – time and lower logistical costs.

According to Delic, Mia, and Daniel R. Eyers [18] and Delic, M., Eyers, D. R., & Mikulic, J. [19], AM implementatpositively influence flexible supply chain has a beneficial impact on supply chain performance. So, the AM can bring more benefits like transportation expenses are reduced. Since spare parts are manufactured at client sites or a local 3D printing supplier, there are no costs for producing tools, and spare parts production is more flexible because 3D models are easy to update. Spare-parts modifications can be made rapidly and at a low cost. They are avoiding overproduction, which occurs when more components are created and stockpiled than customers require for many reasons, and the COVID-19 pandemic is one of the most significant examples.

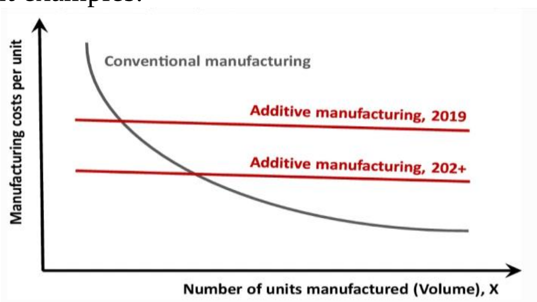

Figure 4

Conventional and additive manufacturing: manufacturing cost per unit versus the production volume [17]

As shown in *Figure 4* the conventional manufacturing is costly when the number of units manufactured decreases while AM technology shows an economical improvement in the manufacturing cost of small numbers of units manufactured.

2.5. Topology optimisation

Vehicle reduced weight is a trending topic in the automobile sector, especially among high-performance automotive manufacturers. In reality making the automobile lighter will enhance its overall stability and performance, allowing for better acceleration and greater braking. Furthermore, being less weight to transport implies better fuel economy and lower harmful emissions. Generally, every 10% decrease in car weight results in a 5-7 percent reduction in fuel usage [20]. To suggest an ideal design of vehicle parts and components, topology optimisation is implemented. AM (AM) allows for complicated designs and offers an excellent approach for fully exploiting topology optimisation. Zhu, Jihong et al. [21] illustrated the key findings and applications of the latest studies on topology optimisation and AM in the industry. *Figure 3* shows the uses of topology optimization and AM for an upright on the SAE Formula student racecar [22]. The results showed a decrease in the overall manufacturing cost by 51.7%. Another option to reduce the mass of cars the use of new materials and new manufacturing methods. [23]

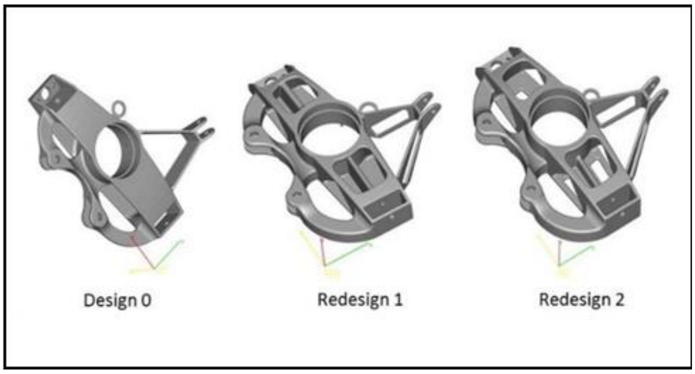

Figure 5
Using the AM and topology optimisation in-vehicle part [22]

3. SUMMARY

AM has been used to develop design iterations, improve quality through cost-effective prototyping, and make specialised tooling components [24]. Other AM pathways in automotive, however, exist that alter products and supply chains more dramatically. The main AM potentials are reducing the machining energy, which was used in high consumption rate in traditional manufacturing, transportation and logistics, and reducing waste. Furthermore, AM helps in the spare parts and supply chain field by closing it to the end-user. It is also played a crucial role in topology optimisation with the complicity of the new redesigned parts. Optimising Stamping Die Fabrication through AM can offer a great deal of many advantages like shortening the lead time, machine shop enhancement, integration, and geometric complexity at lower costs.

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