Additive fabrication in Automotive sector

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December 18, 2019

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Abstract

Automotive sector faces new challenges every day, new design trends and technological deployments from research push companies to develop new models and facelifts in short term, requiring new tools or tool reshaping. The Automotive sector is one of the most competitive business areas where time-to-market decrease plays an important role. Additive fabrication is the solution which enables the flexible production of customized products without significant impact on costs and lead time. Automotive companies developing new models and facelifts every day, pushed by new design trends and technological evolution where aesthetics, aerodynamics, safety, and weight reduction of the vehicle are key issues. Therefore, new tools or tool reshaping for new components is required, for body panels or other technical components. Digitalization helps the Automotive sector to turn their ideas into successful vehicle faster and more efficiently. Automobile manufacturers can increase the efficiency of their research and development processes, enabling them to get their products on the market with less time and efficiently.. An important parameter of using metal AM processes in the automotive sector is fabricating complex lightweight structures which at the same time possess good rigidity. The weight of the automotive parts can be reduced significantly by using the ability of AM processes to maximum advantage to produce parts with complex geometries while maintaining relative strengths. This paper provides a review of today and future of additive fabrication in Automotive sector.

Keywords: Automotive sector, Additive fabrication, 3D printing, STL, CAD.

1. Introduction

Additive fabrication commonly known as 3D printing allows the direct conversion of design construction files into fully functional objects. It is a process of joining materials to make object from 3D model data usually layer upon layer. In this the material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together) typically layer by layer.
Vehicle manufacturers have been at the forefront of implementing additive fabrication technology. One of the most prolific additive fabrication applications in the automotive world is in rapid prototyping. This is also among the oldest uses of the technology, with some large auto manufacturers having prototyped parts with 3D printers for more than 20 years. Beyond prototyping, automotive manufacturers are now increasingly bringing it into use for actual production. In recent years, additive fabrication (AM) technologies have radically changed our way to design, develop and manufacture new products. In the Automotive sector, additive fabrication technologies have made wonders to bring new shapes to life, allowing for lighter and more intricate structures at the best possible cost.

Aim and Objectives:
- Innovative and without making use of tools fabrication of intricate shape and light weight components is possible.
- Maximum freedom for design, allowing the creation of complex yet light weight components with high level of rigidity.
- Additive fabrication can significantly reduce the material waste, reduce the amount of production steps, inventory being held and reduce the amount of distinct parts needed for an assembly work.
- Reducing the need for manual assembly
- Additive makes it possible to create internal complexities and precisely control microstructure.
- Enables production of components with integrated functionality without the need for tools, thereby cutting development and production costs.
- Time and cost reduction (shorter lead time).
- Leads to more market opportunities.

Firstly we'll explain the procedure i.e., how the additive fabrication is carried out and then requirements in Automotive sector, AM in the Automotive sector, common automotive applications, current and future uses of AM in Automotive sector, challenges for Automotive sector. But before that you should have the knowledge of different AM processes.

2. Additive fabrication Procedure

I. CAD: Producing a digital model is the first step in the additive fabrication process. The most common method for producing a digital model is computer-aided design (CAD). There are a large range of free and professional CAD programs that are compatible with additive manufacture. Reverse engineering can also be used to generate a digital model via 3D scanning.

II. STL conversion and file manipulation: A critical stage in the additive fabrication process that varies from traditional fabrication methodology is the requirement to convert a CAD model into an STL (stereolithography) file. STL uses triangles (polygons) to describe the surfaces of an object. A guide on how to convert a CAD model to an STL file can be found here. There are several model limitations that should be considered before converting a model to an STL file including physical size, watertightness and polygon count. Once a STL file has been generated the file is imported into a slicer program. This program takes the STL file and converts it into G-code. G-code is a numerical control (NC) programming language. It is used in computer-aided fabrication (CAM) to control automated machine tools (including CNC machines and 3D printers). The slicer program also allows the designer to customize the build parameters including support, layer height, and part orientation.

III. Printing: 3D printing machines often comprise of many small and intricate parts so correct maintenance and calibration is critical to producing accurate prints. At this stage, the print material is also loaded into the printer. The raw materials used in additive fabrication often have a limited shelf life and require careful handling. While some processes offer the ability to recycle excess build material, repeated reuse can result in a reduction in material properties if not replaced regularly. Most additive fabrication machines do not need to be monitored after the print has begun. The machine will follow an automated process and issues generally only arise when the machine runs out of material or there is an error in the software.

IV. Removal of prints: For some additive fabrication technologies removal of the print is as simple as separating the printed part from the build platform. For other more industrial 3D printing methods the removal of a print is a highly technical process involving precise extraction of the print while it is still encased in the build material or attached to the build plate. These methods require complicated removal procedures and highly skilled machine operators along with safety equipment and controlled environments.

V. Post processing: Post processing procedures again vary by printer technology. SLA requires a component to cure under UV before handling, metal parts often need to be stress relieved in an oven while FDM parts can be handled right away. For technologies that utilize support, this is also removed at the post-processing stage. Most 3D printing materials are able to be sanded and other post-processing techniques including tumbling, high-pressure air cleaning, polishing, and coloring are implemented to prepare a print for end use.

3. Requirements in Automotive sector

Weight - final parts: One of the most critical aspects relating to the Automotive sector is the weight reduction of components. Automotive applications make use of advanced engineering materials and complex geometries in an attempt to reduce weight and improve performance. AM is capable of producing parts from many of the lightweight polymers and metals that are common in the Automotive sector.

Complex geometries - prototypes and final parts: Affecting weight and aerodynamics (and therefore vehicle performance) is the geometry of a part. Automotive parts often require internal channels for conformal cooling, hidden features, thin walls, fine meshes and complex curved surfaces. AM allows for the manufacture of highly complex structures which can still be extremely light and stable. It provides a high degree of design freedom, the optimization, and integration of functional features, the manufacture of small batch sizes at reasonable unit costs and a high degree of product customization even in serial production.

Temperature - testing and final parts: Many automotive applications require significant heat deflection minimums. There are several AM processes that offer materials that withstand temperatures well above the average 105°C sustained engine compartment temperatures. SLS nylon, as well as some photo-cured polymers, are suitable for high-temperature applications.

Moisture - testing and final parts: Most components that go into the production of automobiles must be moisture resistant, if not moisture proof, entirely. One major benefit of additive fabrication is that all printed parts can be post-processed in order to create a watertight and moisture resistant barrier. Additionally, many materials, by their very nature, are suited for humidity and moisture plagued environments.

Part consolidation - prototyping and final parts: The number of items in an assembly can be reduced by redesigning as a single complex component. Part consolidation is a significant factor when considering how AM can benefit the reduction of material usage, thereby reducing weight and in the long run, cost. Part consolidation also reduces inventory and means that assemblies can be replaced with a single part should repairs or maintenance need to take place; another important consideration for the Automotive sector.

3. AM in the Automotive sector

Communication: Designs in the Automotive sector often begin as scale models showcasing the form of a vehicle. These are often also regularly used for aerodynamic testing. SLA and material jetting are used to produce high detail, smooth, scale models of automotive designs. Accurate models allow design intention to be clearly communicated and showcase the overall form of a concept.

Validation: Prototyping using AM is now commonplace in the Automotive sector. From a full size wing mirror printed quickly with low cost FDM to a high detail, full color dashboard, there is an AM technology suited to every prototyping need. Some AM engineering materials also allow for full testing and validation of prototype performance.

Pre-production: One of the areas AM has been most disruptive is the production of low cost rapid tooling for injection moulding, thermoforming and jig and fixtures. Within the Automotive sector this allows for tooling to be quickly manufactured at a low cost and then used to produce low to medium runs of parts. This validation mitigates the risk when investing in high cost tooling at the production stage.

Production: Since production volumes in the Automotive sector are generally very high (greater than 100,000 parts per year) AM has predominantly been used as a prototyping solution rather than for end part fabrication. Improvements in the size of industrial printers, the speed they are able to print at and the materials that are available mean that AM is now a viable option for many medium-sized production runs, particularly for higher-end automobile manufacturers that restrict production numbers to far fewer than the average.
With the possibility of producing multiple design iterations in a shorter amount of time (and at little additional cost), 3D printing is an effective tool for product development. Typically, a part must go through several design cycles before the final design is agreed upon. With 3D printing, this stage can be sped up dramatically. Additionally, cost-efficient design improvements can be made relatively quickly, since the technology does not require expensive tooling to produce a prototype.

Tooling: Tooling is used extensively within the Automotive sector to help produce high-quality products. Additive fabrication can complement this process by creating jigs, fixtures and other customized tooling equipment. The Volkswagen Europa assembly plant is already using AM to produce tooling equipment in-house, rather than sourcing tooling equipment from third party providers. With a 10-day turnaround for positioning and screw assembly (down from 56 days using a third party source), AM clearly shows itself to be a cost-effective return on investment for tooling production, enhancing the overall production process.[3,4]

End-Part Production: Although additive fabrication was originally adopted as a prototyping tool, recent advances in AM technology and materials make the production of small and medium-size production of end parts possible. This can range from exterior components to inner parts such as bellows, complex ducting, mounting brackets, and engine components. One example is Bugatti: only this year, the luxury car manufacturer announced it had produced a fully functional titanium brake caliper — entirely 3D printed. With such breakthroughs in end-part production, 3D printing is set to become a key technology for this application.

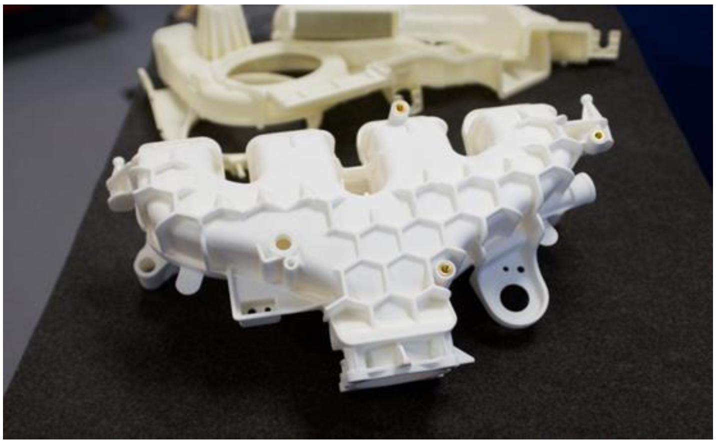
Bugattis 3D-printed brake caliper

Spare parts: Automakers can leverage the benefits of 3D printing to create spare parts on demand. With high inventory costs associated with storing spare (and often rarely ordered) parts, 3D printing provides a cost-effective means to produce parts needed on time and on demand, leading to improved delivery times, reduced inventory costs and a simplified supply chain.

4. Common Automotive Applications

Bellows: AM can be used to make semi-functional bellow pieces where some flexibility is required in assembly or mating. Generally, this material/process is best to consider for applications where the part will be exposed to very few repetitive flexing motions. For projects that require significant flexing, other Polyethylene based SLS materials such as Duraform "Flex" are better suited.

Complex Ducting: By using SLS to manufacture non-structural low volume ducting such as environmental control system (ECS) ducting for aerospace and performance racing, you can design highly optimized, very complex single piece structures.



A complex, functional ducting design printed in SLS nylon

With SLS it is possible to engineer in variable wall thicknesses and increase the strength to weight ratio through the application of structurally optimized surface webbing. This is a very costly detail to apply with traditional fabrication techniques. For SLS there is no cost for complexity, parts are printed without support and to a high level of accuracy.

High detail visual prototypes: Unlike traditional prototyping methods some AM processes are able to produce multicolor designs with a surface finish comparable to injection moulding. These models allow designers to get a greater understanding of the form and fit of a part. This highly accurate method of prototyping is also ideal for aerodynamic testing and analysis as the surface finish that is able to achieve is often representative of a final part. AM is used regularly to manufacture automotive components that rely on aesthetics over function resulting in everything from wing mirrors and light housings to steering wheels and full interior dashboard designs being produced. Material jetting and SLA printing are the two most common methods used for aesthetic prototypes producing parts from a photo-activated resin.

Full colour, textured visual prototypes like this centre console can be produced via AM

Functional mounting brackets: Being able to rapidly manufacture a complex, lightweight bracket overnight is a trademark of the AM industry. Not only does AM allow for organic shapes and designs to be manufactured but AM also requires very little input from an operator meaning that engineers are able to quickly take a design from a computer to assembly in a very short amount of time. This is not possible with traditional fabrication techniques like CNC machining where a highly skilled machine operator is needed to produce parts. Powder bed fusion technologies like SLS nylon and metal printing are best suited for functional parts and offer a range of materials (from PA12 nylon to titanium).

A functional alternator bracket printed using SLS nylon

5. Current Uses of Additive fabrication

Exhausts and emissions:
melting to create cooling vents.

Fluid handling: Selective laser melting and electron beam melting are utilised with aluminium alloys. These techniques can be used to make pumps and valves within the fluid handling system.

Exterior: Using selective laser sintering, polymers are currently used to manufacture wind breakers and bumpers.

fabrication process: Hot work steels and polymers can be used together with a variety of additive fabrication processes such as selective laser sintering, selective laser melting and fused deposition modelling for prototypes, casting and customised tooling.

The above uses in the Automotive sector are used from both small companies and large international conglomerates.

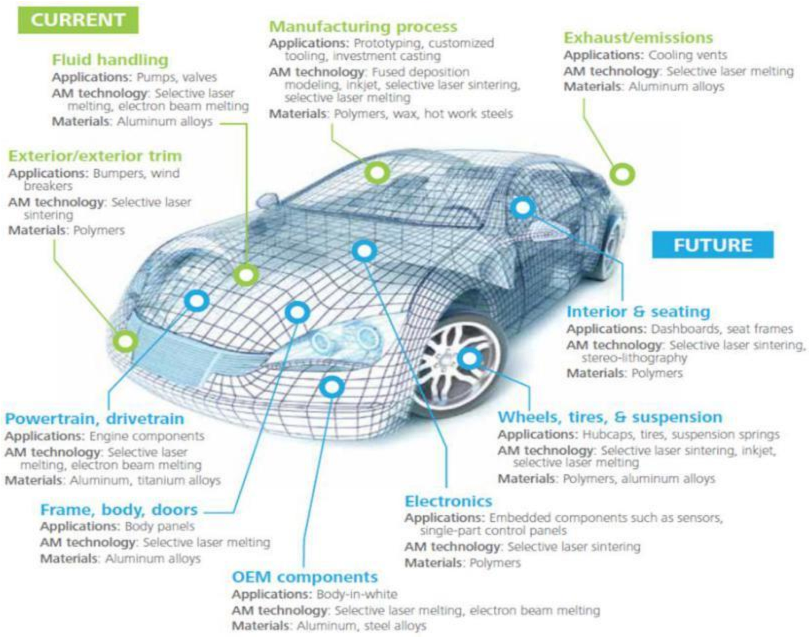
Interior and seating: Using polymers and the techniques of stereo-lithography and selective Laser sintering, dashboards and seat frames could be manufactured.

Tyres, wheels and suspension: Aluminium alloys and polymers can be manipulated with the aid of selective Laser sintering, selective laser melting and inkjet technology to create suspension springs, tyres and hubcaps.

Electronics: Selective laser sintering can be used on polymers to manufacture a range of delicate components including parts which have to be embedded, such as sensors, and single part control panels.

Framework and doors: Selective laser melting can be used on metal compounds such as aluminium alloys to create body panels, including framework and doors.

Engine components: Various functional parts of the engine can be made from metals such titanium and aluminium allows when techniques such as electron beam melting and selective Laser melting are used. [1,2]



6. Challenges for the Automotive sector

Mass production: While automotive OEMs are increasingly incorporating AM systems into development and production, one challenge to wider adoption is a production volume. With over 80 million cars produced in 2017 alone, the Automotive sector is heavily reliant on mass, series production. 3D printing should therefore not be seen as a replacement for traditional fabrication methods, well-suited to mass volumes, but as a complementary tool for lower volume, customised end parts.

Build sizes: Another challenge faced by automakers is the limited build size of many AM systems. Although larger parts can be produced with 3D printing technology, this must be done in the form of modular parts. These in turn currently have to be assembled or attached together through other processes, such as welding. However, large-scale additive fabrication is an important and growing area of research, with technologies that can support larger build sizes, such as Wire Arc Additive fabrication (WAAM) and Big Area Additive fabrication (BAAM), actively being researched and developed.

AM skills gap: Additional investment into developing AM-specific skills must also be addressed if the technology is to take off more widely. Design for additive fabrication as well as the operation and maintenance of AM systems, materials and post-processing are all vital skills that must be developed and nurtured. While much has been said on the current skills gap for AM, partnerships with universities and internal training programmes are one way of ensuring a skilled talent pool able to work with the particularities of AM technology.

Conclusion

This paper aimed to figure out the scenario of additive fabrication in Automotive sector. Improvements in additive fabrication materials and product quality are expanding the usefulness of 3D printing in auto fabrication. Some parts produced using AM technologies occasionally have tiny “voids” or pores that can weaken overall strength. In others, dimensional accuracy is not always on par with parts made with conventional fabrication processes. These and other quality issues can diminish product uniformity and consistency, a challenge for high-volume industries such as automotive in which quality and reliability are critical.

Profitability in the Automotive sector is driven by volume. Given these enormous volumes, the low production speed of AM is a significant impediment to its wider adoption for direct part fabrication. This has made high-speed AM an important area of research.

Despite of this, AM offers a versatile set of technologies that can support auto companies as they pursue performance, growth, and innovation. Traditional fabrication techniques are deeply entrenched and will likely hold a dominant position in the Automotive sector for the foreseeable future. Yet the breadth of AM capabilities—and the success of on-going efforts to broaden their application—suggest that going forward, additive fabrication will also play an important role in shaping the global automotive landscape.

Although, the doors for conventional fabrication are still open and will play a dominant role in automotive fabrication, additive fabrication is making inroads and is obvious to change the global shape of the industry.

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