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General Article

An Exploratory Study: The impact of Additive Manufacturing on the Automobile Industry

Rounak Manghnani[†*]

[†]Fr. Conceicao Rodrigues College of Engineering, Bandstand, Bandra (W), Mumbai 400050, India

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Abstract

In more recent years, the proliferation of additive manufacturing technologies, advancement in 3D printers, and creativity of designers and engineers have amplified the use of additive manufacturing in myriad automotive sectors. Additive manufacturing, mostly referred to as three-dimensional (3D) printing or Rapid Prototyping, is an emerging area in the automotive industry that could not only burgeon in customization options, but also has the potential to influence the design and manufacture of vehicles, parts, and tools, creating many new opportunities in the industry. Leading automotive manufacturers are already undergoing a paradigm shift by expanding beyond prototyping and test part production with 3D printing, and now experimenting with utilizing the technology for production of tooling and other parts to enhance the overall manufacturing processes for automobiles.

Keywords: *Additive Manufacturing, Rapid Prototyping, 3D printing, Nanotechnology, Carbon fiber, Titanium, Urbee*

1. Introduction

The automotive industry historically is a pioneer in applying new technologies to the benefit of business as a whole. Sustainable energy efficient engines, the reduction of CO2 emissions, on-going cost pressure and the continuing demand for innovation has been the think-tank of the automotive industry for decades. Additive manufacturing techniques have become the darlings of the automotive world, improving the value and functionality of existing systems. Selective laser sintering, fused deposition modeling and polyjet 3D printing are making better and faster prototyping possible both at the design phase for new product development, as well as in precision pre-production with form-fit pieces.

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. For example: instead of milling a work piece from a solid block, AM builds up components layer by layer using materials which are available in fine powder form. A wide range of different metals, plastics and composite materials may be used.

The automotive community is increasingly testing the potential of additive manufacturing to break creative barriers within the three major trends driving the industry:

- Product innovation
- High-volume direct manufacturing
- Fuel efficiency and increased performance

*Corresponding author: **Rounak Manghnani**

Today, we are on the cusp of another great leap forward in the automotive industry with manufacturing technologies that make all these goals possible at once.

AM offers maximum design freedom while allowing the creation of complex yet light components with high levels of rigidity. Additive Manufacturing enables the production of components with integrated functionality - without the need for tools, thereby cutting development and production costs.

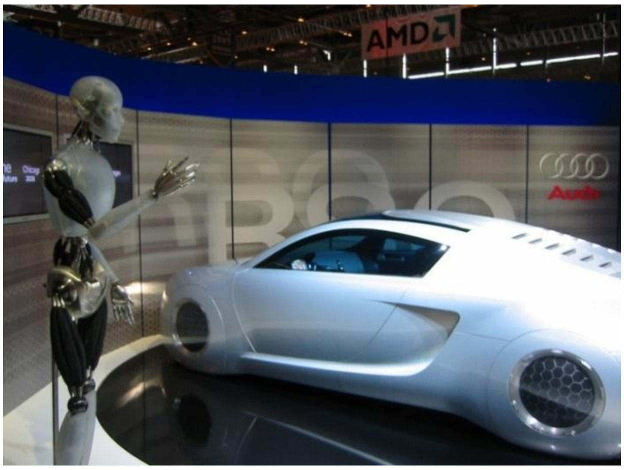

Figure 1: Audi RSQ – made with rapid prototyping industrial KUKA robots

One of the most significant challenges for AM would be multi-material printing capabilities as it would open up new design possibilities and help create innovative end products. Likewise the challenge of embedding sensors, batteries, electronics and micro-electromechanical systems (MEMS) directly into components and parts could revolutionize the manufacturing process.

Rapid prototyping based on the AM technique also signifies that the automobile manufacturers can increase the efficiency of their research and development processes, enabling them to get their products on the market more quickly. Rapid prototyping can save an automaker millions of dollars and allow production to begin months earlier. For example, Ford Motor Company used 3D rapid prototyping to create a cylinder head for its Eco Boost engines. Traditional casting of the part would take four or five months, but using 3D printing, Ford was able to design the part, print the sand mold, and cast the metal in just three months. By saving time and producing higher-quality products, AM can help automakers be more successful and retain jobs at factories.

In addition to prototyping and design, additive manufacturing techniques can be used to expedite diagnosing and resolving mechanical issues in vehicles. In 2010, engineers at Ford used additive manufacturing to address a brake noise issue in the Ford Explorer shortly before it was scheduled for launch. If additive manufacturing tools had not been available, the company may have faced a four-month delay in bringing the new Explorer to market.

Additive manufacturing is evolving from prototyping to diagnostic tools to the production of vehicle bodies, although it's still not feasible for use on a large scale. The automotive industry is rapidly changing: adding new consumer features in its products, optimizing designs, using new materials, and adopting new manufacturing methods. Even as globalization pushes automakers toward global platforms and more shared parts and components between different vehicle models, the demand for personalization and customization is still strong.

2. Scope of materials

In today's competitive scenario, it has become inevitable for small players in parts manufacturing sector to focus on developing cost-effective capabilities to succeed among their counterparts. As such, what lies ahead for AM, is the ability to develop or 3D print the parts made up of different materials that can be produced rapidly.

The challenges of using **nanotechnology** in additive manufacturing have boosted the possibility of adopting this technique in automobile industry. It has been observed that using metal nanoparticles in the sintering process greatly improves part density and decreases shrinkage and distortion of the printed parts. Embedding of these nanoparticles within the polymer materials can also improve electrical conductivity in fabricated products. Moreover, combining different nanomaterials for developing single part using AM technique would open the possibility to print complex products such as fuel cells, batteries and solar cells. With the utilization of nanotechnology, improvement in strength without a corresponding increase in weight of the product can be made possible, which could be a major motivational factor towards manufacturer's adoption of additive manufacturing.

Another noticeable advanced material for 3D printing is **carbon fiber**, which is being increasingly used by vehicle manufacturers to build car roofs, fenders and windshield frames. Carbon fiber being light in weight offers a significant strength against deformation and thankfully, AM too is taking the advantage of this material.

Nevertheless, the most appealing material for automotive product development is **Titanium**; essentially due to its useful properties such as low density, high strength and resistance to corrosion.

Having a look at the research initiatives mingling around additive manufacturing and advanced materials, there's an enormous amount of opportunities to be unlocked by the automotive sector. Tier-1 and Tier-2 suppliers should be quick enough to grab the advantages the AM technique offers and simultaneously transform their supply-chain into leaner and tighter environment.

Additive manufacturing is a technology which already has a firm footing within the automotive industry and is expected to continue to flourish.

3. Advantages

New Shapes and Structures - Additive manufacturing gives great freedom in design. The metal 3D printing can produce highly customized parts with added improved functionalities. Furthermore, the selective laser melting in particularly allows the manufacturing of components with hollows and undercuts, with thin walls and hidden voids.

Figure 2: various components manufactured using AM techniques

New Combination of Materials - Selective laser melting of different types of alloys suits perfectly the needs of lightweight applications involving vehicle and engine technology. Mixing different raw materials as titanium, aluminium, stainless steel or nickel based alloys and constantly discovering new alloys with various strengths and temperature resistance is close to impossible through conventional manufacturing methods.

Cost Efficiency – No additional tooling is required for any of the AM techniques. Therefore expensive sand-casting and die-casting applications can be finally replaced. This doesn't only shorten development times, but also considerably reduces development costs. Industrial 3D printers can finish a component within hours compared to classical manufacturing techniques that will need days till weeks from prototype to end product.

Reduced material wastage - The AM processes make it evident that absolutely no waste is generated when compared to the traditional 'subtractive' manufacturing processes which often remove up to 95 per cent of the raw material to arrive at a finished component. The additive machines only use the specific amount of material they need to make the part.

Lightweight Construction - AM also enables manufacturers to make lighter, customized tools to improve the ergonomics of manufacturing operations for workers. For example, BMW has used additive manufacturing to make custom-designed hand tools used in assembly. These tools have improved ergonomics and reduced weight, cost, and production time compared to hand tools produced using traditional methods.

Functional Integration - Functional integration means implementing as many technical functions as possible into as few parts as possible. The laser sintering technology from EOS often allows all the required parts to be produced in a single step – including functional components like springs, hinged joints or even pneumatic actuators. Thus this technology allows us to have fewer assembly components, less logistical effort and greater flexibility.

Complex Geometries – AM technology has truly made design-driven production a reality. Innovative EOS technology offers designers the greatest possible freedom and enables mind-boggling complex structures to be manufactured. Every possible form that can be constructed with a 3D CAD program can also be produced using innovative laser sintering technology. In sum, the more complex the geometry of a component, the more worthwhile Additive Manufacturing can be.

4. Applications

Exhausts and emissions - Aluminium alloys are typically used for this application, via selective laser melting to create cooling vents.

Fluid handling - Selective laser melting and electron beam melting are utilized 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.

Manufacturing process - Hot work steels and polymers can be used together with a variety of additive manufacturing processes such as selective laser sintering, selective laser melting and fused deposition modeling for prototypes, casting and customized tooling.

5. Future Works

Although the automotive industry has been quick to adopt additive manufacturing and to use it in a variety of applications, there's far more possibilities which lie ahead, particularly with the use of different materials. Here's some of the new ways that additive manufacturing is expected to be used in the very near future.

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

Tires, 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, tires 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.

Figure shows the chassis model made using Fused Deposition Modeling technique

"FDM technology made it easy and efficient to make design changes in the Urbee along the way," said Kor. "

URBEE is a return to fundamentals, and a rethink of traditional automotive design and manufacturing. As a species endangered by our own actions, we must quickly learn to stop burning fossil fuels. Surely, the ultimate goal of design is to serve the 'public good'. Therefore, corporations and individual designers have a responsibility to offer products that are not only useful, but in balance with the environment.

Urbee became the first car to have its body 3D printed, and is the greenest practical car ever made.

Conclusion

Automotive manufacturers were among the earliest adopters of additive manufacturing/3D printing (3DP) technology, but for decades have relegated 3D printing technology to low volume prototyping applications, while other industries have taken additive manufacturing to new levels. But today, an explosion of growth in utilization of 3D printing from automotive manufacturers is powering an evolution in automobile design and production.

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

For the automotive industry, the advances made in the field of AM have paved the way for newer designs; cleaner, lighter, and safer products; shorter lead times; and lower costs.

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