Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 02 ISSUE 05, 2024

3D Printing in Automotive

Matthew N. O. Sadiku
Department of Electrical & Computer Engineering, Prairie View A&M University,
Prairie View, TX USA

Uwakwe C. Chukwu
Department of Engineering Technology, South Carolina State University, Orangeburg, SC, USA

Janet O. Sadiku
Juliana King University, Houston , TX, USA

Abstract:

Traditional methods of car design, once seen as the pinnacle of engineering artistry, are now being overtaken by digital counterparts. Standing tall at the helm of this digital revolution is the 3D printing technology. The technology has given rise to spectacular achievements in the automotive industry, with widespread production of car parts and close to manufacturing of the whole cars. In many ways, 3D printing is influencing but redefining the entire spectrum of vehicle design and manufacturing. The transition from clay to CAD has been a paradigm shift in design philosophy itself.

Affordable 3D printing services are playing a huge role in the development and maintenance of consumer vehicles. The possibilities offered by 3D printing technologies have had significant influence on the automotive industry. This paper explores the significant impact of 3D printing on the automotive industry.

Keywords: 3D printing (3DP), additive manufacturing (AM), 3D printing in automotive.

INTRODUCTION

Since Henry Ford installed the first assembly line for the mass automobile production in December 1913, the automotive industry has been a bellwether for innovation in modern manufacturing. The automotive industry remains fiercely competitive worldwide. The industry aims at creating new and improved ways to make cars faster, lighter, and more cost-effective. Traditionally, when the engineer designs a car, he needs to start with a drawing, and then using the design software to visualize the appearance of the car into an accurate data and 3D model.

The traditional automotive manufacturing is typically shown in Figure 1 [1]. Traditional methods for mass-production of cars such as injection-molding plastic and casting metal might still be more cost-effective, but 3D printing can play a role in the production of vehicles. The growth of the 3D printing market in the automotive sector is driven by the increasing need for low cost and more efficient technology to produce complex and high-quality products which traditional methods cannot fulfill.

Major companies operating in the automotive 3D printing market includes Local Motors, EDAG, Startasys, Autodesk, 3D systems, Porsche, Formula 1, Ford, BMW, Volkswagen, Volvo, Nissan, Lotus, McLaren, Geely, TATA, Rolls Royce, XEV, Tesla, and more. Figure 2 shows Toyota automotive plant [2]. Porche was the first automotive manufacturing company to jump on the bandwagon of 3D printing. Only the best companies have remained on the market, those who are capable to deliver devices at affordable prices. Automotive manufacturers must balance efficiency, lean manufacturing, production costs, sustainability, and agile design processes.

Back in 2014, Local Motors introduced its first 3D printed electric car to the world. It was named “Strati” and could be 3D printed in less than a day using the giant BAAM (Big Area Additive Manufacturing) 3D printer developed by Cincinnati Incorporated and operated by Oak Ridge National Laboratory. Another contemporary specialist in the production of 3D printed vehicles is California-based Divergent Technologies. Unlike Local Motors, however, Divergent isn’t attempting to 3D print an entire car. Car manufacturers like Ford are already running preliminary trials [3].

WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceutics, consumer products, education, entertainment, medicine, space missions, the military, chemical industry, maritime industry, printing industry, and jewelry industry [4]

A 3D printer works by “printing” objects. Instead of using ink, it uses more substantive materials–plastics, metal, rubber, and the like. It scans an object–or takes an existing scan of an object–and slices it into layers, which can then convert into a physical object. Layer by layer, the 3D printer can replicate images created in CAD programs. In other words, 3D printing instructs a computer to apply layer upon layer of a specific material (such as plastic or metal) until the final product is built. This is distinct from conventional manufacturing methods, which often rely on removal (by cutting, drilling, chopping, grinding, forging, etc.) instead of addition. Models can be multi-colored to highlight important features, such as tumors, cavities, and vascular tracks. 3DP technology can build a 3D object in almost any shape imaginable as defined in a computer-aided design (CAD) file. It is additive technology as distinct from traditional manufacturing techniques, which are subtractive processes in which material is removed by cutting or drilling [5].

3D printing has started breaking through into the mainstream in recent years, with some models becoming affordable enough for home use. Many industries and professions around the world now use 3D printing. It plays a key role in making companies more competitive. The gap between industry and graduating students can be bridged by including the same cutting-edge tools, such as 3D printing, professionals use every day into the curriculum. There are 3D printed homes, prosthetics, surgical devices, drones, hearing aids, and electric engine components. 3D printing has been applied in many fields, as shown in Figure 3 [6]. As shown in Figure 4, 3D printing involves three steps [7]. A typical 3D printer is shown in Figure 5 [2].

3D PRINTING IN AUTOMOTIVE

The automotive industry is facing demands on all fronts: the demand for newer, better-performing vehicles, as well as the need to optimize production and streamline supply chains and logistics. One technology that is helping to meet these challenges is 3D printing. Advancements in 3D printing technology in the automotive industry have changed the ways products are manufactured, developed, designed and distributed. 3D printers use a computer-aided design (CAD) to create three-dimensional objects through a layering method. It involves layering materials such as plastic, composites, or even bio-materials to create the objects. It takes a combination of top-of-the-line software, powder-like materials as well as precision tools to create a three-dimensional object from scratch.

3D printing in the automotive sector is not a one-size-fits-all approach. There are multiple techniques and methodologies, each tailored to specific needs. Some of the most popular methods include [8]:

- *Stereolithography* (SLA): This is one of the earliest techniques in 3D Printing for prototyping and it involves using a laser to solidify liquid resin layer by layer. SLA technology is the basic method of rapid prototyping, developed in 1984 by Charles Hull. This method uses the photopolymerization process. SLA as a 3D printing technique is very fast and very accurate. It allows one to obtain ready-made molds of uniform quality.
- *Fused Deposition Modeling* (FDM): This is a method where material is extruded through a heated nozzle, building the object layer by layer. It is particularly popular for producing larger parts. This is one of the oldest 3D printing techniques and therefore it is the most common and cheapest type of additive manufacturing technology. FDM technology has found application in many industrial fields, including the aerospace, automotive, marine, sports equipment, electrical and medical industries. In the automotive industry, FDM is mainly used in the printing of instruments, handles, and prototypes.
- *Selective Laser Sintering* (SLS): This method is based on the successive melting and sintering of polymers or ceramic granules using a programmed laser beam with layer-by-layer production, It involves using a laser to fuse powdered materials, such as nylon or metal, into a solid structure. Given its capacity to produce high-strength parts, SLS finds substantial utility in automotive applications.

While various materials can work for 3D printing in automotive, we consider only common three types that can work with almost all types of 3D printers [9]:

1. *ABS*: Acrylonitrile Butadiene Styrene (ABS) is the most popular filament in 3D printing automotive parts. It can withstand a wide temperature range (-20°C – 80°C) for extended periods.

2. *PLA:* This is more suitable for 3D printers without heated enclosures and would not warp easily. However, it is not as shock-resistant as ABS, and its transition-to-glass temperature is lower.

3. *PETG:* PETG is essentially an upgrade on PLA. It is suitable with 3D printers that do not have printer beds and is less prone to adhesion. The only problem you might have with this filament is its occasional poor adhesion characteristics

APPLICATIONS

Up until a few years ago, 3D printing has been used for making one-off prototype parts for concept cars, but today, 3D printing is now starting to be used to produce good quality car parts. 3D printing has been an important tool for automotive manufacturers to prototype and validate automotive components before production . It can add enormous value to supply chains, unlocking a broad spectrum of production applications. 3D printing can help with many different applications through many materials. The following applications are common [10].

1. *3D Printing Prototyping:* Prototyping is one of the most critical stages of a manufacturing process in the automotive industry. Automotive manufacturers spend a significant amount of time and money on prototyping new parts or vehicles. Before the advent of 3D printing technologies, prototyping used to be a time consuming and expensive affair. With 3D printing, manufacturers can quickly and cost-effectively produce prototypes, allowing them to test and refine designs more efficiently. 3D printing allows the creation of complex geometries that would be difficult or impossible to produce with traditional methods. With 3D printing, manufacturers can quickly and cost-effectively produce prototypes.

2. *3D Printed Parts:* Historically, inventory in the automotive industry conjured images of spare and replacement parts physically stacked in massive warehouses, taking up space until needed. 3D printing is more often used in manufacturing the final car parts. The leaders in using the additive technology to manufacture final car parts include Volkswagen, BMW, and Ford. These established car manufacturers apply 3D printing at their production plants on a large scale. Divergent 3D combines generative design and 3D printing to create custom-tailored components for auto parts manufacturers. 3D-printed parts for cars are shown in Figure 6 [11]. The YoYo is the first “mass market” 3D printed electric car that is now shipping to customers, as shown in Figure 7 [12]. It was developed by electric car manufacturer XEV and filament manufacturer Polymaker.

3. *Building Racing Cars:* Racing car can be constructed using 3D printing technology. Additionally, the use of that 3D printer enabled the creation of other parts and models, including aerodynamic elements dies and battery packs casing, which are independently prepared components needed for the racing car. 3D printing is a toolless fabrication process that is a great match for race cars and motorsports. It is a powerful tool to achieve low-volume production and custom manufacturing rapidly and cost-efficiently.

4. *Engine Performance*: Engine performance can be improved with 3D printed iterative designs. As shown in Figure 8, Forge Motorsport, which makes aftermarket parts for performance cars, uses 3D printing to prototype their parts [12].

5. *Car Body:* Some companies created the 3D-printed chassis, body, and bumper A typical 3D-printer car body is shown in Figure 9 [13].

6. *3D-Printed Custom Seats:* 3D printing is commonly used in the automation industry to customize the process of part production to fit different drivers or vehicles. The German automaker Porsche has recently introduced a new concept for sports car seats using 3D printing. Porsche wants to expand seat customization beyond firmness and color by personalizing the seat to customer’s specific body contour. 3D printing currently remains the only technology that can enable this level of customization. Removable seats allow customers to choose their favorite interior colors and materials to print. Figure 10 shows 3D-printed custom seats developed by Porsche [14].

BENEFITS

Additive manufacturing reduces production time as multiple stages that can be combined into a single production step. This also eliminates the product assembly stage and reduces logistic transport costs. There are a lot of benefits for using 3D printing for the production process of making cars. 3D printing is also revolutionizing classic car restoration. Although you would not be able to buy a 3D printed car at the dealership yet, 3D printing has for many years been a vital part of the development process for automobiles. Other benefits of 3D printing in automotive industry include the following [15]:

1. *Rapid Prototyping:* Speed-to-market is a business attribute that can be the difference between success and failure in many industries, especially the automotive industry. Prototyping used to be time-consuming and expensive as a product goes through many iterations. Legacy prototyping methods, such as machining or injection molding, are expensive and soak up too much time to produce a single prototype. 3D printers use materials suitable for cost-effective prototyping and automotive applications. Designers have been able to produce same-day prototypes.

2. *Improved Design:* 3D printing allows automotive engineers to design and modify complex, organic shapes that would otherwise be too difficult (if not impossible) to produce using traditional manufacturing methods.

3. *Customization:* The ability to create highly customized parts is essential in automotive manufacturing. Such customization is not otherwise possible with traditional manufacturing methods which depend on legacy methods of mass production, outsourcing, long lead time, and higher cost. 3D printers enable an agile development and production process, focusing on high craftsmanship, customization, and performance. The possibilities for car customization with 3D printing look set to expand at a much greater pace over the next few years.

4. *Weight Reduction:* In car production, the car's weight determines how fuel efficient it will be. The automotive industry is constantly trying to reduce the overall weight of its parts and designs. By utilizing lightweight materials, 3D printing facilitates the production of parts with reduced weight, contributing to fuel efficiency and lower emissions. 3D printers enhance this effort by utilizing lightweight materials such as engineered plastics and composites. This results in a significant weight reduction in vehicles, improved fuel efficiency, and reduced emissions.

5. *Sustainability:* The automotive industry always seeks to manufacture with utmost efficiency. 3D printers, again, are right in line with such objectives. Environmentally friendly materials may be tried and used, with less waste. When waste is reduced, and production is much more efficient, the overall manufacturing line becomes more sustainable. The automotive industry, often scrutinized for its environmental footprint, finds in 3D printing a more eco-friendly ally.

6. *Increased Efficiency*: The precise nature of 3D printing enables the production of automotive parts on-demand. This eliminates the need for large inventories of spare parts. This saves manufacturers time and money and reduces the risk of stock-outs of some parts, while maintaining the leanest inventory.

7. *Freedom of Design:* Additive manufacturing allows freedom of design and production of different products in any sequence. Hence, customized products are possible and automotive companies are able to include customers in the development process.

8. *Parts for Classic Cars:* One problem with classic cars is that it is hard to find spare parts for cars that are no longer being made. The older the vehicle, the bigger the challenge. 3D printing allows people to manufacture spare parts that we are unable to find anymore. Customized parts are more affordable than getting it from a garage.

9. *Cost Savings:* Making good cars at optimal costs is vital to making profits. Money, as the lifeblood of business, finds a healthier flow with 3D printing technology. The direct cost savings are evident. There is no need for expensive molds and reduced material wastage. The ability to produce

on-demand with 3D printing for prototyping means less capital is tied up in stock. As the technology becomes more accessible, even smaller manufacturers can embrace 3D printing for prototyping, democratizing the world of automotive design and production.

10. *Amalgamation:* Perhaps the most significant benefit of 3D printing in the automotive industry is the amalgamation of multi-part assemblies into one single piece.

11. *Design Flexibility:* 3D printing allows automotive engineers to bring their most complex and innovative designs to life without the constraints of traditional manufacturing methods.

CHALLENGES

Although 3D printing offers a world of possibilities in automotive design, it is not without its challenges. Finding the perfect material for a specific application can be a tricky endeavor, as not all materials offer the right mix of durability and flexibility. 3D printing is only a few decades old, while traditional manufacturing has gone through centuries of optimization. Other challenges of 3D printing in automotive industry include the following [16]:

1. *Size:* Size poses a challenge. While it is easy to print smaller parts using 3D printing, creating larger components or entire vehicle frames remains a daunting task.

2. *Material Limitations:* Although the range of 3D printable materials is expanding, some materials may not yet meet the strict requirements of certain automotive applications. A number of materials, including alloyed metals, are difficult for 3D printers to process at this point in time.

3. *Post-Processing Requirements:* Depending on the printing method and material used, post-processing steps such as surface finishing and inspection may be necessary, adding to production time and costs.

4. *Production Speed:* While 3D printing offers rapid prototyping benefits, mass production of certain automotive parts may still be slower compared to traditional manufacturing processes.

CONCLUSION

The automotive industry is on the brink of a manufacturing revolution with the emergence of 3D printing technology. 3D printing is increasingly being explored across all areas of automotive production. As the understanding of the value 3D printing continues to spread through the automotive industry, additive technology will continue to reshape the way we design, build, and maintain vehicles around the world. Increasing number of government initiatives in 3D printing manufacturing technologies and consumers demand for new innovations and lower prices are further propelling the automotive 3D printing market forward.

3D printing in the automotive industry is booming. Today, automakers are increasingly integrating 3D printing into their production lines. The use of 3D printing for end-part production is increasingly gaining traction. One could say the future is already here, as 3D printing is being used to produce complete cars – everything from utility concept cars to sporty electric cars. The future of automotive prototyping is lit with innovations.

REFERENCES

1. “Automotive 3D printing market to reach over US$8 Billion by 2024,”

   https://www.equipment-news.com/automotive-3d-printing-market-to-reach-over-us8-billion-by-2024-2/

2. “7 Examples of 3D printing applications in automotive industry,” February 2023,

https://zortrax.com/blog/7-examples-of-3d-printing-applications-in-automotive-industry/

3. "3D printing service in the automotive industry," August 2021, Unknown Source
4. F. R. Ishengoma and T. A. B. Mtaho, "3D printing: Developing countries perspectives computer engineering and applications," *International Journal of Computer Applications*, vol. 104, no. 11, October 2014, pp. 30-34.
5. M. N. O. Sadiku, S. M. Musa, and O. S. Musa, "3D Printing in the chemical industry," *Invention Journal of Research Technology in Engineering and Management*, vol. 2, no. 2, February 2018, pp. 24-26.
6. M. Oleksy, K. Dynarowicz, and D. Aebisher, "Rapid prototyping technologies: 3D printing applied in medicine," *Pharmaceutics*, vol. 15, no. 8, 2023.
7. D. Pitukcharoen, "3D printing booklet for beginners,"

   https://www.metmuseum.org/-/media/files/blogs/digital-media/3dprintingbookletforbeginners.pdf
8. M. Elgendy, "The impact of 3D printing on prototyping in the automotive industry," October 2023,

   https://www.azom.com/article.aspx?ArticleID=23053
9. "3D printing car parts: A complete guide for 3D printing in the automotive industry," August 2022,

   https://autoprotoway.com/3d-printing-car-parts-in-the-automotive-industry/
10. "3D printing in automotive industry,"

    https://3dgence.com/america/3dnews/3d-printing-in-automotive-industry/
11. "Stratasys' largest platinum partner in Asia,"

    https://deed3dprinting.com/
12. "Road to the 3D printed car: 9 Ways 3D printing is changing the automotive industry" November 2022,

    https://formlabs.com/blog/3d-printed-car-how-3d-printing-is-changing-the-automotive-industry/
13. T. Horton, "3D printing in the automotive industry,"

    https://additive-x.com/blog/3d-printing-in-the-automotive-industry/
14. "10 Exciting examples of 3D printing in the automotive industry in 2021," May 2019,

    https://amfg.ai/2019/05/28/7-exciting-examples-of-3d-printing-in-the-automotive-industry/
15. "6 Ways 3D printers changed automotive manufacturing,"

    https://www.stratasys.com/en/resources/blog/how-3d-printers-changed-automotive-manufacturing/
16. Mitras 3D, "Automotive applications of 3D printing," July 2023

    https://www.mitras3d.com/html/blogs/automotive.html

ABOUT THE AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics, computer networks, and marriage counseling. He is a life fellow of IEEE.

Uwakwe C. Chukwu is a professor in the Department of Industrial & Electrical Engineering Technology of South Carolina State University. He has published several books and papers. His research interests are power systems, smart grid, V2G, energy scavenging, renewable energies, and microgrids.

Janet O. Sadiku holds bachelor degree in Nursing Science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and doctoral degree from Juliana King University, Houston, TX in December 2023. She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, Canada, and United States. She is a co-author of some papers and books.

Figure 1 The traditional automotive manufacturing [1].

Figure 2 Toyota automotive plant [2].

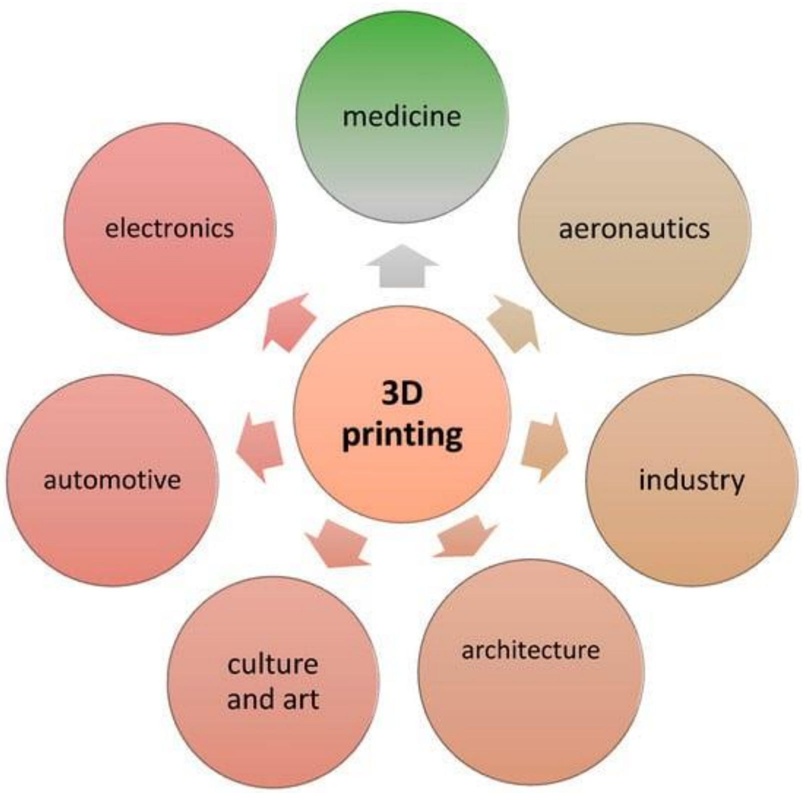

Figure 3 Typical applications of 3D printing [6].

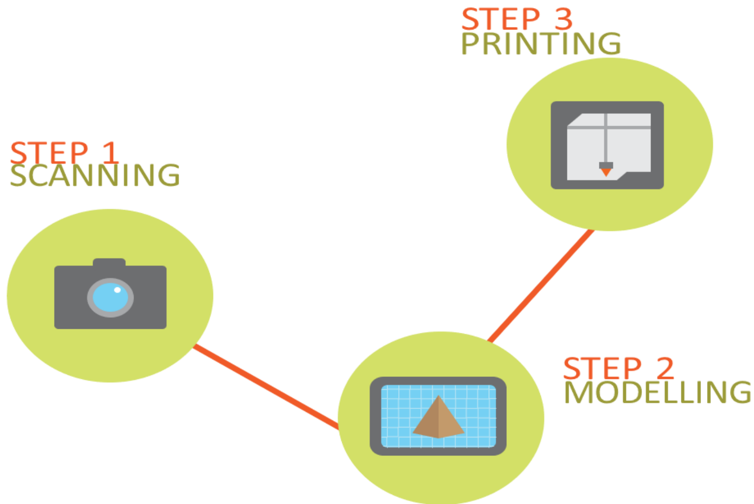

Figure 4 3D printing involves three steps [7].

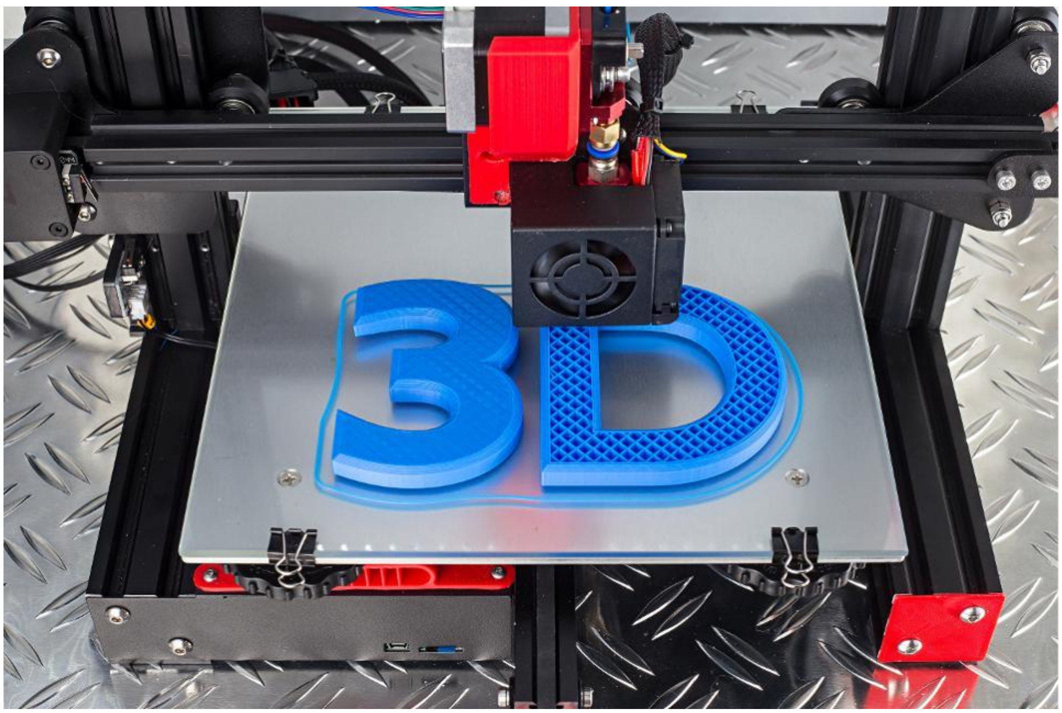

Figure 5 A typical 3D printer [2].

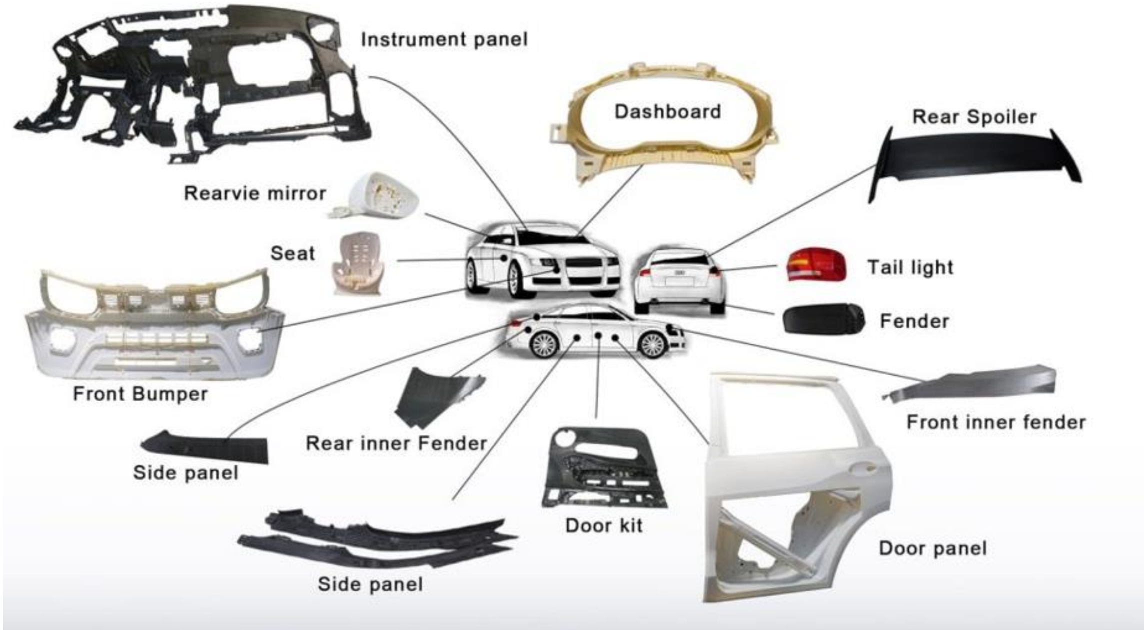

Figure 6 3D-printed car parts [11].

Figure 7 The first “mass market” 3D printed electric car by YoYo [12].

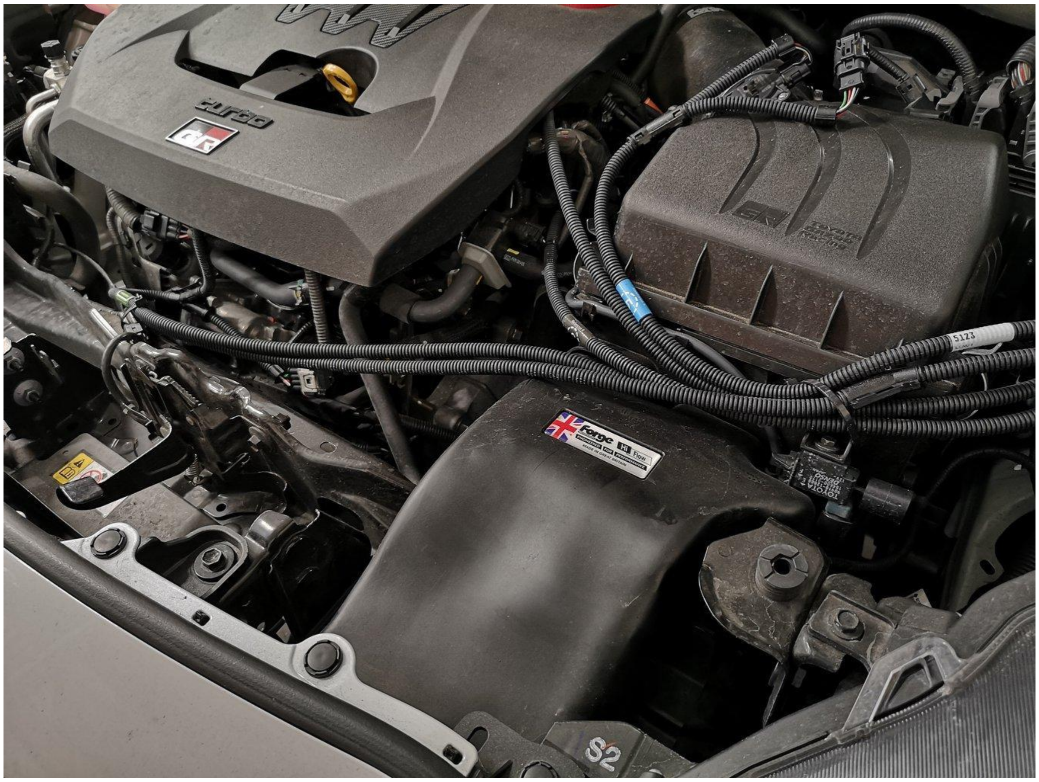

Figure 8 Forge Motorsport uses 3D printing for car performance [12].

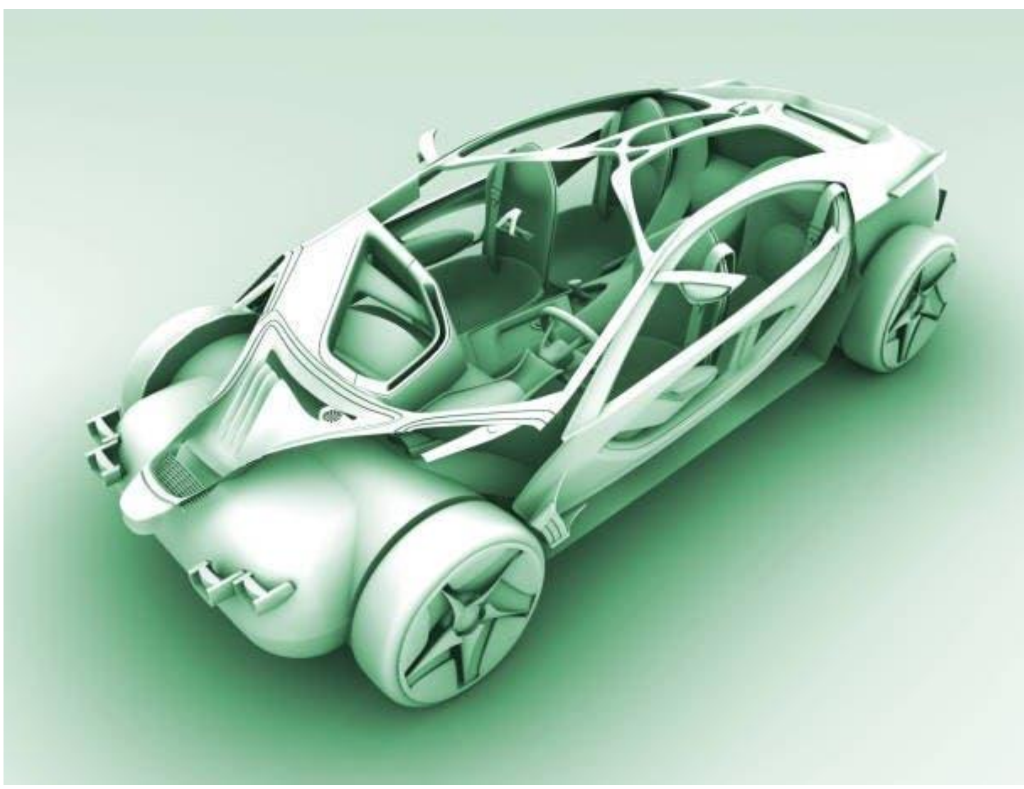

Figure 9 A typical 3D-printed car body [13].

Figure 10 3D-printed custom seats [14].