3dpbm | Insights

Automotive AM

Paving the road for more efficient production and vehicles

January 2022

About
3dpbm is a leading media company providing insights, market analysis and B2B marketing services to the AM industry. 3dpbm publishes 3D Printing Media Network, a global editorial website that is a trusted and influential resource for professional additive manufacturing.

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Welcome

The start of a new year also means the beginning of a new eBook series at 3dpbm. To kick the new AM Focus eBook series off, we are looking at the automotive industry.

In our 2020 and 2021 Automotive AM Focus eBooks, we covered diverse topics, such as automotive restorations and market predictions, and spoke to leaders in the automotive industry, including General Motors and Jaguar Land Rover. This year, we present new insights and features that showcase how AM is today shaping automotive production practices.

In our analysis chapter, we zoom in on Electric Vehicles (EVs), taking stock of how AM is already playing a part in their development and production and where it could be a potential game-changer (i.e. batteries). We are also excited to present an innovative automotive case study by OECHSLER, an exploration of Daimler's growing adoption of 3D printing for spare parts and other applications, insights from HP on its automotive partnerships and an exclusive interview with Czech carmaker Škoda Auto on the transformative influence 3D printing has had on its production workflows.

We hope you enjoy our first eBook of 2022 and be sure to watch this space every month for more AM Focus publications.

Tess Boissonneault
Editor in Chief, 3dpbm

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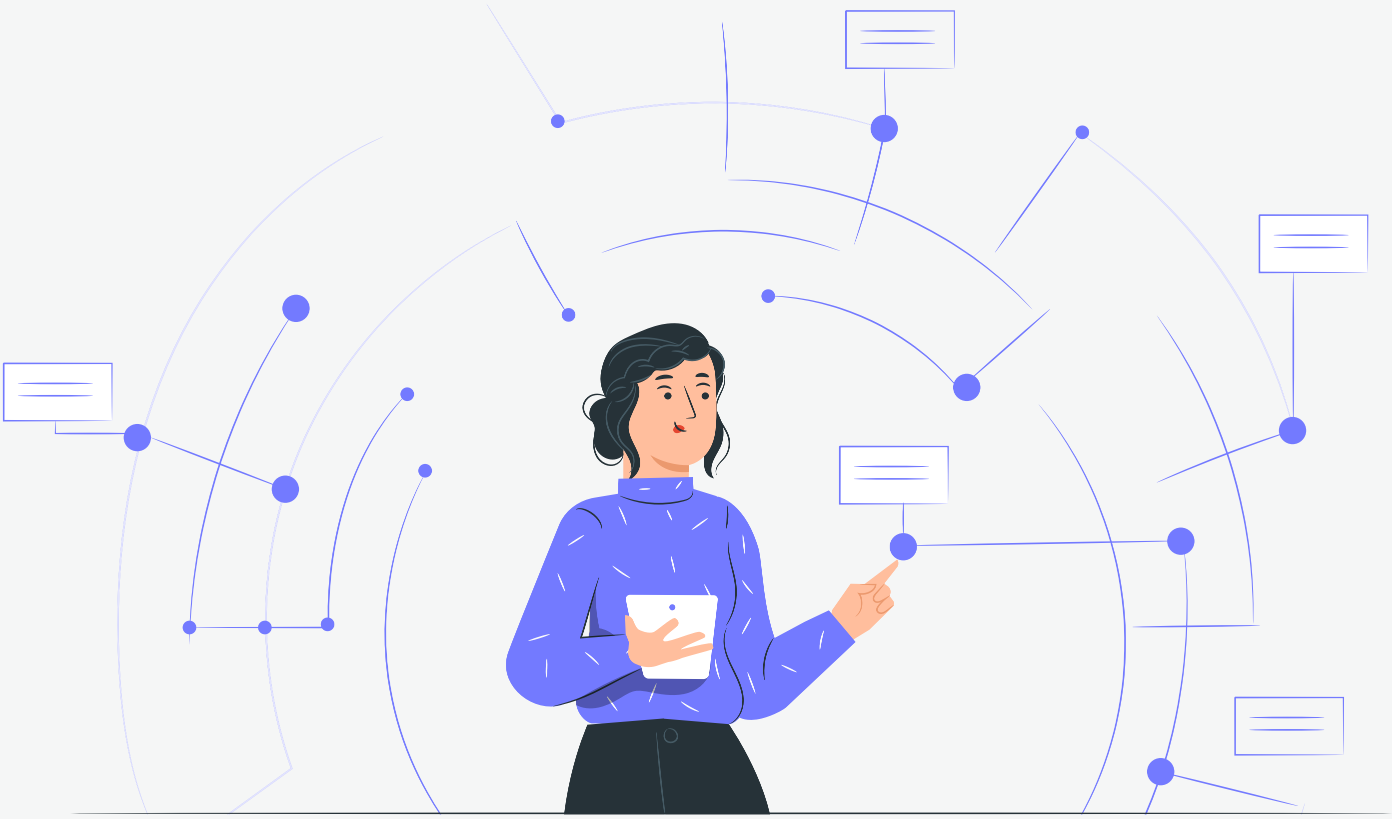

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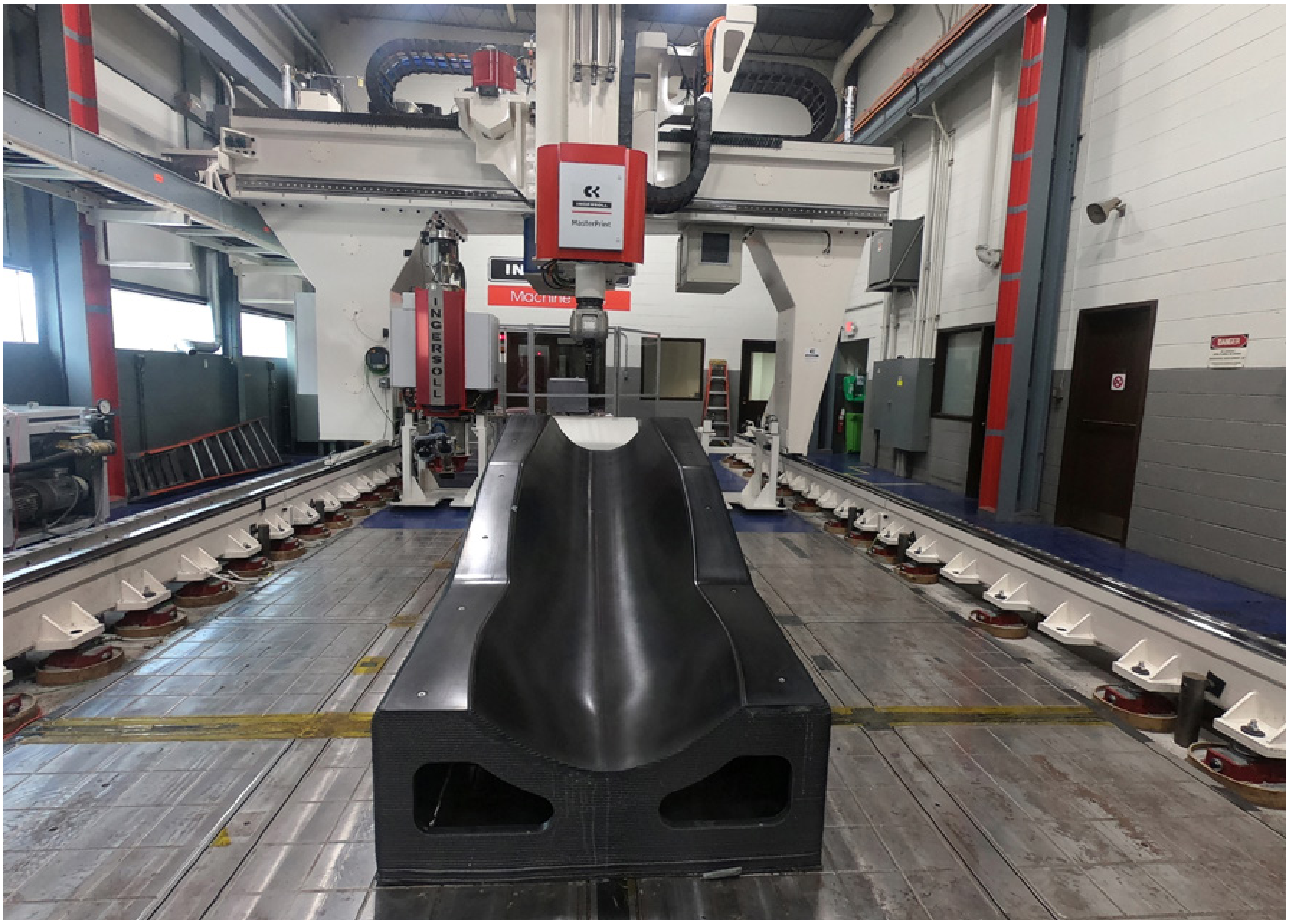
Image: Tesla

ANALYSIS

How much will the EV revolution drive AM adoption in automotive?

It goes both ways: from faster development to ASSBs, AM technologies are going to be a key enabler in the electrification of mobility

Image: Ingersoll



Ingersoll's Masterprint technology is enabling the production of large-format prototypes, tooling and parts for EVs.

The first and foremost advantage of AM is that it can offer better value in low-volume production with quicker speed to market. This is a key advantage to all ensuing technologies and new products challenging the established status quo. The space industry is a clear indication, with dozens of new space startups able to bring products to market thanks to AM eliminating the need for scale economies. Something similar can happen in the EV segment as well, with new startups able to enter the market and large companies more open to experimentation and innovation.

With lower demand and more customized products, the value of using 3D printing increases. With polymers, AM parts can be competitive up to batches of 100,000 units. That goes for small intricate components but LFAM technologies are becoming more competitive, especially for short batches of parts, needed as a new product is first introduced to the market. This is an ideal setup for startups and new projects.

As EV volumes increase so will the productivity of AM machines. This is certainly true today for polymer and composite parts but in the near future it could become even more viable for metal parts. At the same time, it is likely that EVs will use more composite and polymer parts for metal replacement than current ICE vehicles.

Fast prototype iterations via increasingly accessible extrusion, stereolithography and laser sintering technologies, including full size concepts via LFAM

> “ As EV volumes increase so will the productivity of AM machines. This is certainly true for polymer and composite parts but in the near future it could become even more viable for metal parts ”

technologies, such as Massivit’s and Ingersoll Masterprint’s, and custom tooling (including very large composite tools), are all key elements making new vehicle development faster and more cost effective.

Another element where AM could help accelerate the EV industry is digital warehouses (and on demand spare part production. Production can be distributed to any location with digital manufacturing systems in place by merely sending a file, enabling a more efficient and sustainable supply chain. Combined with the simplified production process for EVs, with many fewer moving parts overall, this could lead to local micro EV factories. In addition, as many new players in the electric vehicle scene don’t have long-standing supply chain dynamics that they need to abide by, they are likely to be more open to adopting a digital supply chain dynamic.

The cost advantage of 3D printing should be quantified by looking at the entire value structure around it, but there are some parts in particular where these benefits may be more evident. Let’s take a look at them.

EV car body parts

EV firm Local Motors was the first to demonstrate the ability to 3D print entire car bodies using LFAM composite 3D printing technologies. The company just shut down, failing to successfully enter the competitive and challenging autonomous vehicle market however AM offered the company the best chance possible for succeeding.

Local Motors has relied heavily on 3D printing to develop and manufacture its electric shuttle vehicle, the Olli.

Image: Local Motors

After 3D printing the first entire car bodies, the Strati and its successors, starting in 2014, Local Motors followed up with the Olli smart EV shuttle, which integrated an entirely 3D printed body. For example, the team 3D printed Olli's upper and lower structures from recyclable polycarbonate material from SABIC (LNP THERMOCOMP), using LSAM large format extrusion 3D printing technology from Thermwood.

The Local Motors shut down is directly related to a lack of demand for AVs rather than an inability to meet that demand in a cost-effective way: installing its vehicles in 24 sites around the world to date was not enough to support and finance its continued activity. Yet Local Motors has been responsible for a huge number of AM industry firsts, including the use of LFAM technologies (from Cincinnati Inc first and from Thermwood later) and LFAM composite material from SABIC, to produce large size automotive final parts. If anything, Local Motors should have been truer to its nature as a 3D printing company, continuing to emphasize and develop this production method and targeting other LFAM applications along with the OLLI to expand its business.

While AM production of EV body components has not yet made it to the mass production, other companies are following in the footsteps of Local Motors or at least they intend to.

One of them is XEV, an Italian-Chinese company that developed and commercially launched the YOYO, its first fully electric city car (it can be driven from the age of 16 with a B1 license). The company uses the BigRep PRO LFA 3D printer to print customizable car body parts although it's goal is to use AM for a lot more elements of the car's body. XEV's 3D printing production line intends to virtually eliminate the need for limited and resource-intensive tooling, resulting in a flexible and efficient manufacturing process. This technology allows for fewer body components, faster technical updates and significantly reduced production cycles. It also dramatically reduces production costs meaning the savings can be passed on to customers, with the result that the YOYO is available for just over €10,000 in Italy (with EV incentives). Thanks to a pre-designed and standardized chassis, the 3D printed parts can be modified and changed with significantly less re-engineering. For the final surface quality, the 3D printed parts also go through an automated robotic milling process to guarantee a very smooth surface.

These are just two of the most evident examples of AM adoption in EV body parts production. Other more conceptual projects have involved both large automakers and small, innovative startups. In general, the larger companies, such as FCA and MINI, are more conservatively looking at AM for smaller parts and customizations of their upcoming EVs, while some innovative startups are looking at modular elements to increase functionality. For example Swiss automobile manufacturer Rinspeed proposed a unique vision for the future of cars, driven by modularity and efficiency: its MetroSnap concept is an electric and modular vehicle with 3D printed parts that can fulfill multiple functions. The vehicle is based on the company's innovative concept in which the chassis and body are separated, enabling the body of the vehicle to be swapped out. The patent-pending swappable system enables users to use the electric vehicle for multiple functions, whether it be transporting people or goods.

AM potential

Medium term and accelerating, targeting 2-3% of EV market penetration by 2030

AM applications in the production of car body parts for EVs started out as a long term opportunity but it is rapidly getting closer, as EVs continue to grow in adoption, opening new manufacturing

Image: XEV

XEV developed the first fully electric city car, using 3D printing for customized car body parts.

opportunities. Because EVs are expected to have increasingly fewer parts in the future, 3D printing will have a more significant penetration in the EV car body parts production market than in traditional vehicles.

More specifically lightweighting—one of the primary advantages of implementing AM—is fundamentally important for EV development, as any weight saved or improved distribution of weight helps prolong battery life. 3D printing can help to develop new part geometries that can make the EV lighter without sacrificing safety. As demonstrated in aerospace part development, redesigning parts for AM with parametrically optimized geometries can eliminate material—reducing the weight of the vehicle—while maintaining structural integrity needed for safety.

AM also offers the ability to eliminate tools and condense several parts into one. This can be particularly beneficial for companies developing new designs or new startup companies looking to enter the market.

EV auxiliary electrical systems and electronics

This market includes audio/video devices, cameras, low-voltage electrical supply systems, gauges and meters, ignition system components, lighting and signaling systems, as well as several different types of sensors, electrical switches, wiring harnesses and, of course, electronic enclosures that will need to be integrated into the EV's structure. In terms of applications, AM is already used significantly in the production of custom electronic enclosures and switches. Other key applications include the use of copper, in both metal PBF and bound metal/binder jetting technologies.

AM part production firms and AM factories have demonstrated the cost efficiency of 3D printing electronic enclosures (and related products). An advantage of high-volume 3D printing is its ability to produce custom parts at scale without the cost of molds. This freedom allows for products to evolve during production and reduces inventory requirements. Electronic enclosures cannot accommodate the millions of PCB designs that are used in cars, which feature more and more electronic elements—a trend that will increase by several orders of magnitude with EVs and with increased demand for customization. With 3D printing, enclosures can be produced on demand, as the parts are sold, with no molding cost.

Nano Dimension has been specializing in the development and production of electronic components via 3D printing. With the rise in demand for Smart Mobility and internet-connected devices (IoT), the polymer-based industry is searching for new ways of developing innovative and functional devices, with applications that offer efficiency, improved performance and affordability. Nano Dimension's DragonFly System is an ideal technology to accelerate in-house electronics development and increase the design freedom to develop new products, quickly and cost effectively.

Additive electronics enable fast prototyping and manufacturing of conductive components, encapsulated sensors and smart surfaces, all of which can offer car makers the flexibility of printing an entire circuit board or just part of a connector, as well as the ability to develop the RF and digital sections of the board in parallel to test concepts on the fly. All of this can lead to the development of customized electronics, including embedded sensors, conductive geometries, molded connected devices, PCBs and more, that can become the backbone to innovative automotive components that will enhance driver experience.

Similarly, Rogers Corporation worked with Fortify3D to develop the Radix 3D Printable Dielectrics family of products, with the first available material featuring a dielectric constant of 2.8 and low loss characteristics at microwave frequencies. These printable dielectric materials give radio frequency (RF) designers unprecedented design freedom in creating new components, such as automotive radars applications for automotive braking and collision avoidance, eliminating the need to consider typical manufacturing design constraints.

AM potential

Short term and moderate at up to 2-3% market penetration by 2030

The application of AM in the production of electronic components—especially enclosures and switches—is expected to increase rapidly to serial production levels, as combustion engines become more compact and EVs become more streamlined. Polymer 3D printing with high-temperature materials already enables the production of several under-the-hood components. With EVs and, in general, smart vehicles, adoption of AM is expected to be even more significant, as temperatures become less of an issue (outside of batteries), and the need for complex electronic parts increases.

Electrified powertrain parts and AM applications

Grandview Research estimates the global electric powertrain market size to be around $20 billion in 2020, growing at a compound annual growth rate of 13.6% from 2020 to 2027 to nearly $40 billion by 2027.

> “ The use of AM in the production of electronic parts—especially enclosures and switches—is expected to increase to serial production levels, as combustion engines become more compact and EVs more streamlined ”

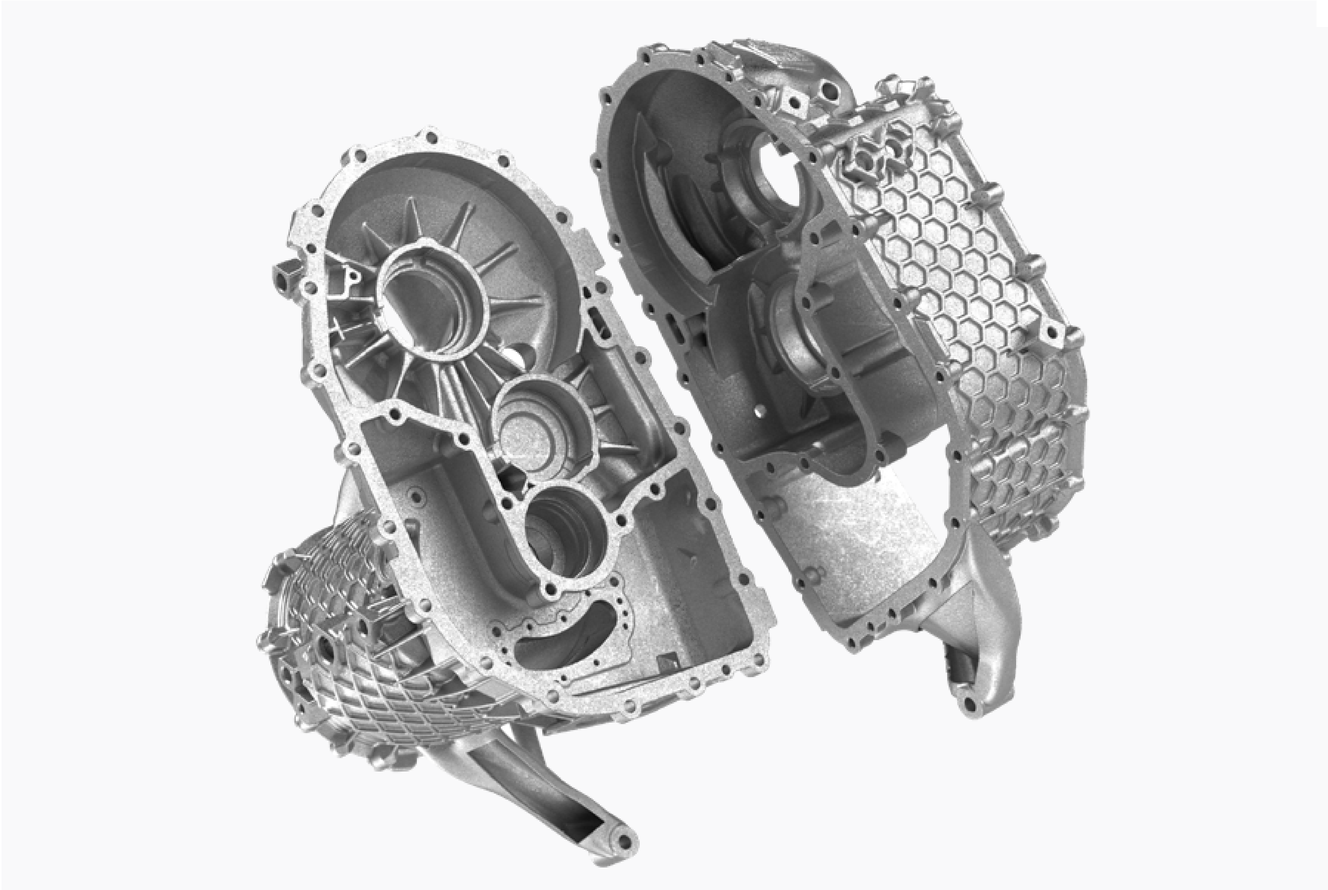
Several powertrain and chassis parts are common to both vehicles with internal combustion engines and EVs, although they may take different forms. Several of these have been 3D printed in some form, starting with the high-profile Czinger 21C hybrid supercar project, which integrates a number of 3D printed parts. Czinger uses additive manufacturing methods to create performance-engineered componentry, including the chassis derived from the project predecessor, the Blade supercar which was produced using SLM Solutions' metal PBF technology.

Bugatti is another major combustion-engine supercar manufacturer that is moving closer to electrification after the acquisition by Rimac. Bugatti has used AM on a number of parts, including the revolutionary titanium 3D printed brake calipers. More recently, the company produced hybrid components, such as the 0.5-meter-long auxiliary drive shaft, combining carbon fibers with a 3D printed titanium end fitting to reduce weight by around half to 1.5 kilograms and increase performance due to the reduction of the rotating masses. Rimac also has been using 3D printing from the very start, when the company turned to Materialise in 2011 to produce interior parts for its Concept_One, one of the world's first electric hypercars. When it comes to hypercars, Lamborghini is another major brand that is looking at both electrification and 3D printing. In particular the Sant'Agata Bolognese company has been working with Carbon on several end use parts (although not yet for chassis or powertrain) for both its sports cars and its top selling Urus SUV.

EVs use the electricity saved in the battery to cycle the motor and generate the power necessary for driving. As such, EVs have no need for the engine and transmission, the two of the most crucial components for internal combustion vehicles. Instead, EVs carry several components for electric power: the motor, the battery, the on-board charger and the Electric Power Control Unit (EPCU). All are essential components to achieve the conversion of the battery's electricity into kinetic force.

The motor is also an electric generator—it converts kinetic energy generated while in neutral gear (i.e. while the car is going downhill) into electric energy saved to the battery. The same energy-saving idea applies when the car is slowing down.

Image: SLM Solutions | Porsche AG



Porsche and SLM Solutions developed a E-Drive housing using the latter's 12-laser NXG XII 600 PBF system.

In electric motors, a particularly interesting focus for AM is on copper. German firm Additive Drives presented promising applications cases. One, in cooperation with the Racetech Racing Team eV of TU Freiberg, involves 3D printed single coils used on the racing engine. In another project, copper 3D printed hairpin windings reduced the time required for the development and production of an electric traction motor prototype to one month. In addition, direct production of individual lots was achieved for Dresden-based pedelec manufacturer Binova: using 3D printed individual coils, Binova produced several different types of electric bikes with an unconventional electric motor design and no tool adjustments. More recently, Porsche and SLM Solutions revealed a project centered on manufacturing a complete housing for an electric drive using 3D printing. The 3D printed E-Drive housing on the engine-gearbox unit produced using the additive laser fusion process passed all the quality and stress tests. In the future this may become a viable production method.

In EVs, the reducer is a kind of transmission that serves to effectively convey the motor's power to the wheels. The motor has a far higher RPM than that of an internal combustion engine, so with the reduced RPM, the EV powertrain can take advantage of the resulting higher torque. This part is a fairly complex metallic component that could be optimized with AM for fast production, improved performance and weight reduction in the future. The Electric Power Control Unit is another complex enclosure that could benefit from AM processes. It includes the inverter, which converts the battery's DC into AC, and is used to control the motor speed; the Low voltage DC-DC

Converter, which supplies the vehicle's various electronic systems; and the Vehicle Control Unit. The VCU oversees nearly all the vehicle's power control mechanisms, including the motor control, regenerative braking control, A/C load management and power supply for the electronic systems.

EV batteries

In 2019, the global battery electric vehicle market reached a size of almost $50 billion. Projections forecast a market increase by a compound annual growth rate of 14.1% between 2019 and 2030, amounting to over $212 billion in 2030, as data from NMSC shows.

The battery stores electrical energy and is the equivalent of a fuel tank in an internal combustion engine: the higher the capacity, the higher the driving distance. However, the battery's size and weight also have large implications on vehicle performance. A larger and heavier battery takes away from cabin/storage space and worsens the energy efficiency and fuel economy. The best way to optimize performance, then, is to maximize the battery's energy density—that is, having a small, lightweight battery that stores as much electric energy as possible.

Batteries are tricky and particularly interesting for AM in (a rapidly approaching) future. Several efforts have been made to produce batteries using different 3D printing technologies, with both polymer and ceramic materials. Because batteries can take many different shapes and sizes for improved efficiency, AM could prove instrumental for testing—and eventually manufacturing—several new design iterations. The batteries used in EVs today are basically rows of hundreds of small-sized batteries fastened together to increase capacity. The Tesla 85kWh pack, for instance, is made up of 7,104 cells roughly the size of AAs. With 3D printing, the individual cells don't have to be manufactured and assembled: the module can be designed and printed in the desired overall shape. AM can also make a difference in the structure of the electrodes of a battery: porous electrodes increase energy density, and AM is ideally suited to build electrode materials into lattice shapes that have more exposed surface area for the chemical reactions to take place, resulting in a more efficient battery.

Swiss firm Blackstone Resources has recently achieved a series of important milestones for its proprietary 3D printing technology to print lithium-ion solid-state batteries (SSBs). Blackstone's 3D printing process claims to offer substantial advantages over conventional battery cell designs that use liquid electrolytes. These include significantly lower costs, a higher level of production flexibility—when it comes to the format of the cell—and a 20% increase in energy density. Moreover, by using this technology, the number of materials that do not store energy (such as copper and aluminum) could be reduced by up to 10%. The Swiss company also developed a workflow to mass-produce these batteries in 2021 in any shape or form using proprietary battery printing technology.

Additive Drives is exploring the use of copper 3D printing to produce coils and windings for EVs.

Image: Additive Drives

Blackstone is not the only company developing 3D printed SSBs. In the US, the company Sakuú Corporation (formerly Keracell) has raised $62 million to finance development of an automated multi-material multi-process AM technology to produce 3D printed SSBs.

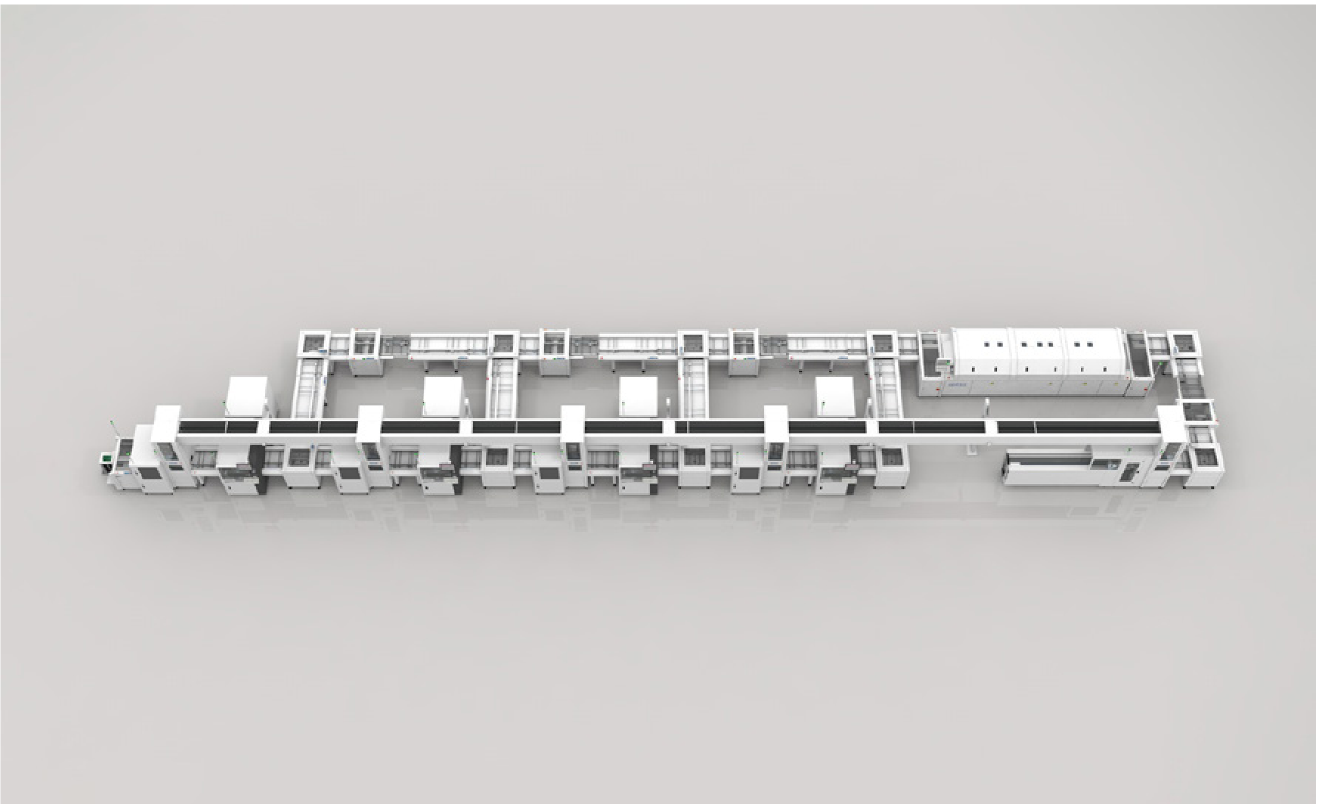
In the 2020-2021 period, Sakuú has increased the energy density of its first-generation battery from 40Wh/l to 600Wh/l, while increasing the cell layer count from 1 to 30 while growing cell capacity from 2.3mAh to 3000mAh, setting a new benchmark in the race for SSBs for EVs. These batteries will be very competitive with current Li-Ion batteries in terms of energy density while bringing the inherent safety benefits of solid-state technology. The company reported that it is on the path to full commercialization of its first-generation SSBs, targeting high volume production in the second half of 2022. Last year, Sakuú also printed the world's first fully ceramic SSB battery as an early demonstration of its second-generation ASSB (All-Solid State Battery).

AM potential

Medium term to long term and very significant at above 5% market penetration by 2030

In electric vehicle powertrains, the use of additive manufacturing is particularly effective for part reduction, leading to weight reduction and performance improvements. Part reduction, in turn, enables greater mileage. However, the actual penetration of additive manufacturing in EVs—beyond applications shared with combustion engine powertrains, such as chassis, brakes and fluid flow applications—is highly dependent on the ability to implement additive manufacturing in serial battery manufacturing. Relevant efforts in this area are already underway, but we are still a few years away from it becoming a consolidated business opportunity.

Image: Blackstone Resources



Automated 3D printing battery production could save up to 70% capital expenditure and 30% operational costs, compared to current production technology.

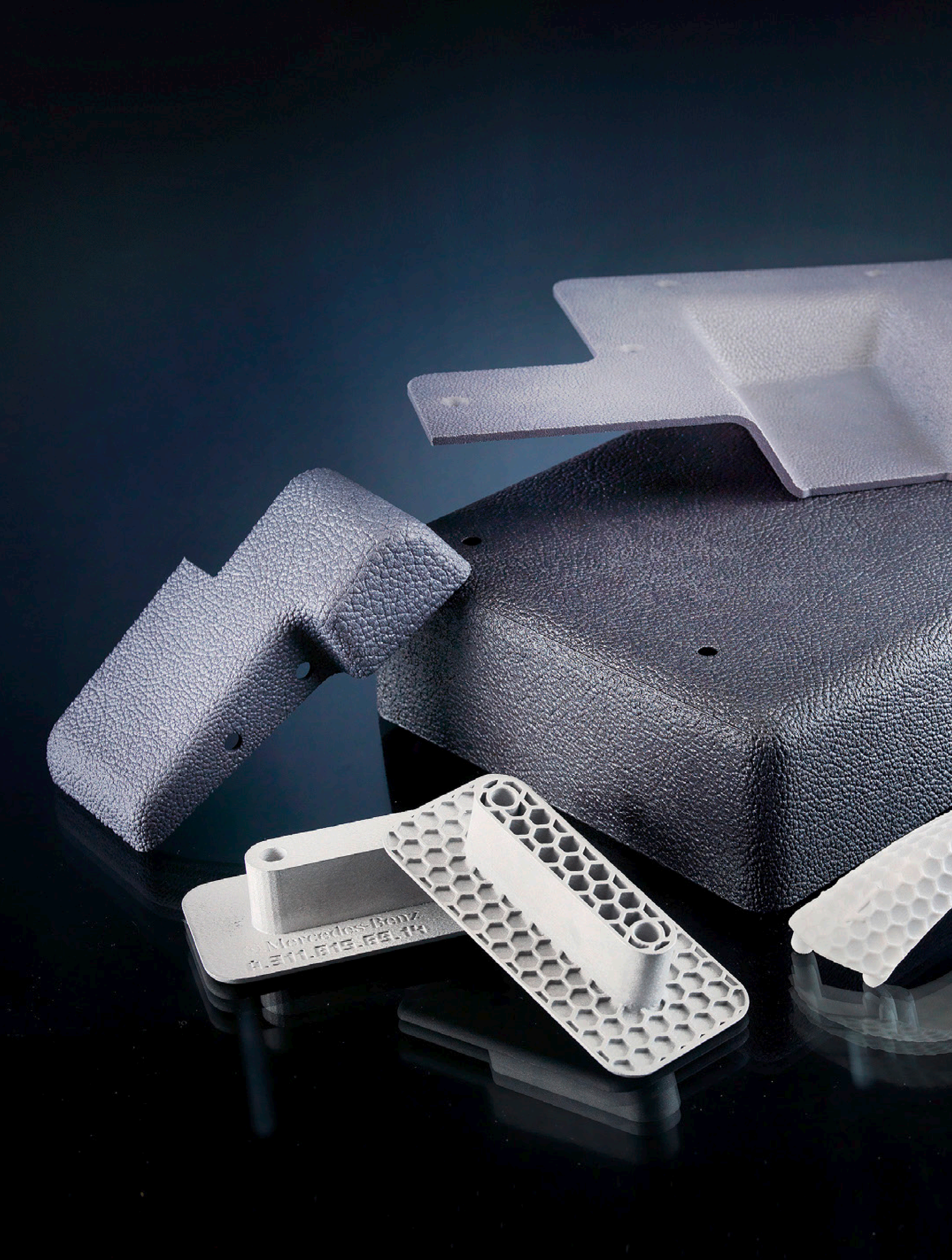


Image: Daimler

SPOTLIGHT

AM adoption accelerates at Daimler Trucks & Buses

How the major commercial transport company is implementing additive manufacturing for spare part production and more.

Image: Daimler

Daimler Trucks & Buses is one of the largest manufacturers of commercial vehicles in the world. It began using 3D printing in 2016.

With over a century behind it, Daimler Trucks & Buses is today one of the largest manufacturers of commercial vehicles in the world, supplying essential transport vehicles, from long-haul trucks, to coaches, to city buses. Driven in large part by the demanding needs of the commercial transport industry, which require minimal maintenance and down times for vehicles, the global company has increasingly turned to additive manufacturing in recent years.

Daimler's exploration of additive manufacturing began in 2016, and after seeing the positive results of integrating the technology in various workflows, like prototyping and spare part production, it has ramped up its adoption in dynamic ways. In Spring 2021, for instance, Daimler Buses launched a mobile 3D printing center dedicated to spare part production. The compact mini factory, being piloted in Germany, is housed in a 12x3 meter container and can be transported on a truck bed to any location for mobile bus maintenance.

Daimler has also initiated Additive Manufacturing Solutions (AMS), a consulting and manufacturing service that offers data preparation, digital warehousing and part production services to customers across various industries. The service is offered through the 3D Printing Centre of Competence at Daimler Buses, EvoBus GmbH. As the AM service provider explains: "We are the AM service department of Daimler Trucks & Buses. We help other

> “ If a vehicle is standing in the workshop for a long time due to a lack of spare parts, then AM is often the best solution to get the vehicle back on the road ”

companies to find out if AM is suitable for them and help them to implement the technology in their organization through custom tailored consulting. Furthermore, we are highly active in developing customer specific materials for AM.”

In other words, AMS is leveraging the years of knowledge and expertise gained from Daimler’s work with AM to help others adopt and benefit from the digital manufacturing technology. Its services span the entire digital value chain, from screening parts to determine if they will benefit from being 3D printed, to the additive production itself, to digital warehousing. Daimler’s AM service arm is also technology agnostic, evaluating the eligibility of parts for AM based on the different technologies available.

While AMS was born out of the automotive industry, the additive service also works outside of this segment, taking on clients from different industries and areas. “Because we are part of the Daimler Truck AG, our first customers came out of the automotive industry. But we also have companies from a wide variety of segments as our customers,” AMS says. Looking specifically at its work with Daimler Trucks & Buses, AMS says it has screened and identified over 7,000 parts to be 3D printed. The 3D Printing Centre of Competence is also currently evaluating many more parts—including over 300,000 spare parts for Daimler’s bus division alone. Looking ahead, the transport company tells us that it envisions at least 40% of automotive components will be suitable for 3D printing, and possibly more.

Spare part production is an important part of Daimler Trucks & Buses’ adoption of additive manufacturing. “Because we’re a commercial vehicle

Daimler’s AMS says it has screened and identified over 7,000 parts to be 3D printed.

Image: Daimler

OEM, our customers have to earn money with their trucks and buses," the company says. "If, for example, a vehicle is standing in the workshop for a long time due to a lack of spare parts, then AM is often the best solution to get the missing part and get the vehicle back on the road."

Traditionally, truck and bus maintenance relied on having a large inventory of spare parts at the manufacturer's disposal. If a given part was not available in this physical inventory, an order would have to be placed with an OEM, which could take weeks if not months to produce and dispatch. Having a physical inventory of spare parts also necessitates a massive warehouse—which comes with significant costs.

Additive manufacturing solves all these problems. 3D models for spare parts can instead be housed in a digital warehouse and can be 3D printed on demand when they are needed. Moreover, they can be 3D printed locally—such as in the mobile 3D printing center—to cut down on transport times and costs. In some cases, 3D printed replacement parts can be implemented temporarily, while the final parts are made. Overall, this leads to faster maintenance and reduces down times for vehicles.

AM is transforming how Daimler sources spare parts and maintains its commercial vehicles.

Image: Daimler

That being said, spare part production is only one aspect of Daimler's use of AM. The transport manufacturer also uses the technology for the production of prototypes, tooling components, and end-use parts. One particular area that the company is interested in is the use of additive manufacturing and intelligent design to create more lightweight parts, which will contribute to the production of vehicles with greater fuel efficiency.

Notably, Daimler Trucks & Buses was part of the NextGenAM project in cooperation with Premium AEROTEC and EOS. This project, which successfully wrapped up in 2019, sought to establish a digital production line to produce aluminum parts for the automotive and aviation industries in a more profitable way. In the end, the partners achieved what they set out to do: using an AM-enabled digital workflow, they successfully reduced the cost of 3D printing a car shock absorber bracket by 50% without sacrificing part quality.

Another area of interest is the production of electric vehicles (EVs). Daimler Trucks & Buses sees enormous potential for AM in its EV development and production. It says: "Our electric vehicles are full of new technologies. There are already 3D printed parts in them and that number will increase. Not just because the vehicle is electrified, but because AM is the best fitting manufacturing technology."

Overall, Daimler Trucks & Buses has been forward-thinking and strategic in its implementation of AM. The digital manufacturing technology is transforming how the company sources spare parts and maintains its commercial vehicles and is creating promising pathways for the future of commercial transport products and production.

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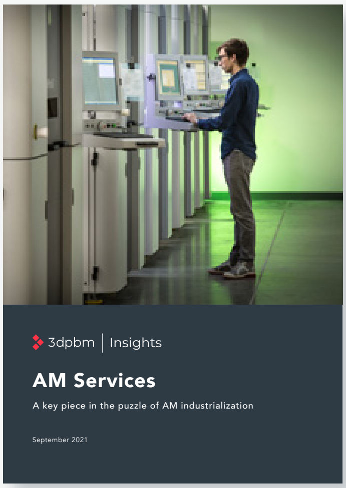

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INTERVIEW

A conversation with ŠKODA AUTO

ŠKODA AUTO's Jana Polášek Filová and Vladislav Andronov on how the Czech carmaker is embracing plastic and metal additive manufacturing

Image: ŠKODA AUTO

Czech carmaker ŠKODA AUTO, a wholly owned subsidiary of Volkswagen Group, has embraced additive manufacturing in a big way, using various 3D printing technologies to transform its product development and manufacturing workflows.

Today, the company boasts an award-winning 3D print farm made up of over 50 plastic 3D printers, which it uses for various applications, including prototypes, replacement parts and jigs and fixtures. The automotive company is also increasingly exploring the use of metal additive manufacturing for tool production—particularly for the production of die casting molds.

In order to get a clearer picture of ŠKODA AUTO's adoption of 3D printing today and how it sees AM fitting in to a longer term strategy, we spoke to two of the company's AM specialists: Jana Polášek Filová, Ph.D., MSc., Expert Coordinator of Innovation Management, who will be talking specifically of the company's plastic AM activities, and Vladislav Andronov, a member of the ŠKODA AUTO Ph.D. program who works as a Data Mining Specialist in ŠKODA AUTO, who will illuminate the company's integration of metal AM.

ŠKODA AUTO operates a 3D print farm with over 50 3D printers.

Image: ŠKODA AUTO

How did ŠKODA AUTO first become interested in 3D printing and what were the company's first applications for plastic and metal AM?

Jana Polášek Filová: Additive manufacturing has a long tradition at ŠKODA AUTO and the technology is irreplaceable in Technical Development and in the ŠKODA AUTO's Production and Logistics department. Here, extensive analyses are carried out and pre-series cars are produced in the Central Pilot Hall during the development of new models. Plastic 3D printing is rapidly becoming a vital part of the Component Production and Central Technical Services departments for printing spare parts, rapid prototyping and material testing for spare parts production. It is, however, most prevalent in the maintenance workplaces of the Vehicle Production department.

It was the maintenance specialists who started the real boom of using plastic 3D printing in the ŠKODA AUTO production plants. The very first 3D print farm was established in 2019 in the maintenance department of the Kvasiny Body Shop, where a 3D printer from Czech manufacturer Prusa Research was put into operation. It was used to print 'fittings' (specifically, shaped parts of auxiliary jigs which are used as support for clamping manufactured parts) and stops for manual manipulators on the Assembly Shop lines.

Vladislav Andronov: Our first experience with metal 3D printing dates back to 2010. At ŠKODA AUTO, metal 3D printing is intensively handled by the Tool Production department. 3D printed products are primarily deployed in die casting molds used for casting engine blocks, clutch housings and gearboxes. The first application was a die casting mold insert with conformal cooling, which could not have been produced with any other technology. Conformal cooling mainly brings a reduction of the production cycle time and an improved cooling

Image: ŠKODA AUTO

The Czech carmaker's 3D print farm is used to rapidly iterate prototypes, jigs and fixtures and replacement parts for its automotive production.

effect to increase the quality of the castings. In some cases, it also brings a reduction to the number of repairs and an increase in tool durability. After the initial experience in our department, we took the position as the main representative of metal 3D printing at ŠKODA AUTO and since 2017 we have been helping to implement various printing projects for other departments. This has subsequently led to other interesting applications, such as prototypes for our development departments and various special jigs and tools.

In the ŠKODA AUTO Toolshop, we implement the entire production process, i.e. from the construction design/design of the part, through simulations to its completion, including heat treatment. The actual printing is then carried out by Volkswagen Group printers.

How have in-house applications evolved since then?

VA: As for the applications in our industry, we strive to follow innovative trends and gain valuable experience. Innovations that we're currently trying to apply are in material development, where we are cooperating intensively on a joint project with Voestalpine to use a newly developed material for the purpose of aluminium pressure die casting in series production. We are also collaborating with universities in the Czech Republic (Czech Technical University in Prague, Technical University of Liberec) on the applications of combining different materials, development of printing parameters for specific materials, the influence of the part orientation on the residual stresses introduced or on the heat treatment of 3D printed parts with respect to their durability in the mold.

Each new case that comes to us is unique in its own way, and new application possibilities are constantly emerging in different departments of our company. If I were to mention one project that could contribute to big savings for the company in the future, it would be our joint project with our colleagues from the new Paint Shop, where we have been testing 3D printed nozzles for applying a special coating to the car body. Due to the high purchase cost of the part, over 60% of the original price of the purchased part can be saved by printing.

JPF: We currently produce mainly functional parts of production equipment, auxiliary jigs and tools with the help of plastic 3D printing, of which there are a large number in production. They range from fittings, sensor holders in production lines, multi-coloured signs and labels to new functional jigs for car body final alignment for example. It is only a matter of time before 3D printing becomes a conventional manufacturing technology. In the medium term, it will find a widespread use especially in 3D printing of spare parts of production equipment. The ŠKODA AUTO's Production and Logistics division is already preparing for this future.

Is there a specific 3D printing use case you'd like to highlight?

JPF: At the time when the carmaker's management decided to begin using plastic 3D printing, the main goal was to facilitate the production of prototypes. The use of AM in mass production was only kick-started by the 3D printing of auxiliary jigs and tools in maintenance, which increased the production efficiency of tailor-made one-off items and smaller series. Plastic 3D printing significantly reduced the lead time required to deliver the necessary parts and accelerated the company's reaction to unexpected production events. The production plants also benefited from the reduction of spare parts in stock and the fixed costs savings associated with it.

In the spring of 2021, ŠKODA 3D farms also proved their worth when the carmaker temporarily lost its supply of parts from external companies. These parts were necessary for the final assembly of the gearboxes of ŠKODA SUPERB and KAROQ models at the Kvasiny plant. The gearbox caps that were printed in our 3D farms for this purpose were only a temporary replacement for the original part. They were used to lock the gearbox in neutral so the cars could complete their journey through the production lines. When the supply of missing parts resumed, the temporary caps were replaced with the original parts.

The benefits of plastic 3D printing became clear at this moment as the cost of all the auxiliary parts produced was not even a quarter of a million crowns—while the market price for the KAROQ model starts at CZK 530,000 and at CZK 730,000 for the SUPERB. Thanks to the rapid prototyping, approval and production of caps across the entire network of 3D printers at ŠKODA AUTO, it was possible to avoid a significant delay to the delivery of 13,000 cars to our customers. The speed of reaction and cooperation across all production plants once again confirmed that the ŠKODA 3D farms are a perfectly functioning team.

VA: Although this is not a cost/time saving issue, it is worth mentioning here the unique case of our 3D printed slide valves with conformal cooling. The part, with dimensions of approx. 270 x 270 x 200 mm, which forms the entire side of a three-cylinder 1.0 TSI engine block has been printed using L-PBF technologies and actually deployed and tested in the series production of our company.

According to the latest information, this is the largest metal part printed in the Volkswagen Group and, according to a search of scientific articles, it's one of the largest printed parts in the field of HPDC (High Pressure Die Casting). This tool was printed on

> “ We have the full support of ŠKODA AUTO’s management to innovate and introduce new technologies in practice. ”
>
> VLADISLAV ANDRONOV

the EOS M400 printer at the AUDI in Germany. This case also shows the disadvantages of L-PBF technologies (high internal stresses and deformations in the case of large parts, precision and high costs) and perhaps also explains why these printers are not massively used yet.

Another interesting application that can be mentioned is the production of a 3D printed headlight holder, which arose from the requirements of the Central Pilot Hall. The prototype molding was replaced with a thin-walled 3D printed part within a week of ordering, without the need for auxiliary or prototype tools.

Can you tell us a bit about how 3D printing fits into the broader ŠKODA strategy?

JPF: The introduction and promotion of 3D printing at ŠKODA AUTO is one of the projects of the FORCE strategic transformation team in the area of Production and Logistics, which focuses on the application of Industry 4.0 technologies and digitization. The emphasis here is not only on hardware and software equipment, but also on the specialized training of our employees. The FORCE Programme is a comprehensive set of strategic digital tools that increase efficiency and flexibility and prepare vehicle production for the challenges of globalization. It is focused on the future of manufacturing and new production processes and technologies. The objective of the initiative is to strategically manage digital processes and systems in order to make the most of production data and increase the digital competence of production employees.

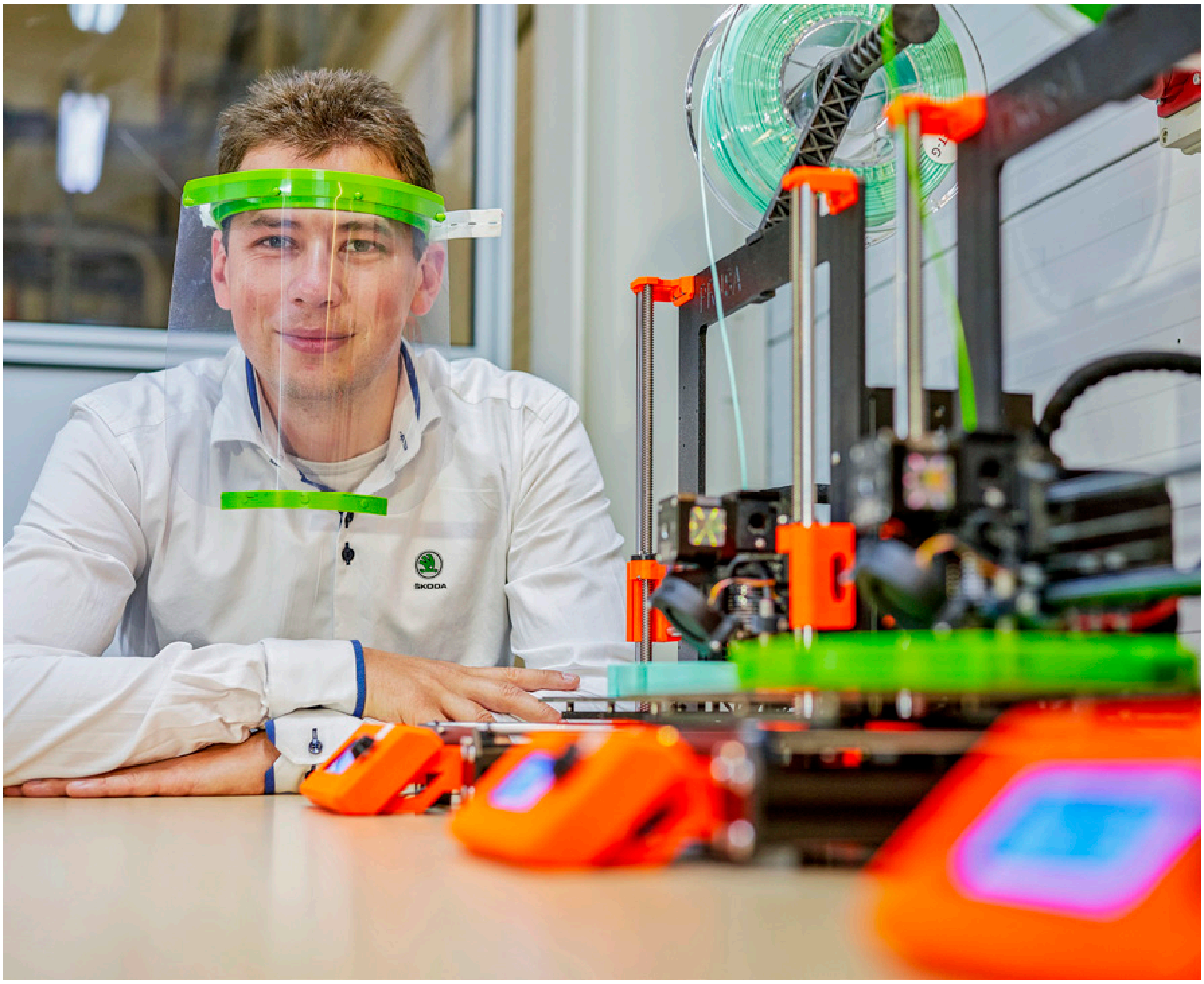
VA: We have the full support of ŠKODA AUTO’s management to innovate and introduce new technologies in practice. And this, of course, also applies to metal 3D printing.

Can you tell us what types of 3D printing/systems the company uses?

JPF: In Technical Development, which is dominated by rapid prototyping, one-off production of prototypes and the production of models and functional parts, we use more expensive sophisticated printers from Stratasys, PolyJet and HP.

In ŠKODA AUTO’s Production and Logistics division, there are currently over 50 3D plastic printers operating at the Kvasiny and Mladá Boleslav plants, which are mostly from Czech company Prusa Research. There are also a few 3D printers from Ultimaker, Stratasys, Markforged and Craftbot.

Image: ŠKODA AUTO



ŠKODA AUTO's Production and Logistics division has over 40 team members who are eager to learn 3D printing skills and utilize them to transform various operations.

PET-G material is used for 3D printing the vast majority of requirements. It is particularly popular for its mechanical properties, problem-free printing, affordability, chemical resistance, dimensional stability, non-flammability and recyclability. Other most commonly used filaments include ABS, PLA, Nylon, Flex, Hips, PVA and BVOH.

VA: We're currently using L-PBF devices within the Volkswagen Group and universities in the Czech Republic, with whom we cooperate. These are mainly machines from Concept Laser, EOS and SLM Solutions. We are constantly keeping track of trends in the development of 3D printing systems. Each manufacturer has something unique, but no single printer from any individual manufacturer is exactly what we need.

As of April 2022, a new machine from DMG MORI, the LASERTEC 125 DED Hybrid, will be commissioned and released for production, which will primarily be used for repairing molds for aluminium die casting in the ŠKODA AUTO Toolshop. This machine is suitable for repairing mold inserts with subsurface cooling channels that were originally printed using the L-PBF method. Also, this machine will bring great time and cost savings compared to the conventional process of welding and milling.

However, this machine doesn't fall in the L-PBF category but works on the principle of DED (Direct Energy Deposition).

What are some challenges you've encountered with the adoption of 3D printing and how is ŠKODA addressing them?

JPF: We are fortunate that ŠKODA AUTO's Production and Logistics division now has more than forty active enthusiasts who are fascinated by plastic 3D printing and whose enthusiasm is quickly spreading into all operations. In September 2020, we unified all production groups involved in plastic 3D printing into one working group coordinated by the Digitisation and Industry 4.0 department.

One of the first priorities was to provide our staff with training courses. Together with the ŠKODA Academy, we were able to create a special training program very quickly. The basic course provides those who are interested in additive manufacturing with general information about 3D printing. The more advanced courses are aimed at those employees who need the practical skills to operate a 3D printer. The courses are designed to focus particularly on constructing 3D models in CATIA and Creo software. The final course in the series provides a special module for experts which addresses the scanning of 3D models. The training also includes the legal aspects of plastic 3D printing.

A total of 160 employees have completed the course since November 2020. Not only are these courses unique, a fact our company can be justly proud of, but they also confirm that we are serious about using additive manufacturing in the future.

In 2021, we created a common database for auxiliary jigs and tools in the CONNECT system, which is the software used by the whole Volkswagen Group. We are now finalizing the standardization of the process of plastic 3D printing of auxiliary jigs and tools at ŠKODA AUTO, which will take into account the digitization of all aspects of the decentralized management of plastic 3D printing in the ŠKODA AUTO's Production and Logistics division. The aim is to make the process of additive manufacturing clearer, faster and easier across all operations.

Our comprehensive approach to plastic 3D printing was also the reason for ŠKODA AUTO's inclusion among the five finalists of the 'Industry 4.0 Award 2021', organized by the Confederation of Industry of the Czech Republic. As the expert jury stated in its evaluation, the project of ŠKODA 3D farms is unique in the Czech manufacturing environment and a model for other companies.

VA: Currently we see the problem in the level of financial investment we would have to make to acquire an L-PBF system. The printers that are currently on the market cannot offer what we need and meet our current expectations in terms of the price/performance ratio.

ŠKODA AUTO is commissioning the LASERTEC 125 DED Hybrid from DMG Mori in April 2022.

Image: DMG Mori

> “ I believe that 3D printing will be a conventional production technology and an integral part of ŠKODA AUTO Production and Logistics in the future. ”
>
> JANA POLÁŠEK FILOVÁ

How do you see the future of AM adoption at ŠKODA AUTO?

JPF: I believe that 3D printing will be a conventional production technology and an integral part of ŠKODA AUTO Production and Logistics in the future. The arguments in favour of its adoption include not only the speed of response, reduction of administration, flexibility of design, reduction of the prototyping and delivery times, but also the price of 3D printed parts.

3D printing from composite materials and metal will become increasingly important in our production plants. At the same time, especially in the case of 3D printing of spare parts, it will be necessary to take a very careful account of contractual terms and conditions with suppliers of production machinery and equipment and respect legal aspects and warranty conditions.

Other services will undoubtedly develop as well, from quality and material testing to specialized trainings, consultancy or workshops focused on seeking opportunities for improvement and innovation in 3D printing. We are already working with our academic partners to ensure that a few of these innovations are created by ŠKODA AUTO.

VA: A very important step for us is the aforementioned acquisition of the hybrid machine DMG MORI LASERTEC 125 DED Hybrid. Although this is a large investment, the benefits expected from this machine are very high. If this trend proves to be correct, it could mean the acquisition of several other machines of a similar nature and a huge streamlining of the entire process of repairing molds for aluminium pressure die casting.

Before that, however, we need to focus on and not underestimate the necessary steps that await us at the very beginning, such as the development of custom parameters for the materials required, optimization measures or research into the heat treatment of parts produced to achieve the mechanical properties necessary. If we look at it from the perspective of additive manufacturing, we want to remain at the centre of developments in our industry and follow the development of technologies and systems for 3D printing.

Let's Partner

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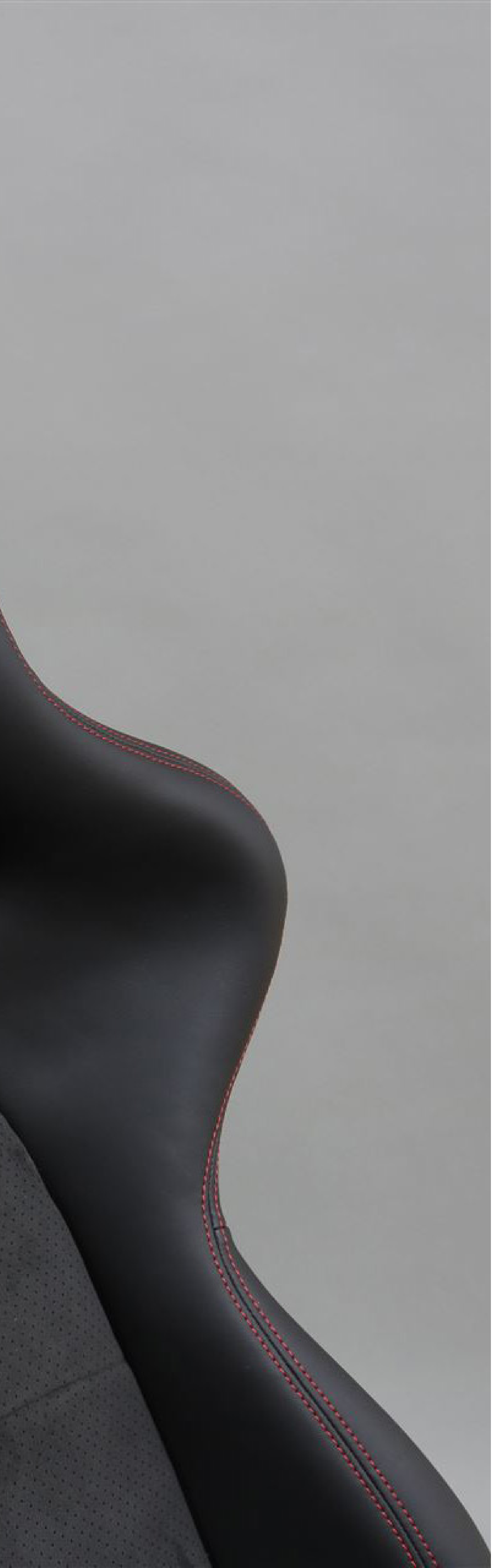
Image: OECHSLER



CASE STUDY

Automotive seating gets an AM revamp

German manufacturer OECHSLER is re-inventing the car seat—with an emphasis on comfort—using additive manufacturing and intelligent design

Image: OECHSLER

OECHSLER is using AM to design car seats that integrate 3D lattice geometries, which can be tuned for various hardness and density levels.

Like the automotive industry itself, the design and production of car seats has undergone an amazing evolution over the years, from beltless bench seating to increasingly ergonomic bucket chairs. As German plastic production specialist OECHSLER sees it, the next frontier for automotive seating could very well be driven by 3D printing technologies. In fact, we may already be at the frontier, as the company is reinventing car seat design and production using AM with the ultimate aim of enhancing comfort and functionality.

Traditionally, car seats are made using suspension or foam-based production processes, which, while effective for mass manufacturing, come with certain limitations, especially when it comes to customization, comfort, breathability and weight. Identifying an opportunity to overcome these challenges, OECHSLER is utilizing additive manufacturing to design cutting-edge car seats that integrate 3D lattice geometries, which can be tuned at the design stage for various hardness and density levels.

"The car seat is a core interface between driver and vehicle," explains Max Lehnert, Program Manager Additive Manufacturing at OECHSLER. "Additive manufacturing enables us to go beyond the limits of conventional materials and manufacturing processes, to deliver greater comfort and driving experience."

> “ The car seat is a core interface between driver and vehicle. AM enables us to go beyond the limits of conventional materials and manufacturing processes, to deliver greater comfort and driving experience ”

Take a seat

The first step in redesigning the car seat was to understand how the body interacts with the seating interface. OECHSLER therefore analyzed heat map data from seating experience. From there, the company used software design tools to convert fixed geometry 3D designs into lattice structures. The properties—especially damping properties—of the lattice structures could then be tuned based on pressure points and seating data.

In the design process, the lattice structures were optimized by adjusting the thickness and size of flexible rod-shaped connections. This enabled OECHSLER to create a car seat with variable hardnesses and cushioning levels—something that would be incredibly complex if not impossible using traditional foam cushioning.

As OECHSLER points out, this capability also creates opportunities for customization. Different vehicle types and drivers have different requirements, so having the ability to produce numerous types of seats to meet these needs is a potential game changer. Additive manufacturing not only resulted in a design with variable hardness but one that improved breathability. Whereas dense foam cushioning limits ventilation within car seats, lattice geometries are ideal for airflow. “The refinement of lattice structures created a new particularly air-permeable comfort layer for passive climate comfort and increased breathability,” the company says.

Exposed lattice details give the seat a modern look.

Image: OECHSLER

Another benefit of the 3D printed car seat is weight. By leveraging a complex internal geometry consisting of thin, elastic rods, there is the potential to reduce the weight of car seats, which can contribute to better fuel efficiency.

How it's made

With over a century of experience in the production of plastic components—including extensive experience in the automotive industry—OECHSLER was more than equipped to take on the car seat project.

To produce the seat, the company turned to HP Multi Jet Fusion technology, which enables the production of flexible and functional components. In terms of materials, OECHSLER used BASF Forward AM's Ultrasint TPU01, a flexible material that meets automotive requirements for skin contact (ISO 10993/ OECD No.439), durability (fatigue bending ASTM D1052), flame resistance (FMVSS 302) and chemical and UV resistance (ISO 4892-2A Cycle 1).

Lattice geometries can be tuned depending on the hardness and density required.

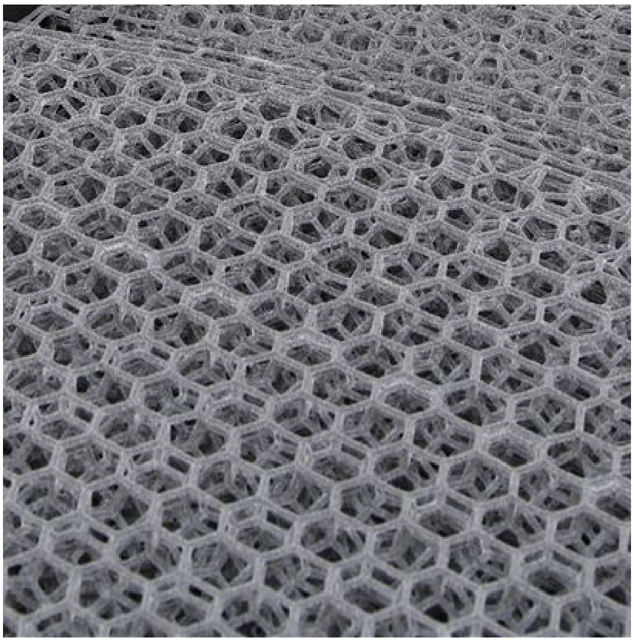


Image: OECHSLER

"The development has taken into account the strict quality standards and fulfilled the further specifications necessary for automotive with regard to fittings, odor and emissions," the company emphasizes.

In addition to the lattice geometry in the seat's structure, OECHSLER also integrated a number of innovative design elements to improve the seat's production and function. For instance, the manufacturer integrated fixing points into the seat's design, which eliminated the need for gluing in assembly. The seatbelt guiding was 3D printed out of PA12 as a single, solid part. Other design elements, like seam channels and folding mechanisms, also contributed to more efficient downstream assembly processes. Notably, the integration of hinging allowed the company to print large seat components in a single print bed.

OECHSLER adds that many elements of the seat, including the backrest, can be customized to the driver's comfort preference with different degrees of hardness and cushioning. The headrest, for its part, is coated with Ultracur3D Coat F from BASF Forward AM, which ensures a perfect match between flexible substrate and applied coating.

And that's not to mention the look of the 3D printed car seat. That is, in addition to the increased comfort and functionality of the seating product, the overall design is, frankly, incredibly cool. While elements of the seat look fairly conventional, there are 3D printed lattice accents that take the design to another level. Moreover, the lattice parts that do remain exposed—notably at the head rest and at the base—can be dyed in various colours to match the car or the driver's preference.

Overall, OECHSLER is leveraging AM to introduce a new era of automotive seating defined by comfort, function and style.

Image: Volkswagen AG

SPOTLIGHT

AM and automotive: the benefits and opportunities are clear

HP and automotive partners pioneer transformative automotive applications with polymer and metal additive manufacturing technologies

Image: Volkswagen AG

HP has partnered with dozens of companies in the automotive industry, including Volkswagen.

Across the world, manufacturing industries are undergoing major shifts driven by new trends and global needs. This is especially apparent in the automotive industry, where car makers are evolving and in many cases embracing new technologies to keep up with changing consumer expectations, supply chain challenges and sustainability goals. In their efforts to stay up to date with industry trends, many automotive companies are increasingly turning to additive manufacturing. We spoke to HP about the ever-deepening relationship between automotive companies and AM technologies and how its polymer and metal 3D printing processes are being used by automakers across the globe.

Automotive partners

Today, HP works with dozens of automotive businesses, including automakers, suppliers and production partners, to design and manufacture prototypes and end-use parts. The company's partners include leaders in the automotive industry like Ford Motor Company, General Motors and Volkswagen, each of which has used HP's AM technologies for various applications.

On a base level, 3D printing enables car manufacturers to redesign parts for greater performance and efficiency. But the technology also creates many other opportunities, including the ability to produce one-off or low-volume production runs, to design and prototype parts faster, to produce on-demand parts locally and more. AM is therefore strategically positioned to help automotive companies advance in their missions to achieve mass customization, improve sustainability and overcome supply chain challenges.

Speaking about the company's polymer 3D printing, Guayente Sanmartin, Global Head of HP's Multi Jet Fusion business, said: "Every day we are seeing growing traction and more mature 3D printed applications across many different industries, especially in automotive. Automakers are forging ahead as they broaden their use of 3D printing, replacing traditional tooling with 3D printed versions, rapidly iterating with functional prototypes, designing entirely new personalized components, and expanding short-run production of fully functional final parts. Our customers are taking advantage of the industrial-grade capabilities—efficiency, repeatability, part quality, cost effectiveness and more—provided by Multi Jet Fusion to deliver on these growing opportunities."

Mass customization

Consumer expectations are continually in flux, and in recent years we've seen a growing demand for customized and personalized products. In the automotive sector, additive manufacturing is playing an important role in enabling greater degrees of customization.
"New innovation and advancements in 3D printing technology are enabling automakers to address a consumer market that is increasingly seeking personalization and sustainability," said Ramon Pastor, Global Head of HP's metal 3D printing business. "As these trends continue to accelerate in 2022, the impact of 3D printing in the auto industry will grow." HP is working in collaboration with Ford Motor Company to develop a range of proof-of-concept 3D printed accessories for the 2022 Ford Maverick truck as part of the new Ford Integrated Tether System (FITS) open accessories platform. Through this platform, Ford Maverick customers can customize their vehicles with a series of accessories, including cupholders, trash bins, phone cord holders, grocery hooks and more.

AM's propensity for localized, on-demand production is vital to achieving mass customization. As Pastor envisions it, automotive supply chains could be tailored to personalization. "Imagine a new model for production in which vehicle bodies continue to be assembled at centralized factories but are then shipped to regional facilities," he explains. "At these regional facilities, the vehicles are finished with customized 3D printed parts that service the needs of a region, a culture or even an individual customer."

AM also makes it possible for automotive companies to produce more limited edition vehicles. "A luxury brand could release specialty vehicle models in extremely limited runs," Pastor elaborates. "For

HP sees automotive companies broadening their adoption of AM.

Image: Volkswagen AG

> “ The efficiency of 3D printing and its on-demand nature makes a more resilient type of supply chain possible, as any location with a 3D printer has a limitless ‘inventory’ in its digital files. ”

that matter, so could a mass-market brand. Added efficiencies and the benefits of 3D printing could also drive a boom in aftermarket customization—whether directly via consumer engagement or through third-party service providers.”

Supply chains

Coming into 2022, supply chains are a major concern for virtually all industries. COVID-19, climate change, geopolitical relationships and logistics challenges have all contributed to supply chain issues in recent years, which will be increasingly exacerbated unless properly addressed. In the automotive industry—and others—additive manufacturing is being considered as a potential solution.

As a digital manufacturing technology that is not as influenced by the economies of scale as traditional production methods, AM is creating opportunities for on-demand production. This is not only conducive to producing custom components, but also easing supply chains through localized production.

“Like many industries, the automotive market has felt the severe impact of supply chain disruption,” Pastor says. “The efficiency of 3D printing and its on-demand nature makes a more resilient type of supply chain possible, as any location with a 3D printer has a limitless ‘inventory’ in its digital files. This can ultimately move manufacturing that much closer to consumers, reducing cost, waste and operational footprint.”

A more agile, AM-enabled supply chain has numerous benefits, including for automotive spare part production. In this area, HP has partnered with digital manufacturing company SOLIZE and automotive brand Nissan to develop on-demand production for discontinued replacement parts for Nissan’s NISMO Heritage Parts program. Through the program, the partners identified and optimized parts for 3D printing, including a plastic component for the harness protector for the R32 Nissan Skyline GT-R. This part and others to be qualified will streamline replacement part supply chains, alleviate inventories and extend vehicle lifetimes.

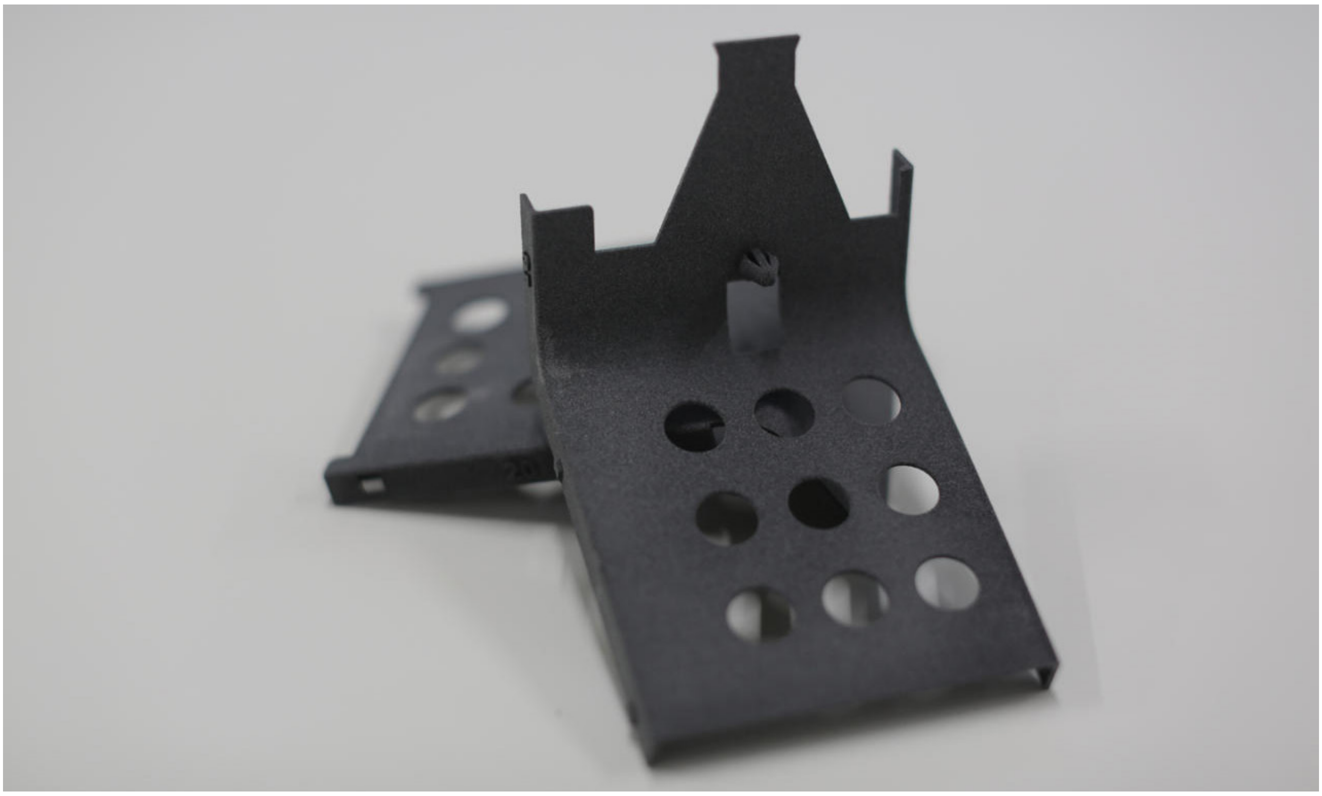
Sustainability

Sustainability is a category in its own right, but is also highly relevant in all intersections of AM and automotive applications. 3D printing spare parts extends the lifecycle of existing vehicles; producing car parts locally reduces transport emissions; and designing more lightweight parts leads to greater fuel efficiency. And that's just the tip of the iceberg. HP is also finding other ways to push automotive sustainability ahead with its partners.

With Ford Motor Company, for instance, HP has embarked on a project to reuse 3D printed powders and parts and transform them into injection molded automotive components. The idea is to close the loop by recycling leftover powder and 3D printed parts and turn them into functional car parts. So far, the partnership has been fruitful: Ford is producing fuel-line clips for the Super Duty F-250 trucks which have better chemical and moisture resistance than the original parts. The parts made from recycled materials are also 7% lighter and 10% cheaper.

Another area where AM and sustainability are aligned in the automotive sector is in the production of electric vehicles (EVs). Pastor sums it up nicely: "AM directly addresses the key requirements for EVs: reducing weight, using less material to enhance sustainability, creating new customized parts. With these benefits comes the massive opportunity for manufacturers to completely rethink how automobiles are designed and created. In an EV, every increase in efficiency extends the vehicle's range—hugely important as EV manufacturers compete to seamlessly replace gas and diesel cars. Using the advantages of AM for complex geometries makes it possible to replace multiple relatively simple parts with a single, complex part, unlocking new potential for optimizing all elements of a car's design."

Image: Nissan | HP



HP, Solize and Nissan are developing on-demand 3D printing production for discontinued replacement parts.

Automotive AM applications on the rise

Overall, HP envisions many automotive applications for its Multi Jet Fusion and Metal Jet technologies. In many ways, this vision is already being realized: car makers are seeing the potential of 3D printing and implementing the technology in dynamic ways like tooling, prototypes, spare parts and production components. In future, we will see even more uses for AM in automotive, especially when it comes to end-use parts. Volkswagen, for instance, revealed its plans to use HP Metal Jet technology to make production-grade components at its plant in Wolfsburg, Germany.

"A recent report published by the U.S. Council of Automotive Research (USCAR) outlines a roadmap for integrating additive manufacturing more broadly into the industry's high-volume production processes," says Sanmartin of the automotive industry's increased use of AM. "The report details the benefits of 3D printing for the auto industry and the potential for growth, focusing on the need for continued innovation across specific areas of additive manufacturing including design, materials, manufacturing equipment and processes, operations and maintenance, and workforce development."

Pastor concludes: "AM can and will play a critical role in the advancement of electric and autonomous vehicles and the demand to produce cars, trucks and other vehicles tailored more closely than ever to consumer needs. Leading automakers like Volkswagen are taking advantage of HP's 3D printing solutions to transform traditional manufacturing and scale to mass production. HP Metal Jet can help customers unlock innovative new designs, and ultimately produce better performing parts much more efficiently."

Image: HP

Both HP's MJF and Metal Jet technologies have been adopted by automotive clients for various prototyping, tooling and end-use applications.

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