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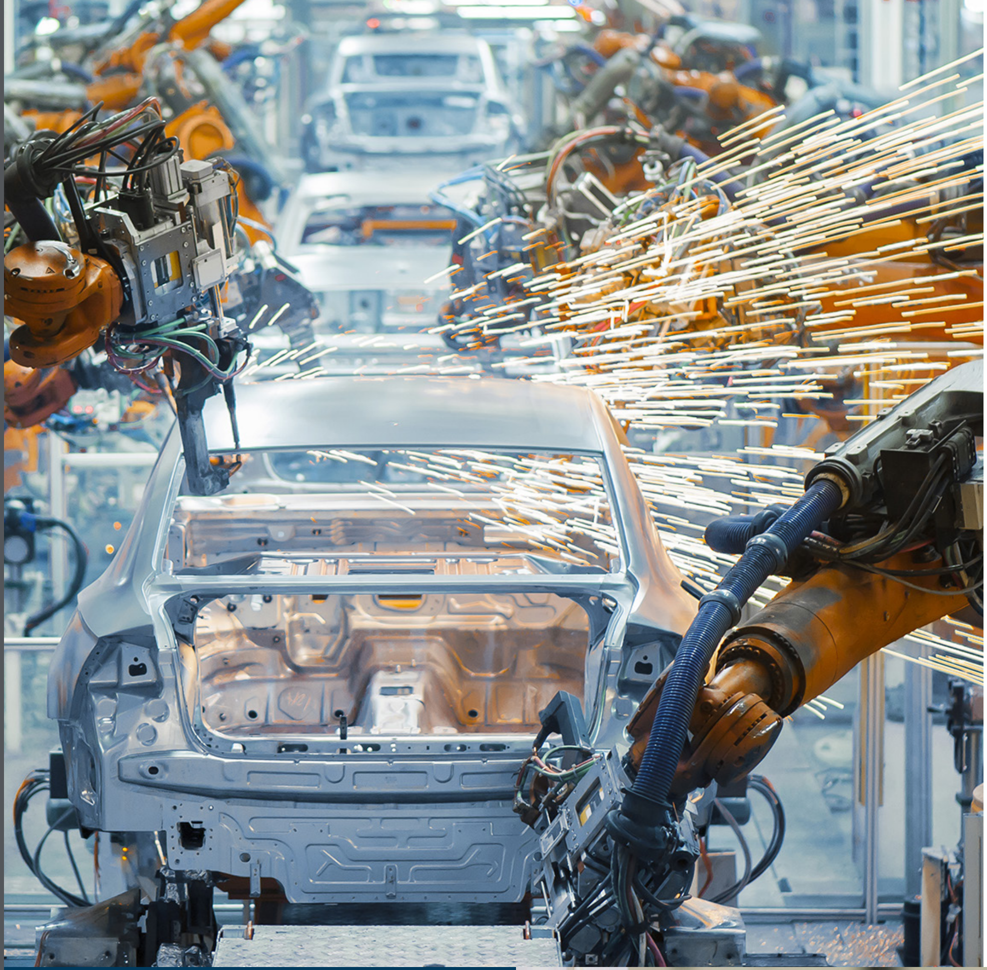


Additive Manufacturing Breaks Innovation Barriers

Accelerating Production in the Auto Industry

stratasys

White Paper

Breaking Barriers

The auto industry innovates at breakneck speed; it has to. Competition is fierce and the stakes are high. Automakers are challenged to maintain a steady stream of innovation given limited resources. Producing a large volume of identical vehicles is your only viable approach when you use traditional methods. There are not enough resources to offer custom vehicles in low volumes.

To stay ahead of the market, automotive manufacturers must understand how to break the barriers to innovation, not just the barriers to entry. They must figure out a new approach to production, because traditional methods are holding them back. Advancing in this industry means automakers must evolve and incorporate new technologies for production so they can move faster and offer bespoke products.

Speed, quality and cost are the primary drivers of production process decisions. Automakers and suppliers need effective, cost-cutting technologies that meet their stringent requirements for quality, safety, production speed and large-scale manufacturing. Around the world, it is difficult to find sufficient tool and die-making resources that support vehicle manufacturing that's up to par. Given the complexity of the product and the industry, new applications that actually meet these stringent requirements are slow to gain adoption. The risk of changing to new materials or methods is perceived as too high.

Although the auto industry has long been at the forefront of creating and adopting new products and processes, the steps to qualify a new material or process for widespread production use are quite difficult. Since safety and durability are primary considerations in the design and production of any vehicle, manufacturers must be assured that new products, technologies or processes meet the existing standards of excellence.

Breakthrough Production Technologies

In 2015, the Center for Automotive Research (CAR) completed an investigation into automotive manufacturing production to examine the potential for additive manufacturing (AM) technologies.

AM, also known as 3D printing, has existed since the 1980s but has recently come into greater use[1]. AM involves the deposition of material to form objects, rather than removing material through processes such as cutting, drilling, milling and grinding. To create a 3D printed object, computer-aided design (CAD) files are sent to a machine that deposits material in a precise manner, building up an object layer by layer. AM can be used to manufacture objects using polymers, metals, ceramics, wood, food and other materials.

Historically, AM was used in automotive primarily to produce prototype parts and models. Today, AM is also used to make tooling for assembly lines or to produce vehicle parts. The AM process can create complex tools more simply than the multiple-step processes of conventional manufacturing such as milling, drilling and welding. Custom lifting tools that streamline processing and make assembly operations more ergonomic require complex designs. Die lifters and checking fixtures, a subset of robotic end-of-arm tooling, are often complex assemblies themselves. But despite the complexity of an assembly or tool, AM has the potential to simplify its production at a lower cost than traditional manufacturing.

CAR's study assessed the potential market in automotive design, tooling and low-volume end-use activities for AM. CAR staff met with several companies, including OEMs, Tier 1 suppliers, and tool and die makers. After reviewing a range of opportunities within the industry and understanding the types of applications that might be most adaptable to AM, CAR focused on tooling and later narrowed the focus to the use of 3D printed lifting tools. Every robotic application used for manipulating parts brings the opportunity for 3D printed components to replace traditionally built cut-and-weld tools. This results in consolidating components, reducing weight, saving time and lowering manufacturing costs.

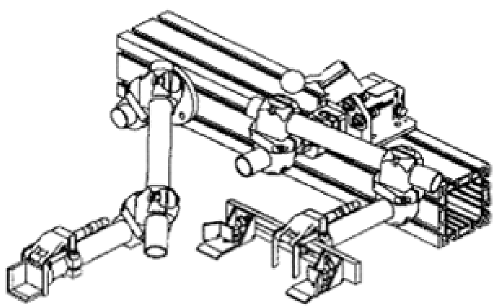
[1]In this paper, the terms additive manufacturing and 3D printing are used interchangeably.

From Rapid Prototyping to Production

AM has primarily been used in the automotive industry to produce prototype parts and models early in the vehicle development cycle—during design, engineering, pre-production operations and testing. Rapid prototyping was the first AM application used by the industry thanks to its prompt verification for function, performance, size and aesthetics. Designers, engineers and testing labs at automaker and supplier facilities use 3D printing for rapid prototyping parts at research, development and design centers. Evaluating prototypes in applications such as wind testing, assembly trials and fluid flow validation allows for quick iterations based on trial results and technician feedback. While prototyping is a good fit for AM, the jump to 3D printing mass-produced parts and vehicle components is limited by print cycle times, material criteria, cost and durability concerns. But that doesn't mean there isn't a benefit to using AM in manufacturing, joining and assembly operations.

Conventional manufacturing of complex parts is constrained by equipment capabilities, restricting the creation of such geometries because of limited part access, line of sight and closed corners. But the design freedom of AM lets users conquer these complexities where milling and drilling fall short. Additive manufacturing can make both simple and complicated shapes, using the same process and the same level of effort. For example, the complex part with curved tubing in the below photo demonstrates the design freedom of AM. Conventional manufacturing would be challenged to drill holes following the curves in such a design. Making this part would require building complicated bent pipes, and then fitting each one individually using expensive fixtures and welding processes. This design would require 12 separate components rather than the single workpiece that was produced on a 3D printer.

A complex 3D printed component



An example of a lifting tool

This lightweight tool is used for punching operations.

Opportunities in Tooling

An automotive assembly plant produces roughly 250,000 vehicles per year and employs about 3,000 people on-site. The average vehicle takes about 20 hours to produce, and before completion, it will visit over 1,000 assembly stations along the conveyor route. While some of these stations are for things like engines, tires, windows and painting, about half the stations involve positioning, lifting, moving or resting parts. This means there are up to 500 stations in every assembly plant using tooling applications. Tooling includes complex and specialized hand tools, jigs and fixtures that hold, position and check parts in the manufacturing process.

Each station utilizes approximately $2,500 worth of conventionally built hand tools, jigs and fixtures – totaling to a conservative, plant-wide estimate of over $1 million. Furthermore, at these volumes, and with approximately 75 operating and planned assembly plants in North America, there is an extraordinary amount of energy and capital spent on conventional tooling.

In contrast, AM can be used to create lightweight, durable tools to pick, place, move, hold, check or locate parts. A tooling example reviewed in this report examines a lifter component that can be made via AM for $400. This is a savings of over $1,500 versus a lifter component produced by conventional manufacturing at a cost of $1,920. In this scenario, a total of 88 such lifter components is required, which sums to a potential savings of more than $130,000 for one production process.

3D printing tools eliminates the production of individual tooling components, fasteners and welding operations, reducing cost, energy and lead time. And because 3D printed tools are lower in weight than conventionally manufactured industrial components, wear and tear, as well as maintenance for the overall system, is also reduced, saving more resources overall.

AM is particularly suited to complex and lightweight applications – exactly what is needed for hand-applied tooling. These hand tools are custom fitted to follow the contour of assembled vehicles and help the operator align labels and trim components. Hand-applied fixtures or tools made using AM are complex, ergonomic shapes that can be created without machining. When made by a 3D printer, these fixtures are light, accurate and quickly made.

A lightweight automotive assembly jig.

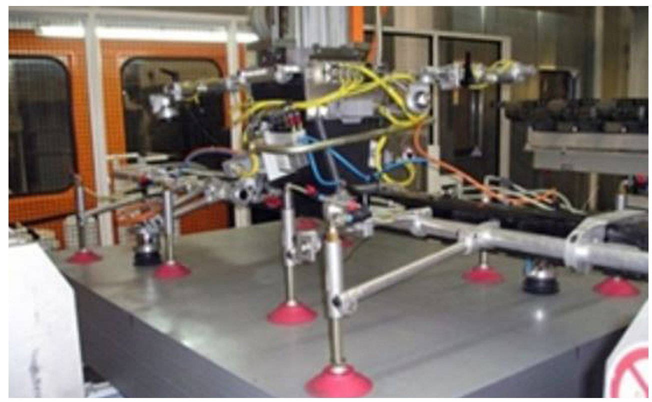
The average vehicle takes about 20 hours to produce, and before completion, it will visit over 1,000 assembly stations along the conveyor route.

Additive Manufacturing For Lifters

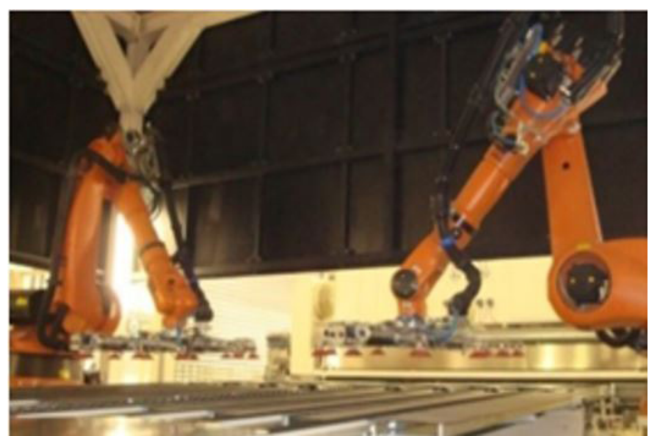
Lifters provide any combination of manual, mechanical or motorized handling of materials and components – particularly heavy or unwieldy items. In this picture top right, the tooling assembly is used to pick sheet metal blanks from a stack. This fixture is so beneficial, it is seen throughout the automotive industry. All the fixture components shown in the image can be replaced by AM.

The picture middle right shows a twin robot layout picking up and transferring flat metal blanks as part of a manufacturing system. As in the picture below left, the fixture concept of multiple components built and attached together is used, this time duplicated for right and left blanks. This tooling is a prime opportunity for an AM application.

The picture to the bottom right shows the same concept of a simple cut-and-welded fixture used to carry a formed part. The formed part has three-dimensional contours, so the lifting fixture can't be flat. These lifting fixtures hold parts for inspection, scanning or support. Because the formed part is complex, there is also complexity in manufacturing it. As the complexity of the part or assembly increases, the the benefit of 3D printing tools used to move the part also increases. The challenge of making anything via AM is limited to the CAD file and size of the printing platform. But the AM process is the same, regardless of the shape of the part or fixture being printed.



Lifting tool used to move sheet metal blanks.



A twin robot assembly used to transfer flat metal blanks.

A cut-and-weld fixture for carrying a formed part.

Additive Manufacturing For Lifters

There are countless examples of 3D printing use cases, and the die lifter component is one of the many promising applications. An automaker makes or buys dies to produce sheet metal parts, which get welded into vehicle subsystems and are ultimately joined together in a body shop of an assembly plant. There are typically four or five stamping dies required for every part.

In the hypothetical scenario here, the automaker designs a part that requires only four operations. This means there are four lifters required for every part. For a standard four-door sedan, there are 22 major panels typically stamped in-house. This means there are 88 lifter systems required for a single styled sedan body-in-white (a sheet metal automotive body before paint, trim and powertrain are added). It costs approximately $169,000 to make these 88 lifter components conventionally[2]. Producing the same 88 lifter sets using AM could potentially save over $130,000. These savings come from eliminating the dies that make the tools used to build the lifters. The table below illustrates these savings, assuming one set of dies produced using conventional manufacturing requires 16 hours of cutting, welding and finishing, and that 88 sets of dies are required to produce all of the lifter systems to make one vehicle. The expected cost of 3D printing one lifting component (of the 88 required) is approximately $400 versus $1,920 through conventional manufacturing[3]. This is a difference of approximately $1,500 per lifter. This scenario assumes that a shop pays for 3D printing as a service rather than purchasing a printer and materials.

If an automaker has four new model launches per year, the savings from using AM lifters can grow to more than $500,000 annually. This is a conservative estimate — it doesn't include the value of the potential lead time reductions (from ordering, testing and producing dies) as well as the value of downsizing other components.

There are hundreds of workstations in each automotive assembly plant; every station brings the opportunity to achieve savings from 3D printed lifting components. Wherever the part is picked up, rotated, repositioned, transferred or held, AM lifting tools have the potential to realize similar savings.

Example of Potential Cost Savings Using 3D Printed Lifting Systems

Line #	Cost Breakdown Comparing Traditional Tools And 3D Printed Tools	Conventional	3D printing	Savings using 3D printing
1	Number of lifter components to be made	88	88	NA
2	Hours of labor to produce one component	16	NA	16
3	Overhead and labor cost per hour	$120	NA	$120
4	Materials	Assume equal cost	Assume equal cost	Assume equal cost
5	Cost to 3D print one component	NA	$400	($400)
6	Marginal Cost: Line 2 x Line 3 or Line 5	$1,920	$400	$1,520
7	Total Marginal Cost: Line 1 x Line 6	$168,960	$35,200	$133,760

[2] These costs could be shared by one shop or across several shops working together.
[3] The cost of $400 was provided by a shop that was interviewed for this paper and is based on their actual cost.

Conclusion

Lifting tools can be produced more easily with high quality and lower cost with AM compared to traditionally manufactured lifting tools. The lightweight 3D printed components dramatically reduce the weight of the entire lifter, which directly improves maintenance and efficiency of the overall system, as well as ergonomics for the operators on the line. An additional benefit is that replacement tools can be produced at relatively low cost and with shorter lead time than traditional tooling, saving time and money.

AM also holds the potential to ease the shortage of tool and die facilities, which could cut costs and inefficiency in ways that are unmatched by traditional manufacturing processes and fixtures.

Using AM as part of the production process with 3D printed tools and fixtures is a logical step towards cutting-edge automotive manufacturing. In the longer term, AM will be used more extensively in manufacturing for mass production. But AM is already being used to quickly produce lighter, multi-material parts with improved functionality, fewer design restrictions and complex geometries. Because it is an additive process, AM can reduce scrap and overall material consumption, which is important when using higher-cost, advanced materials.

Furthermore, AM can enable the production of parts and tools that require less finishing (post-processing) than their conventionally produced counterparts.

As printing cycle times and process consistencies improve, more opportunities for AM will become available. Given its advantages, and the continuous improvements made in the industry, additive manufacturing is expected to become increasingly relevant in transforming the automotive industry's production processes and products.

As vehicle manufacturers become more familiar with AM capabilities and as the cost and durability improve, adoption of the technology will follow.

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