Assessing the Potential of Additive Manufacturing for Lower-Cost Tools in the Automotive Industry

MOVING FROM RAPID PROTOTYPING TO PRODUCTION APPLICATIONS

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By the Center for Automotive Research

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EXECUTIVE SUMMARY

Additive manufacturing (AM) is making inroads into the automotive industry. Historically, AM was used primarily to produce prototype parts and models. Today, AM is also used to make tooling for assembly lines or to produce vehicle parts. One of the advantages of AM is conquering complexity. Additive manufacturing can create complex or simple shapes using the same process and with the same level of effort. The AM process can 3D print complex tools more simply than conventional manufacturing, which must use multiple processes such as milling, drilling, welding, etc. A tooling example reviewed in this report examines a lifter component that can be made via AM for US$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.

Speed, quality and cost are the primary drivers of production process decisions. AM tools can be produced more easily, exactly to print and at a lower cost than traditional tools. As additive manufacturing cycle times improve and print materials grow in variety and functionality, there will be more applications for AM products in automotive manufacturing.

INTRODUCTION

Additive manufacturing, also known as 3D printing, has existed since the 1980s but has recently come into greater use[1]. As the cost of equipment has declined and capabilities have improved, more organizations, and even consumers, are purchasing and using 3D printers to produce many different items. 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, and even food and other materials.

AM has primarily been used in the automotive industry to produce prototype parts and models. 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

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

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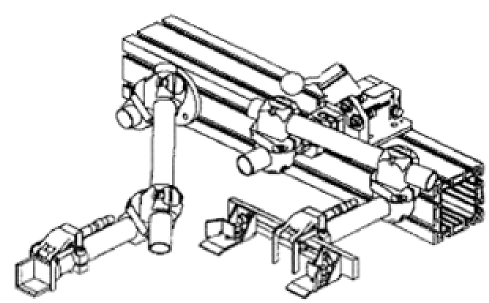
or process to achieve widespread production use are quite difficult. Since safety and durability are primary considerations in the design and production of any vehicle, manufacturers must be assured that new products, technologies or processes introduced into the automotive industry meet the existing standards of excellence.

In 2015, the Center for Automotive Research (CAR) completed an investigation into automotive manufacturing applications of 3D printing for Stratasys, a manufacturer of 3D printers and 3D printed products. This paper builds on that investigation by examining the potential for increasing the use of AM in building lifting tools for the automotive industry. Lifting tools are specially built manufacturing equipment that are used to lift parts and material during processing and assembly. Die lifters and checking fixtures are a subset of robotic end-of-arm tooling. Pictured on the right is one example of a lifter and its many parts. These lifting tools are often complex assemblies themselves, and AM has the potential to simplify production of tools at a lower cost than traditional manufacturing. Although the examples shown here are from the automotive industry, many of these examples apply to manufacturing in general.

ADDITIVE MANUFACTURING AND THE AUTOMOTIVE INDUSTRY

The automotive industry currently uses AM technologies early in the vehicle development cycle—during design, engineering, pre-production operations and testing. Rapid prototyping was the first application of AM technology used by the industry, as it provides prompt physical testing of functions, performance, size and overall aesthetics of parts. Designers, engineers and testing labs at automaker and supplier facilities use 3D printing for rapid prototyping of parts at their research, development and design centers. Evaluating prototypes in applications such as wind testing, assembly trials and fluid flow validation allows for quick alterations based on trial results or technician feedback. However, while prototyping



A complex 3D printed compnent.

is a good fit for AM, the jump to mass-production of parts and vehicle components via 3D printing is limited by print cycle times, material criteria, cost, and durability concerns. But that doesn't mean there isn't a role for this technology in manufacturing, joining and assembly operations.

Conventional manufacturing of complex parts can be constrained by equipment capabilities. Using traditional milling cutters and drills, the creation of complex geometries can be limited by access to the part, line of sight, and closed corners. One of the advantages of AM is conquering complexity. Additive manufacturing can make both simple and complicated shapes, using the same process and the same level of effort. The picture above shows a hypothetical complex part with curved tubing. Conventional manufacturing would be challenged to drill holes following the curves in this 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 shown here that was produced on a 3D printer.

This lightweight tool is used for punching operations.

Tooling, which includes complex and specialized hand tools, jigs and fixtures that hold, position and check parts in the manufacturing process, offers opportunities for high volume and easy adoption of AM. As vehicle design, engineering and manufacturing decision-makers become more familiar with AM capabilities by using printed tools, and the AM process itself improves in cycle time, cost and durability, the industry may eventually use the technology to print production parts.

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A lightweight automotive assembly jig.

POTENTIAL OPPORTUNITY IN TOOLING

AM can be used to create tools to pick, place, move, hold, check or locate parts. Printed tools can be lower in weight than conventionally manufactured industrial components, thus reducing wear and maintenance on the overall system and enabling lightweighting of other components. Making tools using AM reduces build time by eliminating the production of individual tooling components, fasteners and welding operations, which has the potential to further reduce cost and lead time.

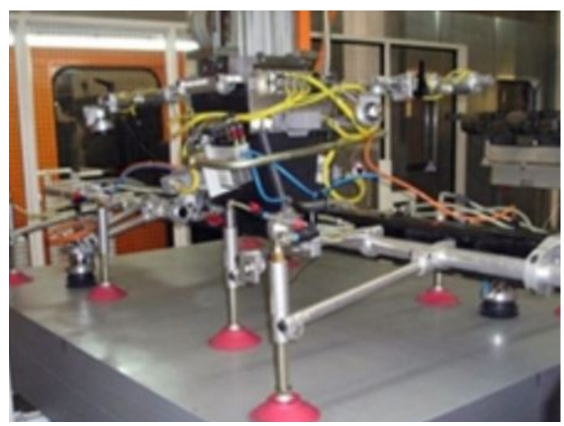
An automotive assembly plant produces roughly 250,000 vehicles per year and employs about 3,000 people on-site. The average vehicle takes about 20 hours to produce, and before completion, it will visit over 1,000 assembly stations along the conveyor route. While some of these stations are for things 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 that could be supplied by 3D printed tools. 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 potential to realize tremendous savings with the use of AM to create various tool types.

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.

CAR's Stratasys 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.

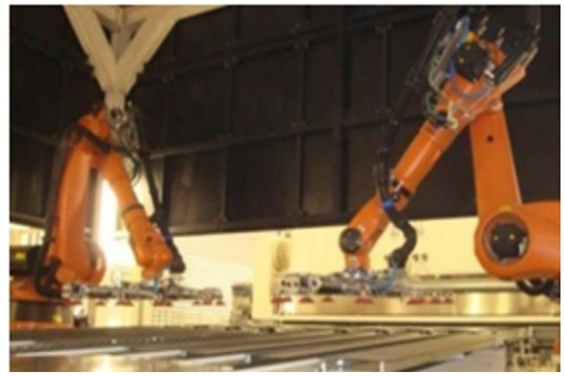
THE USE OF ADDITIVE MANUFACTURING FOR OR WITH LIFTERS

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



Lifting tool used to move sheet metal blanks.

The picture at right shows a twin robot layout picking up and transferring flat metal blanks as part of a manufacturing system. As in the picture above, 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.



A twin robot assembly used to transfer flat metal blanks.

The picture below 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 cannot 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 payback of AM in making tools to move the part also increases. The challenge of making anything via AM is limited

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

to the CAD file and size of the printing platform. The AM process is unchanged, regardless of the shape of the part or fixture being printed.

THE BENEFITS OF USING ADDITIVE MANUFACTURING TO MAKE PRODUCTION 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, which 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 part that require only four operations (a conservative estimate.) 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.

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		
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.

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.

CONCLUSION

Speed, quality and cost are the primary drivers of production process decisions. AM lifting tools can be produced more easily, exactly to print and at a lower cost than traditional lifting tools. The lower weight of 3D printed components dramatically reduces the weight of the entire lifter, which directly improves maintenance and efficiency of the overall system. An additional benefit is that replacement tools can be produced at relatively low cost and with shorter lead time than traditional tooling.

The automotive industry continues to evolve and incorporate new technologies in vehicles and vehicle production processes. It is both a highly competitive industry and one with high barriers to entry. Automakers and suppliers are always interested in effective, cost-cutting technologies that meet their stringent requirements for quality, safety, production speed and large-scale manufacturing. Given the complexity of the product and the industry, even applications that fulfill these requirements are slow to gain widespread application due to the risks in changing to new materials or methods. But in many manufacturing locations, even the U.S. Midwest, it is difficult to find sufficient tool and die-making capacity to support vehicle manufacturing. AM 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 intermediate step in automotive manufacturing. In the longer term, AM will be used more extensively in manufacturing for mass production. Already, AM is occasionally 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.

info@stratasys.com

STRATASYS.COM

HEADQUARTERS
7665 Commerce Way, Eden Prairie, MN 55344
+1 800 801 6491 (US Toll Free)
+1 952 937 3000 (Intl)
+1 952 937 0070 (Fax)

2 Holtzman St., Science Park, PO Box 2496
Rehovot 76124, Israel
+972 74 745 4000
+972 74 745 5000 (Fax)

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