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THE 3D PRINTING SOLUTIONS COMPANY™

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Optimize Production for Agile Manufacturing

SIX 3D PRINTING APPLICATIONS THAT CAN IMPROVE THE BOTTOM LINE

INTRODUCTION

THE FORTUS 3D PRODUCTION SYSTEM

Additive manufacturing technology is dramatically changing how things are made, and Fortus® 3D Production Systems from Stratasys® are at the forefront of this transformation.

Fortus systems are designed with flexibility to meet the user's needs, whether it's adopting digital manufacturing for the first time or getting high-performance materials and high capacity for demanding production environments.

The latest Fortus 3D Production Systems boast faster print times and improvements in the user interface. That ultimately means they're easier to use and increase productivity even further than previous models.

Fortus systems run on FDM® technology, which builds parts layer by layer from a CAD model using a variety of production-grade thermoplastics. With FDM technology, the fabrication process is substantially simplified. Toolmaking becomes less expensive and time-consuming. Intricate designs that are impossible to make with conventional tooling are now possible. As a result, manufacturers realize immediate improvements in productivity, efficiency and quality.

FDM technology also offers a wide range of production-grade thermoplastics, each with specific qualities to meet different manufacturing needs. Whether it's the familiar family of ABS thermoplastics or advanced materials certified for aircraft components, biocompatibility or food contact, there's an FDM material that will meet the challenge. Whether the objective is developing prototypes or production parts, the resulting component is made from the same durable material as traditional injection molded parts.

Fortus 450mc™ 3D Production System

INTRODUCTION

MAKING THE MOST OF 3D PRINTING IN PRODUCTION

When it comes to leveraging the power of additive manufacturing, commonly known as 3D printing, having a versatile family of 3D printers to choose from is essential, but making the most out of what they can do is what really matters. 3D printing has always been a perfect fit for rapid prototyping and will continue to serve this application very well. But the real beauty of 3D printing is that it removes the constraints associated with traditional manufacturing, providing a blank canvas upon which creative minds can develop new applications. To help expand your knowledge of the potential of FDM technology, this e-book addresses six manufacturing applications typically associated with traditional production techniques.

- Jigs and fixtures
- Composite tooling
- Production parts
- End-of-arm tooling (robotics)
- Sand casting
- Thermoforming

It will show how 3D printing can make dramatic improvements in both time and cost efficiency when compared with traditional production methods associated with these applications. Real world examples are also provided to show that these aren't just hypothetical scenarios. The companies highlighted in this e-book found a way to transform traditional manufacturing applications using FDM technology and bring their operation to a new level.

Cast door handles made using FDM patterns for sand casting.

CHAPTER ONE -

USE FDM JIGS AND FIXTURES FOR DRAMATIC TIME AND COST SAVINGS

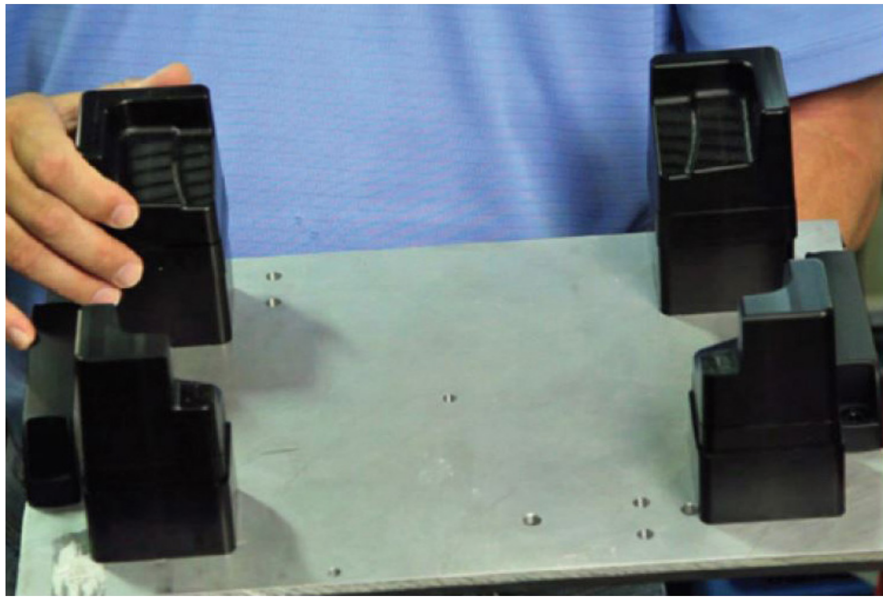
Manufacturing relies on tools including jigs, fixtures, templates and gauges to maintain quality and production efficiency. They are used to position, hold, protect and organize components and subassemblies at all stages of the manufacturing process. And although these tools are virtually invisible when production is running smoothly, their importance becomes evident when problems arise. To avoid production halts or product defects, new jigs and fixtures must be rapidly designed, manufactured and deployed.

THE 3D PRINTING ALTERNATIVE

Jigs and fixtures are most commonly fabricated from metal, wood or plastic in quantities of just a few to several hundred using a manual or semi-automated process. On average, each tool takes between one and four weeks to design and build. However, elaborate or intricate tools may require several cycles of design, prototyping and evaluation to attain the required performance. In contrast to conventional manufacturing methods, FDM technology provides a fast and accurate method of producing jigs and fixtures. Additionally, these tools can be designed for optimal performance and ergonomics because FDM Technology places few constraints on tool configuration and FDM materials are lightweight compared to metal.

What's more, adding complexity does not increase build time and cost. The efficiency of the FDM process makes it practical to optimize jig and fixture designs and increase the number in service. Engineers can easily evaluate the performance of the tool and make quick, cost-efficient adjustments to the design as needed.

Because FDM technology builds geometries from the bottom up, it's not subject to the same design constraints as hand fabricating or computer numerical control (CNC) machining. This makes it practical to produce jigs and fixtures that were previously not feasible from a cost or design perspective using traditional manufacturing methods.



FDM assembly line nest mounted on an aluminum blank.

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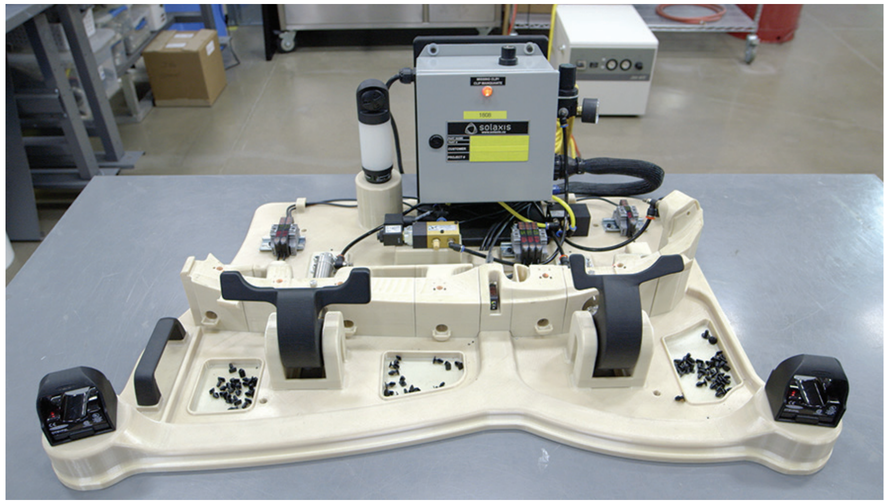
USE FDM JIGS AND FIXTURES FOR DRAMATIC TIME AND COST SAVINGS

CUSTOMER STORY – SOLAXIS INGENIOUS MANUFACTURING

Jigs used to assemble automotive parts traditionally share two downsides: They can be difficult to maintain, and because they're made of metal, they're heavy — up to 150 pounds — too heavy for a single worker to move easily amid a bustling factory floor.

But as the engineers at Solaxis Ingenious Manufacturing in Bromont, Canada have demonstrated, jigs don't need to possess any of those negatives. With the help of Fortus 3D Printers, the company designed and manufactured a jig for an automotive supplier to assemble high-volume plastic door seals. After several design iterations, Solaxis produced a 3D printed jig that is 100 pounds lighter than a typical jig for this application, and slashed the design and manufacturing time by at least two-thirds compared with traditional methods.



Automotive assembly jig built from ULTEM™ 9085 resin and Nylon 12 material.

Solaxis design engineers continued to refine this tool, producing at least a dozen different design iterations over the last couple of years. The rapid speed at which the designs could be completed through CAD software and then quickly printed with Fortus 3D Printers was a relatively new concept for their automotive customer.

"From design to design, we could easily make changes," noted Solaxis president, Francois Gilbaut. "It's not like we had to come back (to the customer) and say, 'We have to redo your tooling'." This agility increases the flexibility of design, enabling Solaxis engineers to integrate minor adjustments. It also enabled Solaxis to lessen the number of parts in the design, integrating off-the-shelf internal hardware that can be quickly replaced if a switch or wire breaks.

Depending on the part's complexity, engineers can make CAD iterations in just eight to 20 hours. Solaxis and the customer's engineers shared files to quickly confirm the design and produce a new jig within days. Unlike a jig produced by an operator using a CNC machine, Fortus 3D Printers can run without supervision, with production scheduled at any time of the day or night, and on weekends.

The results were clear to the customer. "We shrank the overall design/manufacturing cycle time, which is traditionally 16 to 20 weeks, to three to five weeks," Guilbault said.

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USE FDM JIGS AND FIXTURES FOR DRAMATIC TIME AND COST SAVINGS

The jig, which is 34 inches by 22 inches, and weighs just 28 pounds, is light enough for anyone to pick up and move.

In addition, the jig saves an average of four seconds per cycle in the assembly process. With 250,000 cycles a year performed by a typical employee assembling the seals, the supplier has saved hundreds of hours in labor time. “Just that cycle time gain alone justifies the price of the jig,” Guilbault said. “So their ROI is achieved within 12 months.”

Before working with Solaxis, the customer had recurring compliance issues. Deliveries to the OEMs were returned, resulting in substantial time and cost to re-inspect and fix the shipments. Stratasys 3D printing technology enabled Solaxis to improve the jig, saving the customer production time and money. In turn, the automotive supplier has significantly increased the reliability of the door seals it provides to its OEM customer. With zero compliancy issues the last two years, that means higher profits for the company.

This assembly jig made with Fortus FDM materials is only a fraction of the weight it would exhibit if made from metal.


Watch the video to see how Solaxis used FDM for jigs and fixtures.

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USE FDM JIGS AND FIXTURES FOR DRAMATIC TIME AND COST SAVINGS

CUSTOMER STORY – ALSECA ENGINEERING

Alseca Engineering is a tier-one automotive parts supplier based in Bucharest, Romania. Not long after the company was created, it found that one of its major expenses was the development of manufacturing tools. Those tools helped give the company an edge over the large, well-established suppliers that dominate the auto industry. However, in a little over a year, Alseca had spent $250,000 on production-ready tools, a significant cost investment in tooling for product development.

Early design development was labor intensive and included wooden forming tools, and separate tools for testing plastics and plastic bonding processes. That added a fair amount of time, especially when the first versions weren't perfect and new tools had to be created to test additional iterations.

Founders Claudiu Diaconescu and Dan Leuciuc decided that they needed to trim development time and cut costs in order to expand sales to automotive OEMs like GM, Dacia and Renault. To address this, Alseca invested in additive manufacturing, buying a Fortus 3D Printer to create manufacturing tooling.

"The 3D printer lets us shrink the time to create tooling from three or four weeks to three or four days," Leuciuc said. "We don't have to order aluminum or steel and mill it." Additive manufacturing lets the development team try more design options, shorten development times and show customers a part that's production ready.

When Dacia, a Romanian automaker owned by Renault, asked Alseca to develop a trunk plate, their goal was to improve gas mileage by reducing weight.

Alseca used its 3D printer to quickly create tooling for its vacuum forming process. That allowed them to test different trunk plate designs with a twin-sheet structure. The two-sheet design provided extra strength while significantly reducing the weight over the cover's wooden predecessor. Stratasys FDM technology was ideally suited for this application because of the material strength needed for this manufacturing process, as well as the ability to test tool designs including hole placements, shapes and sizes.

The FDM tool (top) was used to proof and then produce the dimpled design of the lightweight, twin-sheet trunk plate.

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3D printed production-ready tools made it simple for developers to compare multiple versions of the trunk plate and decreased the weight from 15 lbs to 5 lbs, a reduction of over 70%. "We needed to do virtual tests to see if a rectangular pattern or circular pattern provided the best combination of strength and light weight. We validated the design with five prototypes that were built using production-ready tooling made on our 3D printer," Leuciuc said.

Though Alseca has only used additive processes for about a year, the technology is already transforming the company. When iterations can be made in days instead of weeks, engineers have more design freedom and can create tooling that would be difficult to make with conventional manufacturing processes. "3D printing is starting to change the way we design and engineer our parts," Leuciuc said.

See how Alseca made lighter tooling with FDM technology.

The final trunk plate produced with an FDM thermoforming tool.

HOW DOES FDM COMPARE WITH TRADITIONAL TOOLING FOR ALSECA?

METHOD	WEIGHT
Traditional Manufacturing	15 lbs
FDM Technology	5 lbs
Savings	10 lbs **(71%)**

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USE FDM JIGS AND FIXTURES FOR DRAMATIC TIME AND COST SAVINGS

CUSTOMER STORY – VOLVO

The Volvo truck, an ultra-reliable paradigm of automotive innovation, is built for the long haul. And like the truck itself, the tools used to build its engine need to be rugged, streamlined and efficient. To produce tough manufacturing and assembly tools in 94% less time, Volvo Trucks now 3D prints many of them on a Fortus 3D Production System.

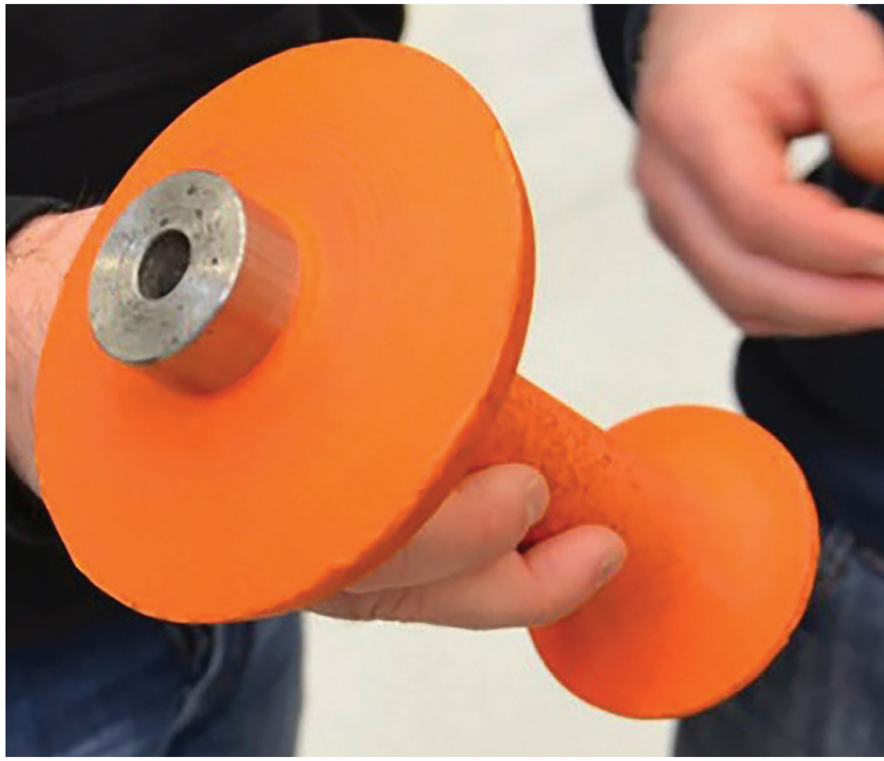
Pierre Jenny, manufacturing director at Volvo Trucks' engine production facility in Lyon, France, estimates that the tools his plant previously machined in metal required 36 days to design and manufacture. Now in just two days, their Fortus system can 3D print lighter-weight tools and fixtures in production-grade ABSplus™ thermoplastic.

These game-changing productivity gains are improving the plant's overall flexibility, helping them meet delivery targets while reducing cost and waste. Jenny estimates that for customization or small quantities, the all-in cost of 3D printing ABS tools is, in some cases, as little as 1 euro per cubic centimeter – just 1% of what the same tools would cost if machined from metal.

"Stratasys 3D Printing has made an incredible impact on the way we work," Jenny said. "The capability to produce a virtually unlimited range of functional tools in such a short timeframe is unprecedented, and enables us to be more experimental and inventive to improve production workflow."

Within three months of purchasing its Fortus system, Volvo Trucks had already 3D printed more than 30 different production tools including a range of lightweight-yet-durable clamps, jigs and supports, and ergonomically designed tool holders to organize their work environment.

"We're working in the heavy-industry sector, so reliability is naturally critical. So far, every piece that we have 3D printed has proved to be 100 percent fit-for-purpose," said Jean-Marc Robin, technical manager at Volvo Trucks. "This is crucial from a practical aspect, but also instills trust among operators and quashes any traditional notion that everything has to be made from metal in order to function properly."



A lightweight but durable punching tool produced on a Fortus 3D Production System.

According to Robin, developing production tools using additive manufacturing enables the equipment design team to be far more responsive, avoiding unnecessary waste in the event of last-minute design changes.

“The fast and cost-effective nature of additive manufacturing means that we are far less restricted than we were even six months ago, allowing us to constantly improve our processes,” Robin said. “We now have operators approaching our 3D print team with individual requests to develop a custom clamp or support tool to assist with a specific production-line issue they might be having. From a time and cost perspective, this is unimaginable with traditional techniques.

“Additionally, in the rare case that the design specifications of a traditionally manufactured metal tool were inaccurate, the lengthy and costly design and manufacturing process had to begin again. With a 3D printed part, we can simply alter the design specifications and re-3D print the piece in a few hours.”

Volvo Trucks used FDM technology to dramatically reduce the time required to produce jigs, tools and assembly aids.

CUSTOMER STORY - ORECK

The Oreck Corporation is a well-respected manufacturer of vacuum cleaners, sweepers and other household cleaning appliances. Oreck products are valued for being lightweight, exceptionally durable and easy to use. Every new Oreck vacuum incorporates 20 to 30 complex injection molded parts that must meet demanding dimensional tolerances to ensure proper assembly and performance.

Before production of a new product can begin, sample parts called first articles are made for testing. Each first article is inspected by a coordinate measuring machine (CMM) before the mold is shipped to the manufacturing facility, and once again before the mold is placed into production. During each inspection, the first article must be held rigidly in place. If any shifting occurs during the inspection process, the CMM will register a false failure.

Previously, Oreck’s quality-control team would manually attach a variety of modular aluminum clamps to hold the first article in place. This painstaking process generally took 30 minutes and was followed by up to four hours of CMM programming time. The total time to test all first articles for a new vacuum model was approximately 30 days. If a defect was found — which happened about once a month — the timeline was further delayed while the team investigated the problem.

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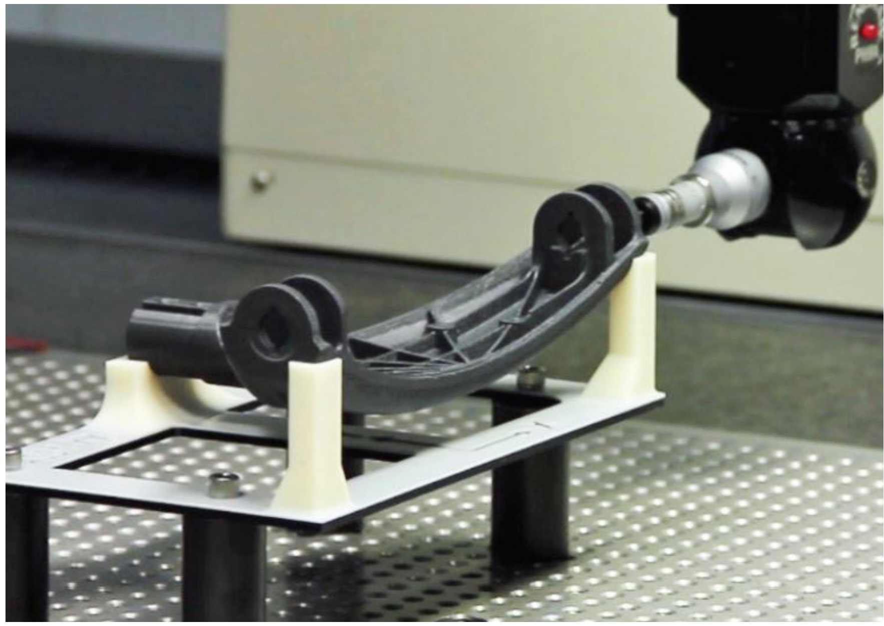
Oreck now uses FDM technology to make fixtures that are specifically designed to quickly and perfectly position each first article for testing, eliminating the need for manual placement. Furthermore, they can create an FDM prototype of the first article to use in conjunction with the complementary fixture. This allows the quality-control department to preprogram the CMM while the first article is in production, virtually eliminating the risk of testing error. And the quality control process that previously took a month is now done in one day — a 2,900% improvement.

“The accuracy and consistency of FDM technology allow us to move the programming stage up in the process, and essentially remove the first article inspection process from the critical path in the product development schedule. This makes it possible to start production faster,” said Craig Ulmer, senior QA labs technician for Oreck.



Oreck uses an FDM surrogate first article on an FDM fixture to conduct CMM programming.

Watch the video to hear Oreck employees describe the advantages of FDM for manufacturing and inspection fixtures.

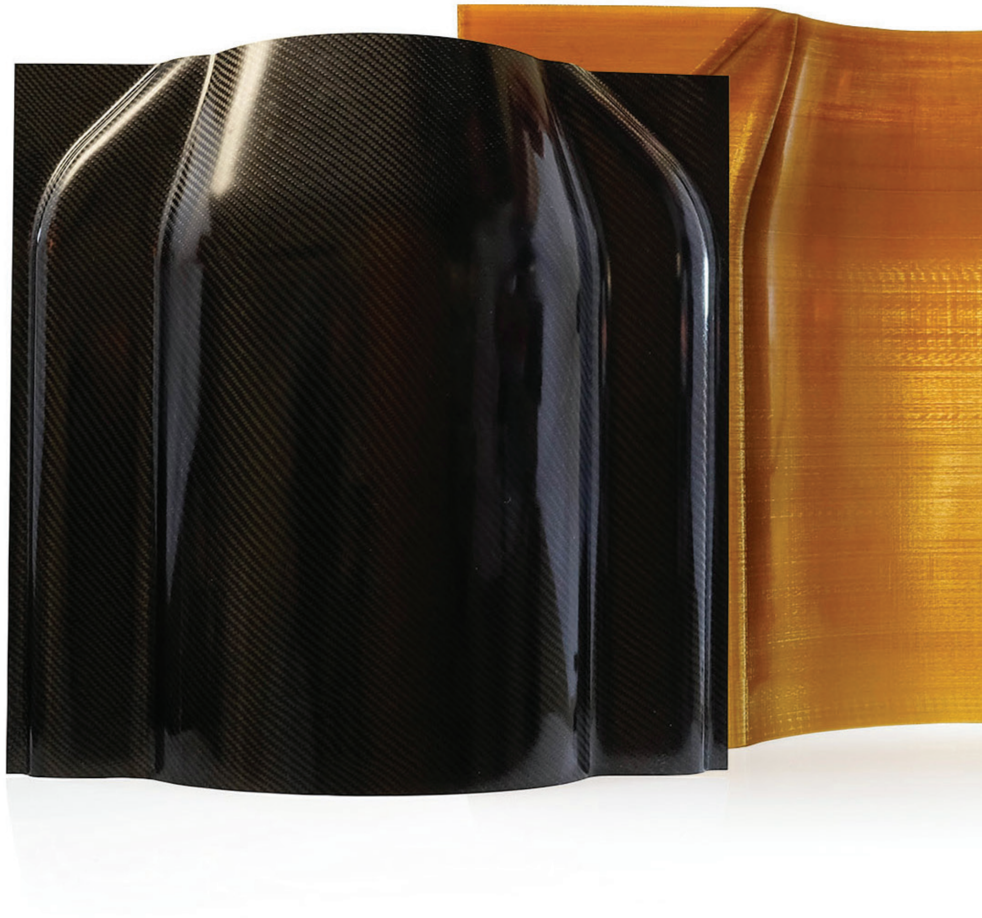
HOW DOES FDM COMPARE WITH TRADITIONAL METHODS FOR ORECK?

METHOD	PRODUCTION TIME	COST	TOTAL INSPECTION TIME
CNC	7 hours	$250	30 days
FDM	3.5 hours	$55	1 day
Savings	3.5 hours **(50%)**	$195 **(78%)**	29 days **(2,900%)**

CHAPTER TWO -

FDM TOOLING ENABLES FASTER, MORE AGILE COMPOSITES PRODUCTION

The aerospace and automotive industries pioneered the use of composite materials for strong, lightweight vehicles and structures. However, the tooling used to create them is often heavy and bulky, machined from aluminum, steel or Invar (a nickel-iron alloy), at a substantial cost and lengthy production time. These same characteristics also hinder design flexibility. Changes to a composite part's design mean the tooling needs to change, too. This repeats the cycle of high cost and long lead times, ultimately extending production cycles.



THE 3D PRINTING ALTERNATIVE

FDM technology offers an attractive alternative with disruptive potential. Composite lay-up tools made from FDM materials can be designed and created in a fraction of the time and cost it takes to create them using conventional manufacturing. That frees up time and money for design iterations, while still maintaining acceptable production schedules.

FDM technology also provides a range of materials suitable for low to mid-range cure cycles such as ABS, ASA, PC and ULTEM 9085 resin. For higher-temperature cure cycles, ULTEM 1010 resin is capable of withstanding temperatures in excess of 350 °F and pressures greater than 100 psig that are often required for aerospace structures.

FDM composite tooling can be vacuum bagged using either surface or envelope methods and is highly effective for autoclave, oven and electric heat blanket curing.

CHAPTER TWO -

FDM TOOLING ENABLES FASTER, MORE AGILE COMPOSITES PRODUCTION

CUSTOMER STORY – AURORA FLIGHT SCIENCES

Aurora Flight Sciences (AFS) is a recognized leader in aviation and aeronautics research that specializes in designing and constructing special-purpose aircraft. AFS and Stratasys partnered to evaluate and implement FDM composite tooling, ancillary manufacturing tooling (jigs, fixtures, trim tools) and flight parts during the development and production of multiple manned and unmanned aircraft structures. AFS was called upon by a key customer to design and produce a large, nine-foot-long belly-pod fairing for a modified Centaur aircraft in a very short timeframe. After receiving multiple external quotes for traditional composite tooling, AFS turned to Stratasys FDM technology to tackle the project.

The size of the fairing required the tool design to be segmented to fit the build chamber of the Fortus 900mc™ 3D Printer. Additionally, the optimally sized part design resulted in a trapped-tool geometry, meaning the cured part could not be removed from the rigid tool without disassembly or destruction.

The flexibility of FDM technology enabled segment designs that allowed the critical, trapped cylindrical section of the tool to drop down out of the part easily after lay-up and curing. Since the fiberglass/epoxy fairing used low-temperature curing and out-of-autoclave materials, the tool was built in polycarbonate to save cost. Sections were built in two construction styles – sparse and hollow shell. The sparse sections were built on a Fortus 900mc in combination with Xtend™ 500 high-capacity material canisters to reduce build time and material changes. After the build, the hollow sections were filled with high-temperature expanding foam to further improve tool rigidity with minimal cost and fabrication time.

Taking full advantage of FDM capabilities, AFS was able to meet the demanding timeline of their customer due to a 60-80% reduction in lead time, while also providing a 60-75% cost savings, compared with traditional tooling. In addition to the significant savings in cost and time, the FDM process enabled trouble-free segmentation of the design, permitting the use of a trapped-tool configuration.

The belly pod forming tool assembled from several sections produced on a Fortus 900mc 3D Printer.

HOW DOES FDM COMPARE WITH TRADITIONAL METHODS FOR AURORA FLIGHT SCIENCES?

TOOLING MATERIAL	COST	LEAD TIME
Aluminum	$65,000	7 weeks
Carbon / epoxy	$95,000	12-14 weeks
FDM-Polycarbonate	$25,000	2-3 weeks
Savings	$55,000 (average)	7.5 weeks (average)

CUSTOMER STORY – SWIFT ENGINEERING

Swift Engineering is a recognized leader in motorsport and aviation product development and manufacturing, with an extensive pedigree in open-wheel racing and a strong emerging presence in aerospace. While developing schedule-critical hardware for wind tunnel testing, Swift took advantage of FDM composite tooling's multiple benefits to quickly produce a complex, matched-mold for carbon fiber-reinforced UAV propeller blades.

The 14-inch mold halves were built using a relatively small layer thickness in a horizontal build orientation. The tool was built using a solid construction in ULTEM 1010 resin, which provides the required temperature resistance and mechanical performance. As designed, the two mold halves took 30 hours of build time. For post-processing, the mold halves were manually abraded and sealed with a two-part epoxy, resulting in a final surface finish smoother than 16 µin. Ra.

ULTEM 1010 resin forming tool used to create composite UAV propeller blades.

Watch the video to see other ways that Swift Manufacturing uses additive manufacturing to maintain its philosophy of innovation.

The tool has been used successfully to produce multiple sets of propeller blades for wind-tunnel testing. The specific processing details are proprietary, but the carbon/epoxy blades are cured at a temperature of approximately 250 °F and pressures exceeding 500 psig. The resulting blades met all initial inspection requirements.

Using FDM technology, Swift Engineering met aggressive timelines and all initial technical objectives for its innovative product development and evaluation process. This was achieved while realizing more than 50% cost savings on the complex compression mold tooling.

CHAPTER THREE -

3D PRINTING PRODUCTION PARTS

Most companies that manufacture high-volume products are looking for ways to stay competitive in today's marketplace. However, the processes they use to manufacture their products are still heavily reliant on expensive tooling and long lead times. As a result, these companies are limited in their ability to respond quickly to market changes or implement product refinements. By integrating FDM technology into production, manufacturers can bypass the traditional constraints to quickly develop and manufacture new products, and improve existing ones.

THE 3D PRINTING ALTERNATIVE

FDM has unprecedented benefits for low-volume manufacturing and can also be used to bridge the gap between product concept and traditional manufacturing processes. FDM is well-suited for these manufacturing applications:

- Pilot production: Pilot production is commonly used to validate new products and processes in mass-production industries. It often leads to a better product, lower development and manufacturing costs, a more efficient manufacturing operation, and reduced time to market. FDM can be used in this stage of production planning to quickly build one-off products and tools designed to speed the production process along.

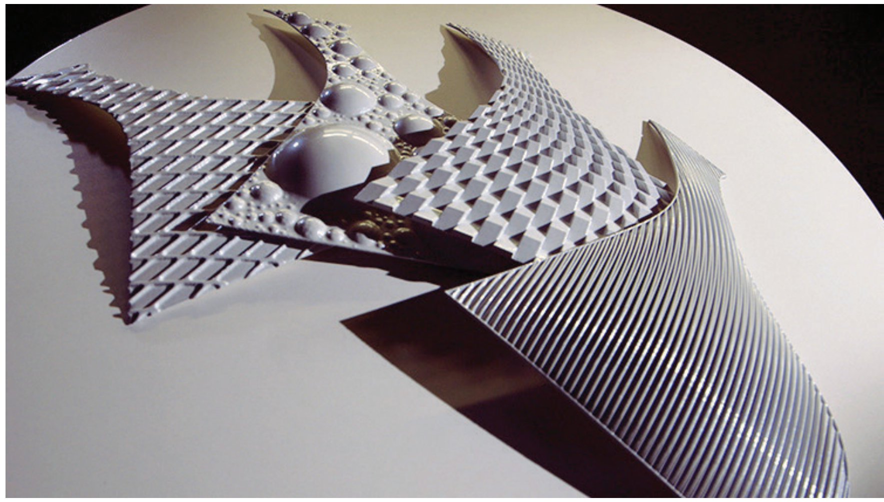
- Bridge-to-production: This is an interim step between prototyping and full production that allows manufacturers to build products for sale while full-scale tools and production processes are being created or finalized. This is a great fit for FDM technology because it requires no tooling, products can be built in hours instead of weeks or months, and manufacturers can respond efficiently and cost-effectively to the desires of the changing marketplace.

- Low-volume production: Sometimes manufacturers build their businesses around the production of low-volume, highly customized and/or complex products. In this scenario, FDM technology can maximize sales opportunities while minimizing cost and lead time because there's no minimum quantity requirement. Plus, part complexity doesn't add time or cost, so production can begin as soon as the CAD files are sent to the 3D production system.

- End-of-life production: As a product nears the end of its life cycle, investments in repairing or replacing tooling may not be justifiable, and high-volume production equipment and operators may be diverted to other products. FDM technology can be used to extend a product's life by manufacturing spare parts on an as-ordered basis, eliminating the need for physical inventory.

CUSTOMER STORY – DAIHATSU MOTOR COMPANY

Daihatsu Motor Company, a manufacturer of small, lightweight cars based in Osaka, Japan, partnered with Stratasys and outside design partners, to create Effect Skins – intricate, tactile patterns built with Fortus 3D Printers. When placed on the front and rear bumpers of the Daihatsu Copen, a popular two-door convertible, the Effect Skins frame the head and tail lights, creating a flash of expression as the "face" of the car.



Unique Effect Skins showing the customization that's possible with FDM production parts.

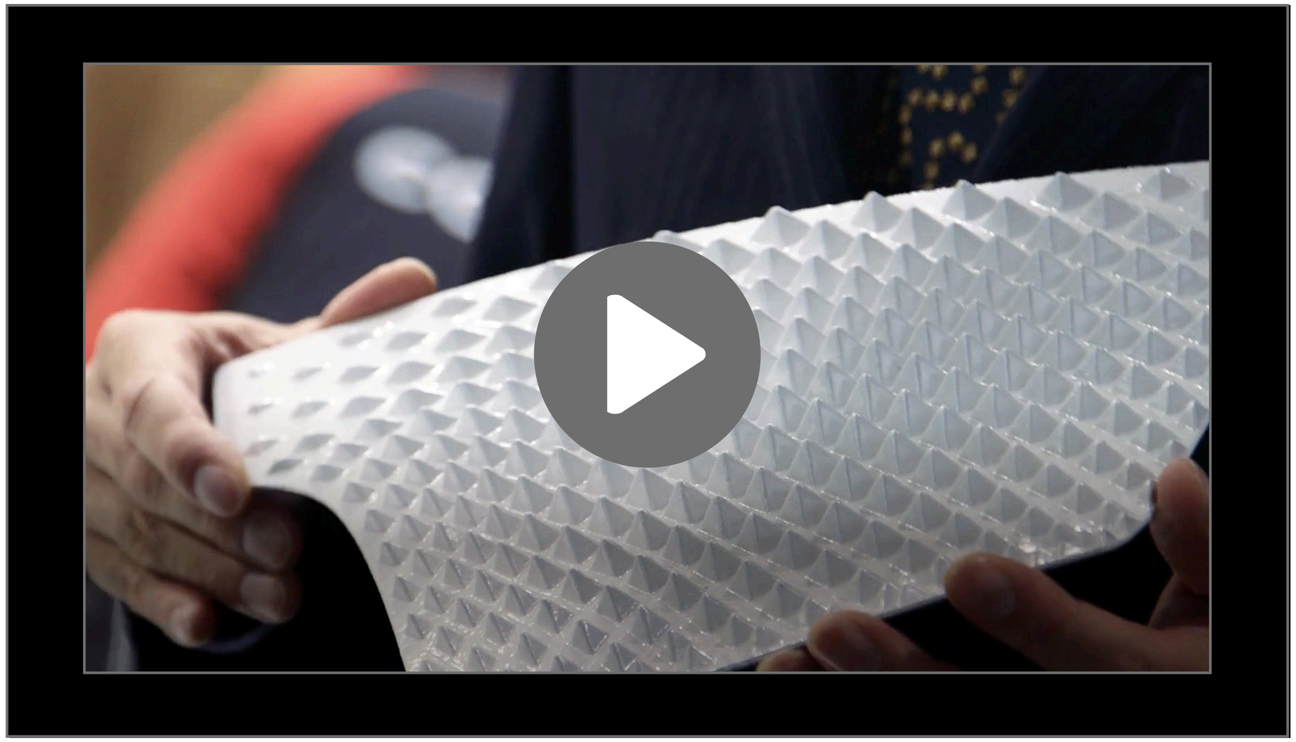
Osamu Fujishita, general manager of the product planning division for Daihatsu, said the automaker chose the Copen model for the Effect Skins because owners are enthusiasts who have tremendous passion for their cars and enjoy sharing it by customizing them. This project harnessed direct digital manufacturing to produce production parts – instead of prototypes – engineered to withstand real-world conditions on the exterior of the car.

Daihatsu 3D printed the Effect Skins in ASA thermoplastic, which is durable and enables thin, but sturdy walls. It is also available in 10 colors, allowing for even more design possibilities. The ability to quickly 3D print and test design concepts and iterations empowered 3D modeling artist Sun Junjie to experiment with many different design algorithms and iterate numerous styles quickly.

"Normally, there is a gap in the process going from data created with 3D CAD to producing the object—the modeling and the actual sculpting are different areas," Junjie said. "This project would not have been possible with traditional manufacturing or tooling methods," said Kota Nezu, head of Znug Design, who served as a design facilitator between Daihatsu and Sun Junjie.

The traditional manufacturing method of reducing costs is mass production of parts to take advantage of economies of scale. But this Effect Skins project illustrates the power of 3D printing when it comes to creating both on-demand and cost-effective production parts.

"We believe on-demand production offers definite benefits to supply chain efficiencies and allows easy access for customers," Fujishita said. "So we see it as essential in growing the market for these products and that's how we are moving forward."



Watch how Daihatsu created the 3D printed Effects Skins.

An Effect Skin shown in place on a mockup of the Daihatsu Copen vehicle.

CHAPTER FOUR -

BETTER END-OF-ARM TOOLS WITH FDM TECHNOLOGY

End-of-arm tools, also known as end effector or EOATs for short, are the “hands” that give life to robotic machinery used in a variety of manufacturing applications. They empower the robot to grip, hold and push, among other capabilities, and are an indispensable part of this tooling. But like other traditional forms of tooling, they’re not easy or fast to manufacture. They can often be bulky, expensive implements that take time to design and produce and are usually machined from metal.

THE 3D PRINTING ALTERNATIVE

End-of-arm tools made with FDM technology offer a number of benefits over the traditional methods and materials used to make them. 3D printing can produce working end effectors in a very short amount of time and for much less cost because there’s no machining or long lead times involved. Tool designs can be changed quickly and easily by revising the CAD model and printing a new tool. And design complexity isn’t a factor in the tool’s cost because of additive manufacturing’s inherent freedom from design-for-manufacturability constraints.

Another benefit is that FDM EOATs are much lighter than their metal counterparts. Rather than being made from solid metal, a 3D printed tool can be manufactured with a hollow or honeycomb-like core. A lighter end effector results in a lighter robotic tool, requiring less power to move. This means the robot can move faster and operate with smaller, more efficient motors, or move a larger payload. Weight reduction also improves motor efficiency and reduces component wear, extending time between preventive maintenance cycles.

Plastic FDM materials also provide advantages: they won’t scratch the products they grip and they dampen impact forces, reducing the chance for robot damage in the event of a tool crash.

CHAPTER FOUR -
BETTER END-OF-ARM TOOLS WITH FDM TECHNOLOGY

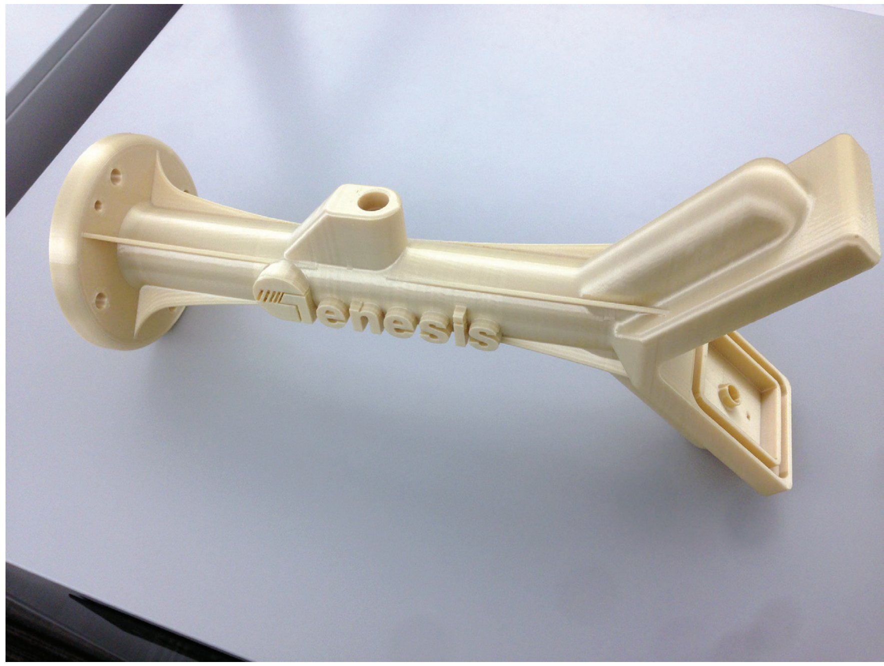
CUSTOMER STORY – GENESIS SYSTEMS GROUP

Genesis Systems Group, headquartered in Davenport, Iowa, designs, builds and implements robotic tooling for work cells used in assembly automation, material handling, non-destructive inspection and welding. One of Genesis' specialties is building robotic, waterjet cutting systems used to trim composite parts.

Genesis pioneered a safer approach for waterjet cutting. Instead of using a robotic arm to move the waterjet cutter, it keeps the waterjet fixed and uses the robot to move the part. However, this approach posed a challenge because each unique part required a custom gripper to hold and manipulate it. Genesis found that outsourcing for CNC-machined custom grippers was adequate but each tool cost nearly $8,000 and took 20 days to make.

For a better solution, Genesis turned to FDM for a faster, lighter and less expensive EOAT to replace conventionally fabricated metal grippers. Engineers began by redesigning the EOATs to include internal vacuum channels, which was cost prohibitive with CNC machining. Using FDM simplified the assembly and removed external vacuum hoses that would be damaged during waterjet cutting. "FDM grippers offer major advantages over metal grippers and conventional fixtures. Using FDM gives us tools that are quick, cheap, easy, durable and repeatable for the waterjet application," said Doug Huston, process engineer for Genesis Systems Group.

The redesigned tool, made with lightweight FDM plastic, also reduced its weight from 35 pounds to just 3 pounds. Huston noted that the weight reduction made it possible to use smaller, less expensive robots. "Switching to FDM dramatically reduced the cost of building grippers. Delivery time was substantially reduced too, which is important because if a gripper is destroyed in a crash, production may have to be shut down until the replacement gripper is built," said Huston.

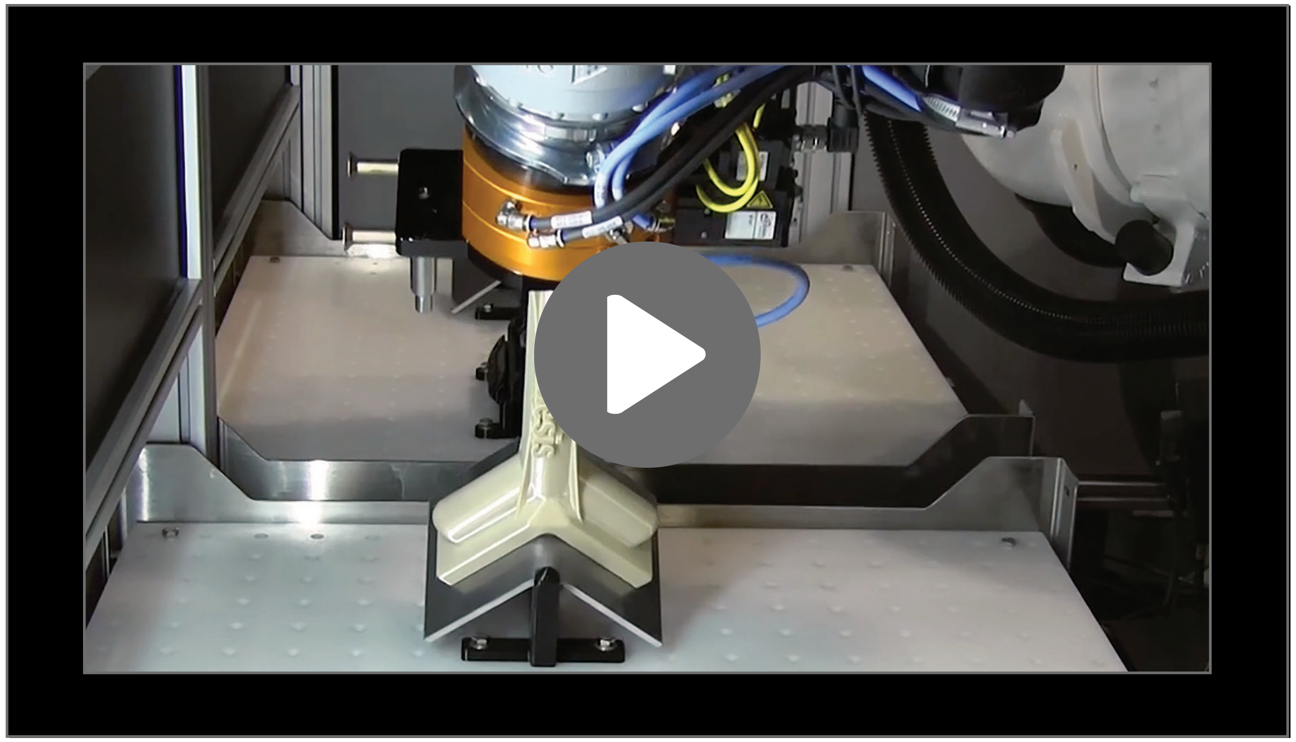


A lightweight FDM end effector designed by Genesis Systems Group incorporating integral vacuum channels.

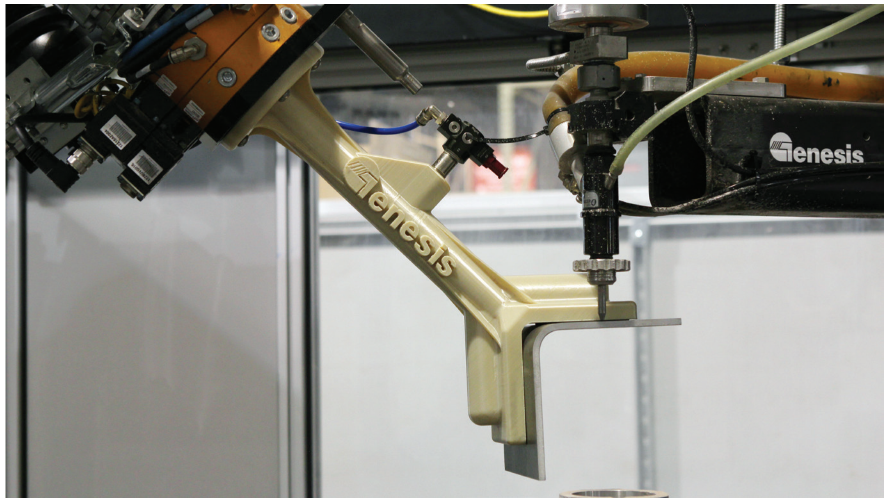
HOW DOES FDM COMPARE WITH TRADITIONAL METHODS FOR GENESIS SYSTEMS GROUP?

METHOD	TIME	WEIGHT
CNC Machining	20 days	35 lbs
FDM	3 days	3 lbs
Savings	17 days **(85%)**	**91%**

CHAPTER FOUR -
BETTER END-OF-ARM TOOLS WITH FDM TECHNOLOGY



Watch the video to see Genesis Systems Group's lightweight EOAT.



The end effector in use in a waterjet cutting operation.

CHAPTER FOUR -

BETTER END-OF-ARM TOOLS WITH FDM TECHNOLOGY

CUSTOMER STORY – ROBAI CORPORATION

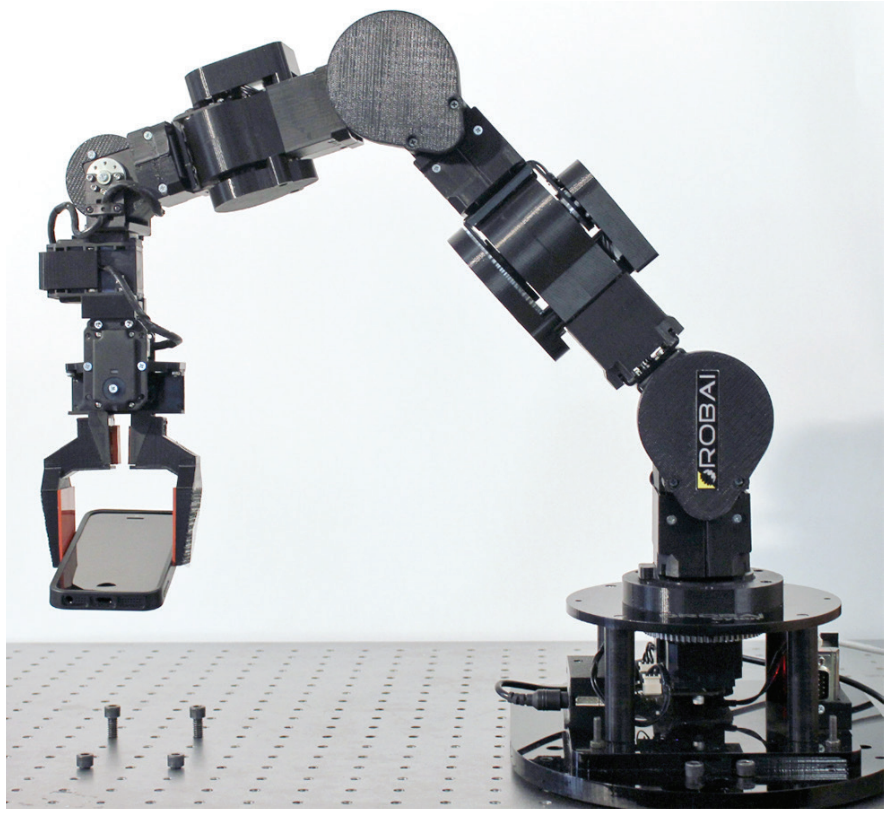
Robai Corporation, located in Cambridge, Massachusetts, makes high-dexterity robots used in a wide range of applications. One example involves using robotic arms to simulate the effect of a human's movements on mobile electronic devices.

In most robotic applications, the end of arm tool is custom-designed to hold a unique part or piece of equipment. It is usually made from metal via traditional manufacturing methods and can take up to two weeks to produce. In contrast, Robai's software capabilities allow it to develop sophisticated robotic programs very quickly. This lead time disparity between the two parts of production creates a self-imposed bottleneck in the company's ability to turn products quickly and nimbly meet customer needs. Moreover, metal end of arm tools are expensive to produce, heavy, and cannot incorporate intricate design components.

To alleviate this, Robai's management considered several different 3D printing methods as an alternative to CNC machining. Ultimately, they purchased a Stratasys 3D Printer with FDM technology as the means to create their end of arm tooling. "We selected FDM because it has much greater strength and durability, uses materials that are available in a wide range of colors, and reduces the need for secondary processing," said Ranjan Mishra, Cyton Engineering Manager for Robai.

FDM technology allows Robai to produce plastic EOATs in a fraction of the time and cost required for conventional metal tooling. The lighter weight of 3D printed tooling also makes it possible to use smaller, less expensive robots. For example, Robai used a 3D printer to produce an EOAT for accelerometer motion testing on devices ranging from smartphones to a small laptop. Each device was designed in 90 minutes and printed overnight.

"Using traditional methods to make end of arm tooling requires about 70 hours of manufacturing time, costs $7,000 and is generally delivered in about two weeks," said David Askey, Chief Business Development Officer of Robai. "The use of FDM has made it possible to reduce the labor to about four hours, the cost to $400 and lead time to one day." For Robai, that means a 94% improvement in both time and cost from its previous way of doing business.

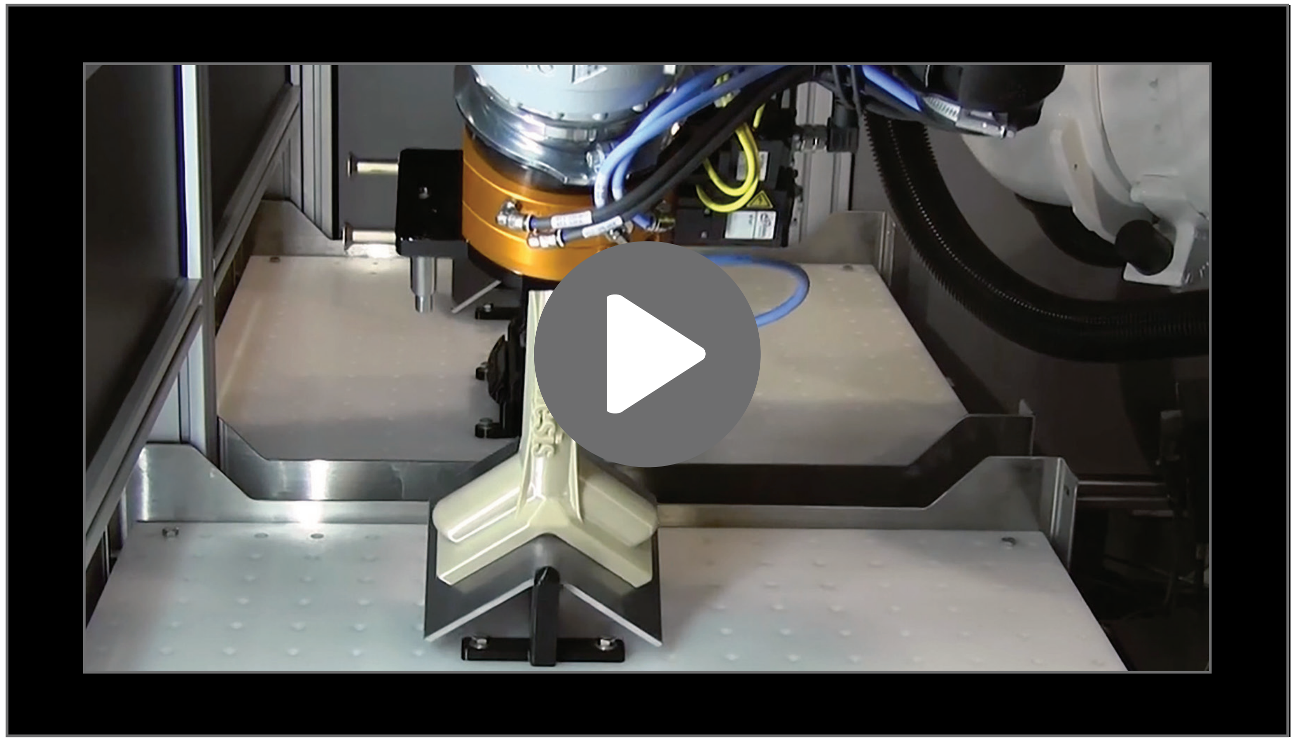


This Robai robot arm contains FDM components including the end effector gripper.

CHAPTER FOUR -

BETTER END-OF-ARM TOOLS WITH FDM TECHNOLOGY

Askey concludes, "With FDM, we're able to print the part, tailor it exactly to the customer's needs and have it ready for them in a day or two. That lets us deliver quick, high-quality solutions for our customers."



See how Robai uses FDM technology to quickly make versatile end of arm tools.

HOW DOES FDM COMPARE WITH TRADITIONAL METHODS FOR ROBAI?

METHOD	TIME	COST
CNC Machining*	70 hours	$7,000
FDM**	4 hours	$400
Savings	66 hours **(94%)**	$6,600 **(94%)**

*CNC machining outsourced locally

** FDM parts produced on in-house 3D printers

CHAPTER FIVE-

FDM TECHNOLOGY ACCELERATES THE SAND CASTING PROCESS

Sand casting is the process of casting metal using sand as the mold material. When creating a sand-cast mold, sand is packed around a pattern. When the pattern is removed, the resulting mold cavity is then used to create metal parts. If voids are required within the mold cavity, core boxes are used to create sand cores.

Sand casting is a cost-effective, efficient process for small-lot production or high-volume manufacturing when used in conjunction with automated equipment. There are three common types of sand casting patterns:

- Loose patterns are simply replicas of the cast piece.
- Split patterns are made in two or more pieces and dowelled together to permit separate removal.
- Match plates are similar to split patterns except the cope and drag (top and bottom) sides are combined into a single piece.

THE 3D PRINTING ALTERNATIVE

The production of sand molds and cast metal parts is relatively straightforward and suitable for automated methods. However, fabrication of the patterns used to produce the sand molds is often difficult, time-consuming and expensive. The most common approach is to produce patterns using CNC machining, but the production costs are high and the lead time is substantial.

Problems like incorrect shrink compensation and design flaws generally require that the pattern is reworked, which adds to the expense and lead time. Gate and runner systems (distribution channels and entry points to the mold) are typically cut from modeling board or a similar material, hand-carved and then sanded to the finished shape. This also adds expense and lead time.

Because of these problems, foundries have turned to additive manufacturing. To replace the machined pattern, additively manufactured patterns must withstand the ramming forces that are applied to pack the sand, be abrasion resistant, and be unaffected by the chemicals in the sand binders and mold release. Most additive manufacturing technologies have been unable to meet these challenges.

However, FDM materials like ABS, polycarbonate (PC), PC-ABS and ULTEM 9085 resin meet all of these requirements.

FDM parts have the compressive strength needed for use as a sand casting pattern. The surface finish of FDM parts meets all the requirements of sand casting patterns when post-processed. Post-processing also seals the molding surface to prevent release agents from penetrating and sand from sticking.

CHAPTER FIVE-

FDM TECHNOLOGY ACCELERATES THE SAND CASTING PROCESS

CUSTOMER STORY – MELRON CORPORATION

Melron Corporation is a manufacturer of window and door hardware using traditional sand casting techniques and modern foundry practices. As a means of becoming more competitive in the global marketplace, the company began focusing on the production of high-margin, low-volume items for the residential and restoration markets.

In the past, Melron used a subcontractor to machine match plates from aluminum at a cost of approximately $5,000 each with a delivery lead time of three to four weeks. However, the match plates often required design changes. As a result, Melron considered rapid prototyping technologies but found that most were not able to withstand the ramming forces necessary to pack sand, and lacked abrasion and chemical resistance.

Melron then investigated FDM technology. They started on a small scale by ordering an FDM match plate from a service bureau. Then, because it worked so well, the company ordered an FDM 3D printer and began producing match plates that combined pre-fabricated aluminum blanks with FDM inserts.

Thanks to FDM technology, the cost of producing match plates is now approximately $2,000 — a 60% reduction from CNC machining. Additionally, lead times have been cut in half, to one and a half weeks. Melron also uses its FDM machine to create a gate and runner system, saving an estimated six hours of hand work per match plate.

“FDM is facilitating our transition to new markets by enabling us to produce match plates at a lower cost and in less time than ever before,” said Dan Schaupp, Melron engineer.

Matchplate with FDM insert in molding machine.

CHAPTER FIVE-

FDM TECHNOLOGY ACCELERATES THE SAND CASTING PROCESS

Listen to Dan Schaupp, Melron director of engineering, describe how FDM sand casting patterns shorten the development cycle and lower cost.

HOW DOES FDM COMPARE WITH TRADITIONAL METHODS FOR MELRON?

METHOD	PRODUCTION TIME	COST
CNC	3 weeks	$5,000
FDM	1.5 weeks	$2,000
Savings	1.5 weeks **(50%)**	$3,000 **(60%)**

CHAPTER SIX-

FROM PACKAGING TO AEROSPACE — FDM MAKES QUICK WORK OF THERMOFORMING TOOLS

Thermoforming is the collection of manufacturing methods that heat and form sheets of extruded plastic. It is a relatively simple process that starts with heating a plastic sheet to a pliable state. Once softened, the sheet is forced against a mold with the desired shape using different methods.

In vacuum forming, a vacuum is drawn through tiny holes in the mold, “pulling” the pliable plastic sheet into the mold. In pressure forming, air pressure is applied to the top surface of the material, “pushing” it into the mold.

Thermoforming is mainly used in the packaging industry. However, it is not limited to small products; hot tubs, aircraft cowling and refrigerator door panels are examples of relatively large thermoformed parts.

Virtually any thermoplastic available as extruded sheet stock may be used to thermoform prototypes or manufactured parts. Wall thicknesses can range from foils to thick-gauge stock — thicknesses ranging from 0.0005 to 0.5 in. — with no molding stresses.

Thermoformed packaging cover and FDM mold.

THE 3D PRINTING ALTERNATIVE

While vacuum-formed production and tooling costs tend to remain reasonable for large parts, preparing tools for vacuum forming can be costly and time-consuming. Tools are usually made of aluminum for large production operations while wooden tools are sometimes used for small production series. Regardless of the material, tooling requires the time and labor associated with setting up and operating a milling machine. If machining is unavailable onsite, tooling may be outsourced, slowing time to market and potentially increasing design expenses.

Because thermoforming doesn’t require extreme heat or pressure, additive manufacturing is a viable alternative. Although tool life will not equal that of aluminum, the materials available with FDM technology are ideal for prototyping and short-run manufacturing. Tool life ranges from 100 to 1,000 parts depending on the tool and part materials that are used.

3D printing eliminates much of the time and labor associated with machining vacuum-forming tools. Data preparation is completed in minutes, so tool construction can begin immediately after tool design. Automated, unattended additive manufacturing operations eliminate the time typically needed for fixturing, setup and operation of CNC machines. FDM technology offers the option to design vent holes into the mold, eliminating the labor and potential unevenness of manual drilling. It also allows building the mold as a porous structure for finely distributed vacuum draw. Customizing the internal structure to reduce the amount of material used results in additional time and cost savings. This custom interior can also be used to adjust the porosity around features such as deep draws.

From an application standpoint, FDM technology is a best fit for thermoforming when smooth parts are required or parts have challenging characteristics that include deep draws or organic shapes. Other good applications include when multiple designs are required and/or when lead time is short.

Stratasys ABS-M30™ material is suitable for most vacuum-forming applications. It offers mechanical properties that exceed the requirements of most thin-gauge sheets. The FDM process also uses materials that can withstand the high temperature required for some thermoforming materials, such as polycarbonate, HDPE and Kydex. FDM materials offer increased resistance to thermal degradation, often resulting in extended tool life. Their increased compression resistance makes them suitable for higher-pressure forming of thicker materials.

CHAPTER SIX-

FROM PACKAGING TO AEROSPACE — FDM MAKES QUICK WORK OF THERMOFORMING TOOLS

CUSTOMER STORY – DEFENSE INDUSTRY CONTRACTOR

Military aircraft are sophisticated tools for intelligence, surveillance, targeting and reconnaissance. One defense contractor uses FDM technology and vacuum forming to prototype and manufacture these complex systems. The company uses a Fortus 3D Production System and a Formech vacuum–forming system to reduce time, cost and labor demands for components including air ducts, engine cowlings and antennae covers. Vacuum forming replaces pre-impregnated carbon-fiber layup, which can be labor- and time-intensive.

Using FDM technology to construct a tool, vacuum forming begins in as little as one day after a design is complete, with minimal labor. Since vacuum forming parts takes only minutes, prototypes are done in less time than it would take to create a fiber layup tool.

When a functional prototype was needed for an antennae cover, FDM technology helped create a thermoforming mold. A Lexan cover was formed to replace the traditional composite cover. Lead time shrank by half, and cost went down 34%.

HOW DOES FDM COMPARE WITH TRADITIONAL TOOLING METHODS?

METHOD	COST	TIME
Fiber Lay-Up	$580	4 days
FDM	$380	2 days
Savings	$200 **(34%)**	2 days **(50%)**

BONUS MATERIAL

WEBINAR: "THE VALUE OF FDM JIGS AND FIXTURES"

Jigs and fixtures are the "third hand" in the manufacturing process and essential for maintaining production efficiency and product consistency. Despite their importance and ultimate benefit, many of these tools are often dismissed as too costly and time-consuming to create, diverting resources from primary production needs.

This webinar, presented by Rob Winker, Stratasys director of corporate applications engineering, shows how jigs and fixtures made with FDM technology avoids the hurdles associated with creating these tools using traditional methods and materials. It shows how FDM is used to decrease the time and cost of jig and fixture creation by 40 to 90%. It also includes information about where this application is a best fit and how it's being used successfully in industry.

View the Webinar

WEBINAR: "PAYBACK TIME"

Despite the financial and productivity improvements provided by a 3D printer, justifying the cost might seem challenging. However, there are several ways to approach this effort, depending on a company's goals and the best application of a 3D printer in its operation.

The webinar "Payback Time" uses the application of jig and fixture production to show how additive manufacturing produces savings that easily justify the cost of a 3D printer. Todd Grimm, additive manufacturing consultant, provides three real-world examples of how companies used the savings they gained by 3D printing jigs and fixtures to justify the purchase of their machines.

View the Webinar

WEBINAR: "MAKE END OF ARM TOOLS FASTER, LIGHTER AND EASIER WITH FDM"

End of arm tools give robotics the dexterity needed to perform whatever function they're designed for. Typically made from metal, they're often heavy, bulky and not conducive to an agile production environment. EOATs made with FDM technology are lightweight and can be designed and produced in a fraction of the time of metal tools.

In this webinar, Rob Winker, Stratasys director of corporate applications engineering, presents the benefits of FDM EOATs and gives a detailed view of one company's successful integration of FDM technology for this application.

View the Webinar

BONUS MATERIAL

WEBINAR: "ADDITIVE MANUFACTURING FOR COMPOSITE TOOLING"

Conventional composite tooling is expensive, time consuming to make and, depending on the application, heavy and difficult to transport. An innovative alternative is additively manufactured composite tools that provide multiple advantages such as reduced lead time, cost and weight.

Watch the webinar and listen to Tim Schniepp, Stratasys business development director for composite tooling, as he expands on these advantages, including a faster, more efficient means of making sacrificial composite tools for trapped-tool geometries and the use of high-temperature materials capable of autoclave cure.

View the Webinar

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