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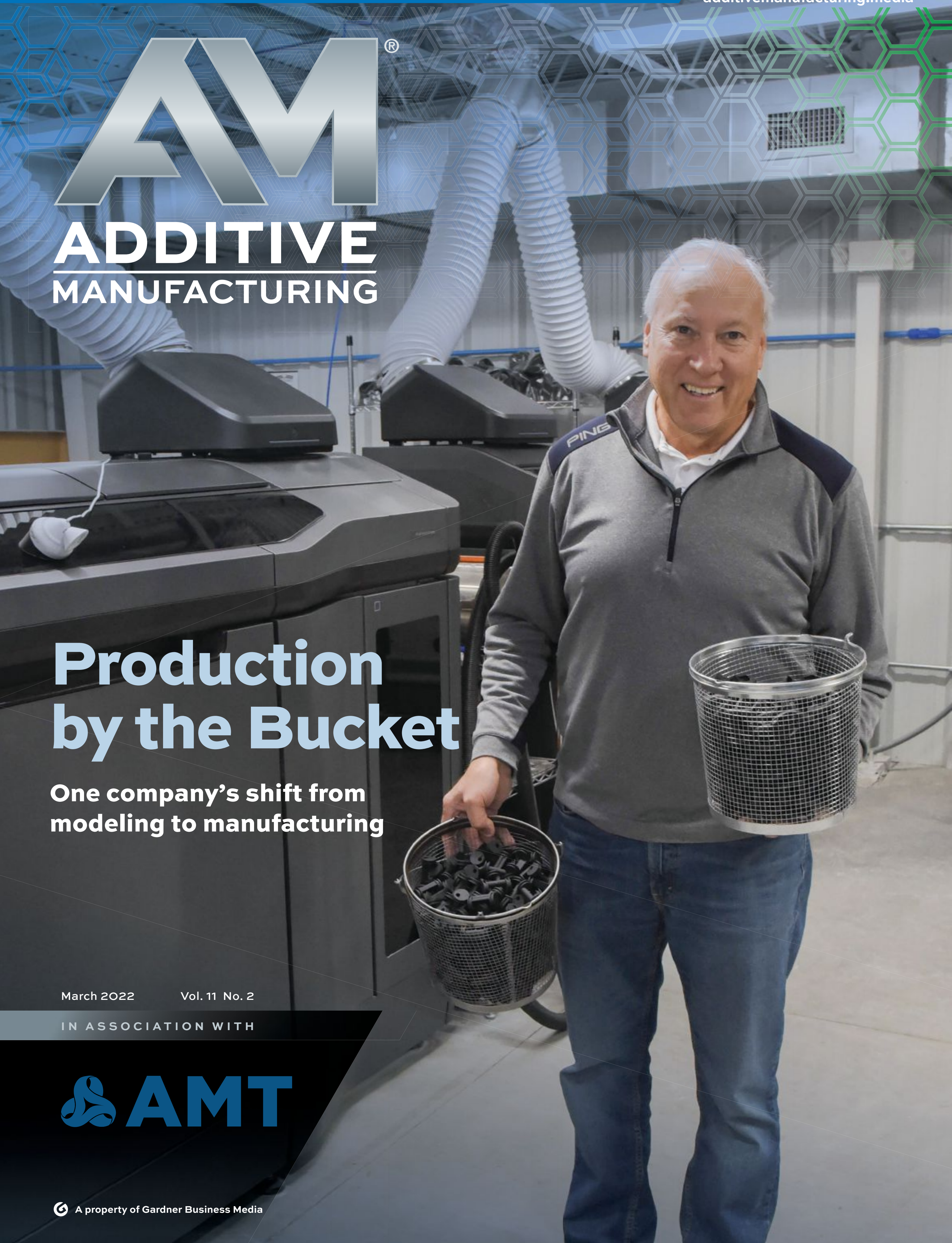

Production by the Bucket

One company's shift from modeling to manufacturing

March 2022 Vol. 11 No. 2

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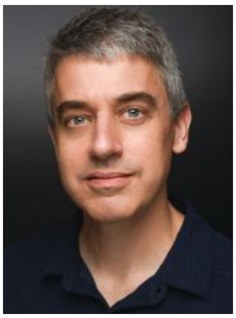
How Much Additive Capability Is Already in Reach?

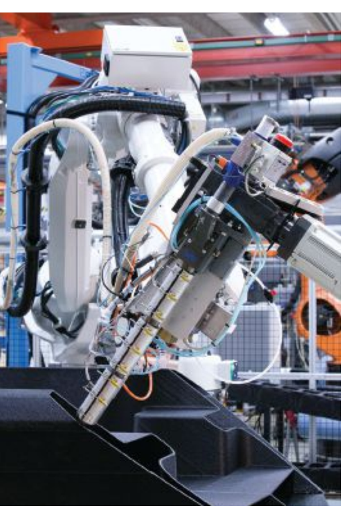
Robots are 3D printers just waiting to be unboxed.



3D printing is multiple decades old, but additive manufacturing arguably is not. The arrival and recognition of additive digital layering processes as a potential means of making functional components, across a wide variety of industrial applications, is a threshold crossed more than one decade ago, but less than two. Against the time span of manufacturing technology development, that is very recent development. Additive is so new, it is likely we have not yet seen the extent of what it will be in its fully realized state, and all the ways it will perform.

I thought about this recently during a conversation with the French-Swedish technology startup Adaxis — specifically, with its CEO, Emil Johansson. Adaxis is developing software that aims to make any industrial robot easy to program for deposition-style 3D printing.

Robots and AM naturally fit together. Others see this — one robot producer just introduced new functionality enabling its robots to be programmed for 3D printing from slicer output (see page 13). But Adaxis aims to go farther, seamlessly connecting CAD systems and robot programming languages so that CAD models can seamlessly become 3D printing programs that (importantly) make full use of the robot's rotating and pivoting range of motion. The firm is now working with major CAD software formats and working to support major robot producers (so far including ABB and Kuka) aiming toward this goal. Because robots are commonplace and multi-axis deposition so freeing, this development might expand our picture of what additive manufacturing itself entails.



A robot employing its range of motion could print an angled form by following the angle, as seen here, rather than layering a stairstep. It could also follow a complex form like that of the surface of a tool. Photo Credit: Adaxis.

Indeed, even for as wide a range of processes as additive manufacturing has come to encompass, it is still possible that the picture we have developed is too narrow. We tend to imagine 3D printing happening inside a 3D printer. It might be a desktop model costing hundreds of dollars or a powder bed fusion machine costing hundreds of thousands, but the principle is the same: A part is grown inside a box in straight parallel layers perpendicular to the Z axis of motion. But what if this is just a part of what AM will come to be? What if this mode of fabrication — flat layers within a box — comprises only a portion of how AM will ultimately be deployed?

Fully empowered robots for 3D printing potentially bring AM that is different in all these ways:

1. No box. Depositing material doesn't involve high forces the way molding or machining does, so 3D printing does not need the rigidity of a machine structure all around. Printing could happen wherever a robot could reach. Possibilities include robots collaborating on big parts or printing parts onto the conveyor of an automated line.

2. No slicer. Slicer software assumes straight, parallel slices. A different programming system such as Adaxis' that makes use of the full range of motion of the robot can mean adapting the angle of a given layer to the geometry of the part in that region, as well as printing onto existing forms by following their geometry — to modify or repair an existing die, for example.

3. No dedicated machine. This difference might be strangest of all. We are accustomed to manufacturing operations having purpose-built machines. Grinding is done on grinding machines, for example. But, in the future, a significant share of AM might be performed on robots that manufacturers also use for other purposes. The polymer extruder or metal DED head might be just another end effector.

This last point is particularly significant, because it potentially makes AM so accessible, and therefore (in a good way) so mundane. Certainly a large portion of manufacturers have robots, and many of these have robots currently going underused. Today, they are difficult to program for 3D printing, but tomorrow, if that obstacle is removed, then all those robots become additive manufacturing capacity that is just waiting to be put to use.

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Women in 3D Printing Names New President

Kristin Mulherin has been named president of Women in 3D Printing. Photo Credit: Women in 3D Printing

Women in 3D Printing (Wi3DP), a nonprofit dedicated to promoting, supporting and inspiring women using AM technologies, is celebrating seven years of operations as it creates a new leadership structure with Kristin Mulherin stepping into the role of president.

Wi3DP has grown from a blog to a global organization with nonprofit status. Founder Nora Touré has been leading the way at Wi3DP since starting a blog in 2014 which featured interviews with women working in the 3D printing industry.

Since then, Wi3DP has become a global community with more than 23,000 members across all gender identities, coming together in 80 local chapters across 36 countries on six continents. Touré is stepping into the role of chairwoman of the Wi3DP board of directors.

The new Wi3DP president has deep roots in the AM industry with leadership positions across various disciplines at companies such as HP and Dyndrite, and founding the 3D printing consultancy AM-Cubed. Mulherin also served as a chapter ambassador in Portland, Oregon, and a member of the Wi3DP board of directors. Mulherin also heads sponsorship opportunities and sits on the executive committee of the TIPE 3D Printing by Wi3DP conference.

Wi3DP welcomes individual and corporate members to join the growing community.

womenin3dprinting.com

Marle Group Acquires Tangible Solutions

Marle Group, a global medical device contract manufacturer, has acquired a majority stake in Ohio-based Tangible Solutions, to work alongside its founders who remain CEO and COO. Marle Group now has eight global production facilities which are exclusively focused on orthopedic and spine implant manufacturing for OEMs worldwide.

Tangible Solutions — now operating as Marle Tangible — has fully established itself as a production-scale additive manufacturer.

Tangible Solutions specializes in engineering, design and development, and production of 3D printed titanium implants for the orthopedic, spine and trauma markets. The Fairborn, Ohio, facility serves several dozen customers and produces more than 40 FDA-approved medical devices with another 20-plus in the works. With more than 2 million implants manufactured annually, Marle Group says it offers end-to-end manufacturing capabilities, including forging and casting, machining, polishing, coating and packaging services. The company says this enables it to offer complete solutions to its clients for orthopedic, spine and trauma implants.

The acquisition of Tangible Solutions expands Marle Group's contract manufacturing abilities in the U.S., the company says. The transaction is also said to strengthen the company's 3D AM expertise in research and innovation in combination with Marle 3D Medlab, as well as product development and prototyping, specifically for spine and extremities. According to Tangible Solutions, its mission is to be a premier international contract manufacturer of 3D printed titanium orthopedic implants. Tangible Solutions will now operate as Marle Tangible.

marlegroup.com

tangiblesolutions3d.com

Nvision Launches First 3D Printed Anterior Cervical Plate

Nvision Biomedical Technologies and Watershed Idea Foundry have received FDA clearance for the first-ever completely additive manufactured titanium anterior cervical plate, the Quantum Titanium Cervical Plate System. Recently cleared, the companies say the Quantum system leads the way for game-changing design freedoms which push clinical benefits to new levels and ultimately impact patient care.

The Quantum system offers multiple specialized features, including a nested assembly in which the screw-locking cover is 3D printed as a single unit inside the anterior cervical plate; and dual-plate finishes with a textured posterior surface and smooth, polished anterior surface. Enhanced screw holes accommodate 30 degrees of cephalad/caudal angulation, which enable the surgeon to use a shorter plate.

nvisionbiomed.com

watershedideas.com

Sciaky Delivering World's Largest Metal EB DED 3D Printer

Sciaky will deliver the world's largest EB-directed energy deposition (DED) 3D printer — a customized 300 Series Electron Beam Additive Manufacturing (EBAM) system — to Turkish Aerospace Industries (TAI). The contract between TAI and Sciaky also includes collaboration on a series of projects aimed at optimizing TAI's use of the EBAM machine and its technology. The EBAM machine is going to TAI's Ankara, Turkey, plant where it will 3D print some of the largest titanium aerostructures in the industry. The machine's work envelope stretches beyond 6 m × 2 m × 1.8 m. Deposition rates will exceed 20 kg/hr. for many metal alloys. This 3D printer can quickly switch over to an Electron Beam Welder for large-scale welding applications, giving TAI the advantage of combining EB welding and 3D printing functionality for applications that require both technologies.

sciaky.com

AddMan Engineering Acquires Domaille Engineering

AddMan Engineering has completed the acquisition of Domaille Engineering, a precision machining manufacturer of mission-critical aerospace and defense components, and proprietary fiber-optic instruments. Domaille is headquartered in Rochester, Minnesota, and also operates manufacturing locations in Wright City, Missouri, and Glen Burnie, Maryland.

The acquisition is designed to bolster the company's portfolio of end-to-end solutions and bring long-term relationships with blue chip aerospace and defense customers, exceptional engineering talent and geographic reach to AddMan.

addmangroup.com

EOS North America Delivers, Installs 1,000th Machine

EOS has delivered and installed its 1,000th machine in North America. The printer — an AMCM M 4K from EOS' AMCM business unit — is a large-scale, four-laser, high productivity system. It was installed at Florida-based Sintavia, one of the world's largest metal additive manufacturers focused on the production of advanced propulsion systems for the aerospace, defense and space industries. The delivery of this machine in North America comes at a time when AM is experiencing incredible market growth. A 2021 report from Lux Research anticipates that the AM market will reach $51 billion by 2030, up from $12 billion in 2020.

eos.info/en

sintavia.co

Health Canada Approves First Medical Implant 3D-Printed by Canadian Manufacturer

Health Canada has approved the first 3D printed medical implant by the 3D anatomical reconstruction laboratory (LARA 3D) at Investissement Québec — CRIQ's facilities in Quebec City, Canada. This is the first time a Canadian organization has been authorized to produce a 3D printed implantable medical device in Canada. The 3D Specifit mandibular plate, patient-specific device, will be used for mandibular reconstruction of patients with oral cancer. LARA 3D has been ISO 13485 certified since April 2021. Surgeons can now treat patients and produce the 3D specifit mandibular plate along with surgical cutting and drilling guides. Also, patient-specific implants can be made before surgery, designed from the patient's internal imaging to follow the unique contours of the bone to be repaired. The company says the use of patient-specific metal prostheses that are printed will improve the quality of health care in Quebec by reducing patients' surgery and recovery times, hence improving their quality of life. AM

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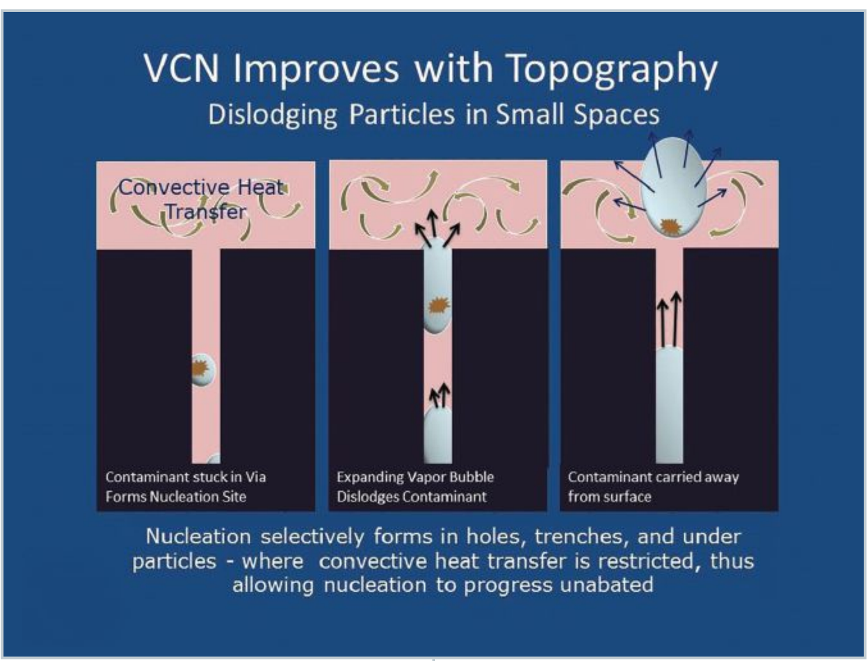
A Technique for Removing Resin, Powders from 3D Printed Parts

By Stephanie Hendrixson

This double-cone was 3D printed from Inconel with only these four small holes to remove the powder from its interior. Photo Credits: Vacuum Processing Systems



The VCN process causes nucleation to form around powder particles or other contaminants, which are then dislodged as the vapor bubble expands.

Additive manufacturing enables complex parts with tortuous internal geometries. However, for these parts to be made in real production scenarios, postprocessing techniques that can clean those complex features must keep up. For many manufacturers, automated cleaning solutions that can handle demanding geometries will be necessary to scale AM to production volumes. Vacuum Processing Systems, a company that has historically provided cleaning solutions for parts made through more conventional methods, has found that its Vacuum Cycling Nucleation (VCN) technique has applicability for those 3D printed parts with tortuous internal geometries and porosity. The parts cleaning process is capable of removing uncured photopolymer resins or unsintered metal powders from 3D printed parts with cycle times under 30 minutes from start to finish.

The Rhode Island-based company's proprietary VCN technique clears excess material from internal chambers and small-diameter channels through the use of fluid in a vacuum environment. Once parts are placed inside the sealed vacuum chamber, the air is removed and the chamber is flooded with heated liquid (either isopropyl alcohol [IPA] for polymer applications or a mild soap solution for metals). Once the liquid gets above its vapor pressure, bubbles form — essentially "boiling" the cleaning fluid.

The vacuum pulses on and off in 1.5 to 2-second intervals, enabling the fluid to flood the part before generating bubbles that drag the monomer or metal particles out from its internal geometries. Once cleaning is complete, the chamber is drained and parts are rinsed and dried still in the vacuum environment. The entire cycle can be completed in as little as 15 minutes.

The Inconel double-cone part pictured above was produced for NASA in a project funded and technically supported by DLA Aviation Hazardous Minimization (HAZMIN) and the Green Products Program (GPP). It was filled with powder after

This screenshot shows the powder leaving the interior of the cone under vacuum. Watch the video at gbm.media/VCNforAM to see the process in action.

printing, and VCN was used to remove the interior material. Find a video of this part and others being cleaned with VCN at gbm.media/VCNforAM. The cleaning cycles shown in the video were recorded using the company's lab Vacuum Cycling Nucleation system with a glass chamber — useful for both tuning the cleaning "recipe" for each individual part as well as reporting results back to potential customers, says Joe Schuttert, sales manager. Vacuum Processing Systems provides these recipes alongside custom VCN machines that are tailored to each customer's typical part size and other needs.

The self-contained systems enable users to automate the cleaning process while also providing safety and environmental benefits. The IPA used as a solvent for uncured resin is a potential fire hazard, for instance, but in the VCN unit, the fluid is isolated from oxygen and ignition sources, greatly reducing that risk. The fully enclosed units also help to minimize fluid loss over time and can include filtration and distillation to keep the fluid clean for long periods of time.

Though the Vacuum Cycling Nucleation process was not originally developed with AM in mind, it has proven to be applicable for cleaning porous parts like hip implants as well as parts with small internal channels, such as hypodermic needles and heat exchangers. Whereas other cleaning options like high-pressure air or water lose energy inside a tortuous path (making it more challenging to remove both the fluid and the waste), the vacuum pulsation applies energy internally for more efficient waste egress. AM

Robot Maker Simplifies Robot Programming for 3D Printing

By Peter Zelinski

Robots are ready to serve as fast and capable industrial 3D printers, but they are not necessarily easy to program for this application. Robot maker ABB has addressed this challenge with new 3D printing capabilities added to its simulation and programming software, RobotStudio, enabling the output of any third-party 3D printing slicer software to be converted automatically into a program for robot motion. No special knowledge of robot programming for 3D printing is required, the company says.

Robots are a natural fit for 3D printing. The programmable motion control of an industrial robot is easily precise enough for material-deposition 3D printing, while the long reach of a robot provides an option for large-format AM that is potentially more economical than a large, dedicated 3D printer necessitating a large, enclosed machine frame.

ABB ran this demo of robotic 3D printing at a recent trade show, Fabtech. In this build, the robot motion coordinates with the motion of a programmable rotary table beneath the part. The Massive Dimension extruder affixed to the robot deposits material at up to 2 pounds per hour. A larger extruder capable of 10 pounds per hour is sitting on the 3D printed table in the foreground. (The 3D printed table was made by furniture maker Model No., a company we've also covered.)

3D printing capabilities added to the robot maker's simulation and programming system now enable easy generation of robot paths for AM, starting with the file output from slicer software. Photo Credit: ABB.

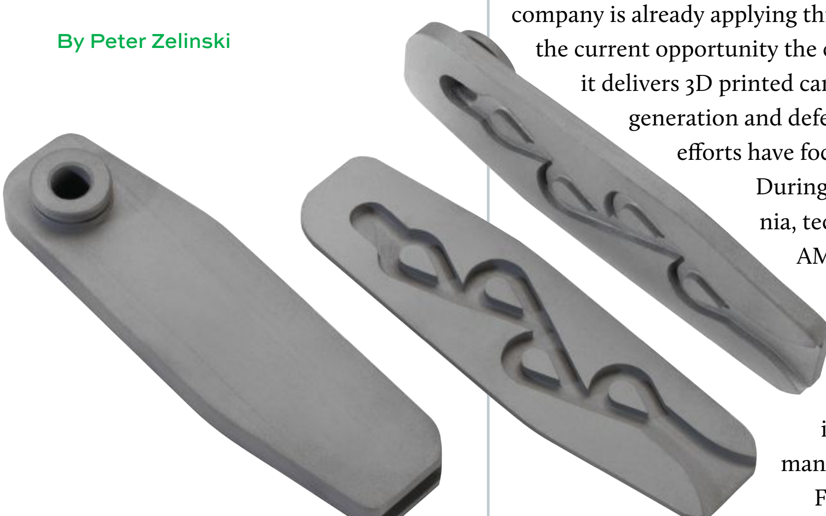
ABB is a leading industrial robot provider; the company's robotics division has shipped about 400,000 robot solutions, the company says, across applications including part handling and welding — as well as AM. Lincoln Electric Additive Solutions, a provider of AM capability in metal, uses ABB robots coupled with its own welding technology in its wire-arc AM platform.

Hardware to enable robotic 3D printing in polymer is just as ready. Extruders engineered for 3D printing provide an effective means of deposition. Programming has presented the most significant remaining barrier to making use of these resources. In ABB's case, programming a robot for 3D printing has, until now, generally required a third-party software tool combined with specialized robot programming skill.

The company says the new RobotStudio capabilities enable a robotic AM program for a new part to be created in about 30 minutes. The model first is input to slicer software. (A company representative noted Simplify3D and Ultimaker's slicer software as tools ABB team members have applied effectively.) The slicer output is then input to RobotStudio. The user needs only to choose top-level characteristics such as the robot's target-point density (for the precision of the additive build), the speed of traverse for deposition, and the wait time between layers. Robot path programming is then written automatically.

Cutting Toolmaker Succeeding With 3D Printed Carbide (Just Not Yet for Tools)

By Peter Zelinski



Much of Kennametal's AM work in wear-resistant materials such as tungsten carbide focuses on producing wear parts, such as this component for an energy-industry application. Photo Credit: Kennametal.

Could additive manufacturing be used to produce a tungsten carbide cutting tool for use in CNC machining?

In principle, yes, says cutting toolmaker Kennametal. Tungsten carbide, the principal material used in high-performance cutting tools for machining, is a material the company is already applying through AM. However, tools for metal cutting are not the current opportunity the company has found for 3D printed carbide. Instead, it delivers 3D printed carbide wear parts for applications in oil and gas, power generation and defense, among others — and material development efforts have focused on these applications.

During a recent visit to the company's Latrobe, Pennsylvania, technology center, I spoke with two members of the AM team: Kennametal Additive Manufacturing General Manager Jay Verellen and Director of Advanced Machining and Additive Solutions Ed Rusnica.

The different ways the company is advancing AM illustrate the various channels by which additive is finding opportunities in and around conventional manufacturing.

For Kennametal, they say, efforts in AM can be characterized as "powder, printed parts and [the company's own] products." These are three different pursuits, not all of them necessarily related to one another. Taking each one in turn:

Powder. The company develops tungsten carbide and Stellite powders adapted to 3D printing via binder jetting for its own part production efforts. An example is the company's newly introduced KAR85-AM-K carbide grade. Targeted for wear parts in uses such as downhole oil and gas applications, this grade emphasizes corrosion resistance — particularly valuable for the downhole applications.

Parts. For industries that can benefit from new design options in carbide hardware thanks to material such as the new grade, Kennametal also offers part engineering and production services on its array of binder jetting machines in Latrobe. Wear parts are a great application, as they are made in low quantities and subject to redesign according to the specific uses. By contrast, carbide cutting tools do not have this same suitability to 3D printing; they are frequently made in high volumes through molding and grinding, processes that remain unchallenged.

Products. Within Kennametal's own cutting tool product line, the opportunity for AM is found not in cutting edges but in the tool bodies, made from steel or another metal. 3D printing enables precise curving and branching channels for cutting fluid inside these tool bodies that, in some cases, could not be made another way. The company's KenTIP FS line of modular drills, for example, includes tools 10 mm in diameter and smaller that employ through-tool coolant passages thanks to AM's ability to economically create the small tool body with these passages inside. Notably, though, these tool bodies are made with a different process — powder bed fusion rather than binder jetting — and they are produced in Kennametal's facility in Germany, not Latrobe. That is, Kennametal's own AM production is an effort distinct from the AM opportunities it is realizing for other industries.

3D Printed EV Boring Tool on The Cool Parts Show

Another example of success in 3D printing a tool body involved a very large tool: A boring tool used to produce electric vehicle components was made 15 to 20 pounds lighter than it would otherwise need to be, thanks to AM. Learn about this aid to automotive machining in the episode of The Cool Parts Show available at **gbm.media/EVbore.**

Multitasking and More at IMTS 2022

By Tim Shinbara | VP & CTO, AMT – The Association For Manufacturing Technology

One of the hottest trends in manufacturing technology is the advancement of the single-setting concept embodied in the new multitasking machines exhibited in the Additive Manufacturing Pavilion and Metal Removal Pavilion at IMTS 2022.

Hybrid multitasking machines add laser hybrid, friction stir welding, additive and hot wire EDM. Multitasking machines combine cutting with turning, milling, drilling, tapping, deep-hole boring, hobbing, skiving, broaching, grinding and surface preparation. By performing all work in a single clamping, these machines cut setup time, eliminate the risk of losing zero when parts move between workstations, and free operators to perform other tasks.

This is especially appealing to job shops that would previously move parts between a lathe, vertical mill and other machines to produce a final part profile. With labor scarce and demand high — orders of manufacturing technology surpassed $650 million in November 2021 and are up 11.4% from 2020 (read report at **gbm.media/CuttingToolMktRpt**) — multitasking machines are a simple way to boost efficiency and quality with fewer operators. Even better, exhibitors are launching a new generation of more affordable machines with new controls and conversational programming. They are making a concentrated effort to remove barriers to technology adoption.

"IMTS 2022 also embodies the 'one-and-done' concept, as there is no more efficient way to explore new manufacturing technology than a single visit to McCormick Place," says Peter R. Eelman, vice president and CXO at AMT – The Association For Manufacturing Technology, which owns and produces IMTS. "Lean companies need smarter approaches. Connecting with the exhibitors at IMTS 2022 helps them develop new strategies for more efficient part manufacturing."

Automation and Data

Because almost every strategy for manufacturing efficiency includes automation, multitasking machines now come prepared with such features as an automatic door and robot interface. Machine designs have changed to facilitate the ability to install a robot in front of a machine, while also enabling operators to easily access the machine's work envelope or tool magazine for setup or manual process intervention.

"Machine manufacturers are also making it easier to harvest data by connecting machines with open standards such as MTConnect," says Benjamin Moses, director, technology at AMT. "The emphasis is on tapping into the efficiencies possible through online data analysis applications, whether that's related to CNC machine components or parts production. A recent report from McKinsey (**gbm.media/McKinseyRptStds**) noted that benefits include decreasing downtime by 30 to 50% and increasing throughput by 10 to 30%. Visitors will be surprised at how easy it is to harness the power of data. All it takes to start is a conversation with exhibitors at IMTS 2022."

Register now for IMTS 2022 at **imts.com**, Sept 12-17 at McCormick Place, Chicago, Illinois.

The University of Nebraska-Lincoln uses Optomec's LENS Hybrid Controlled Atmosphere System to develop next-generation dissolvable medical implants. Photo Credit: University of Nebraska-Lincoln

Buckle Up for Texas

By Michelle Edmonson | Senior Director – Events and Content, Technology, AMT – The Association For Manufacturing Technology

What makes a great road trip? Fun friends, good snacks, excellent destinations and brief run-ins with cults. What? That last one might not be on everyone's checklist, but Stephen LaMarca, AMT's manufacturing technology analyst, and his crew did it anyway while filming season two of "Road Trippin' with Steve" (**network.imts.com/category/videos/road-trippin-with-steve**). They recommend you focus on the snacks and additive manufacturing.

In March, AMT launched IMTS+, a curated online destination to inform, inspire and entertain while capturing the lightning-speed advances, ideas and captivating stories of our industry. Tune in to IMTS+ at **imts.com/network/programs**.

A Not-so-New Technology

In the long-awaited second season of Road Trippin' on IMTS+, Steve and his team explored the history of additive manufacturing with stops throughout Texas.

"When you talk to veterans in the industry, they will tell you they were invested in additive manufacturing as far back as the '80s, but so many people didn't hear about it until 2010 or later. That is a 30-year gap," Steve explained. "This season was incredible because it was like watching the Wikipedia page for additive

manufacturing come to life! We explored the rich history of the technology and saw firsthand how things got started."

Steve loves to take viewers behind the scenes and delve into history. In season one of Road Trippin', he embarked on an East Coast manufacturing history tour that began in Windsor, Vermont, at the American Precision Museum. The second season takes that same focus on history and turns it toward additive manufacturing. It will be released in spring 2022 on the new IMTS+ — a digital channel dedicated to all things manufacturing technology.

A Custom History Tour

There was no better place to start a tour of additive manufacturing history than at the University of Texas at Austin. The Road Trippin' crew had the pleasure of learning from Jared Allison, Ph.D., the operations manager at the Center for Additive Manufacturing and Design Innovation. They also got to peek at vintage videos of folks doing some 3D printing at the Center — in the '80s! Next, the crew headed to Essentium, a small startup that quickly became a heavy hitter in the industry by using a painstaking manufacturing process to create high-quality pellets and filaments for 3D printing.

At EOS, Steve explored the future of metal 3D printing, including projects requiring a fine surface finish and using extreme specialty alloys. Next, the team stopped in at Hybrid Manufacturing Technologies, a company making additive toolheads that can print parts using conventional milling machines.

A Slight Detour

Of course, it wouldn't be Road Trippin' if there weren't some outtakes that had to hit the cutting room floor, including a brief jaunt to Waco. After stopping in at Texas' most epic gas station, Buc-ee's — a Sheetz-meets-Walmart-meets-Cracker-Barrel temple of American ingenuity and beef jerky — Steve spotted a sign for Waco and decided a side trip was in order.

The crew found a simple memorial to the tragic 1993 FBI siege, but they were surprised that members of the Branch Davidians still live at the infamous location. "People started coming out of their houses and pointing at us," Steve said. "We hightailed it back to the highway. To be fair, we probably shouldn't have driven past the 'No Trespassing' sign. Lesson learned."

Tune in to season two of "Road Trippin' with Steve" presented by EOS, to see what else Steve and the crew learned in Texas. You can't make this stuff up. But with additive manufacturing you can, indeed, make anything! Buckle up, folks. We're headed to Texas!

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AMT

By Stephanie Hendrixson, Executive Editor

Finding the Serial Production Wins for Polymer Additive Manufacturing

It is hard to overcome the impression that "production" for plastic parts means injection molding, but 3D printing is gaining ground. Aerosport Additive is aiming to grow its serial production work by seeking out the niches where AM materials, costs and capabilities align.

"Additive manufacturing isn't going to replace injection molding — they are going to live in the same world," says Geoff Combs, principal at Aerosport Additive. The natural question then might be: Where does additive stop, and where does injection molding (or machining or some other process) take over? But this isn't entirely the right question because it implies that production will always move to one of these other processes, an assumption that is no longer true given maturing 3D printing technologies. Instead, the right question today might be: Where does additive manufacturing (AM) win for serial production?

This is a query that Aerosport Additive is facing on a near-daily basis. Jobs that come in because of the company's production 3D printing capabilities might be prototyped this

A juxtaposition of production AM: Although the 3D printing step is a digital, largely automated process, parts often require many more touches once they leave the printer.

way but turn out to be better suited to machining, urethane casting or injection molding. Meanwhile, parts that the customer imagines will be made conventionally might turn out to be a better fit for 3D printing given the volumes or lead time required. And (consistent with the assumption above) many part numbers that the company might 3D print initially do go on to be made in higher quantities through a more conventional process.

"We are very successful at short-run and bridge production with 3D printing," Combs says. Today, much of that production effectively leaves AM after a 3D printed run, headed for injection molding or another process for higher volumes. Going forward, Aerosport expects to hold onto that work, and continues to expand with an eye toward capturing more serial additive production — printing recurring jobs which will continue to be made additively for a long time. This aim will not be realized by increasing volumes alone, but by cultivating and winning more work suited to the processes, materials and finishing capabilities this additive manufacturer can offer.

Combs lifts a bag full of production parts for an industrial equipment manufacturer. These small parts are packed in around other jobs in the MJF printers, allowing Aerosport Additive to continually produce them so that a 3-month supply is always available for the customer.

From Model Shop to Additive Manufacturer

Located in Canal Winchester, Ohio, Aerosport Additive is a model shop-turned-additive manufacturer that still offers services connected to its origin, ranging from prototyping through hand finishing. As a model manufacturer, the company was originally known as Aerosport Design and Modeling — the "Additive" was incorporated in 2020 to reflect the growing significance of this part of the business. Production additive manufacturing accounts for about 25 to 30% of the business' income today, with the rest coming from a mix of prototype 3D printing, CNC machining and urethane casting.

Although Aerosport adopted its first SLA 3D printer for modeling in 2002, the company didn't make the leap to production 3D printing until 2017, with the installation of its first Multi Jet Fusion system from HP. Today the company's primary production AM capacity is its two MJF machines, plus a Carima Tool digital light processing (DLP) 3D printer and its newest machine, an Xtreme 8K DLP printer from Envisiontec. All three are located in the company's additive manufacturing wing, a recent addition to the building completed in 2020 pictured to the left. It also maintains a room in the original facility dedicated to stereolithography and DLP 3D printers from 3D Systems, Carbon and UnionTech.

For additive manufacturing to win serial production work it must compete on cost and deliver on quality. But it must also do so within the right niches. One of Aerosport Additive's current niches is vents like these for aircraft, where the quantities and complexity of the parts make AM a better production process over injection molding.

The 3D printing capacity, however, tells only about half the story — if not a little less. "Postprocessing is more labor-intensive than building the part," Combs says. That dynamic can be seen in the additive wing, where the machines for depowdering, bead blasting, shot peening, resin removal and vapor fusing today outnumber the production 3D printers. A dye station that the company developed itself rounds out the postprocessing capacity. Even after testing other automated dyeing solutions on the market, Aerosport employees prefer this solution for its quality, ease-of-use and speed — only about 15 minutes per cycle.

In short, Aerosport Additive has the 3D printing knowledge, technology and materials to make end-use production parts. It has the equipment and know-how to clean, finish and dye them. And, for the scale and variety of parts it is producing right now, the company is well-equipped to handle the demands of AM production.

The Hurdles to Serial Production

But, to capture more repeatable, serial production work for its AM capacity, there are other ways the company aims to expand and grow. Today, the challenges that Aerosport Additive faces in capturing that work mostly have to do with volume, cost and customer education. To consider each in turn:

1. Managing Increasing Volumes

With the equipment and staff it has in place right now, Aerosport Additive's sweet spot for serial AM is in the range of 2,000 to 10,000 parts per year. Its Multi Jet Fusion printers run full batches unattended seven nights a week, plus quarter- or half-sized batches during the day when employees are present to remove completed builds. Six build units enable rapid changeover between print jobs and one postprocessing station has so far been enough to handle this work.

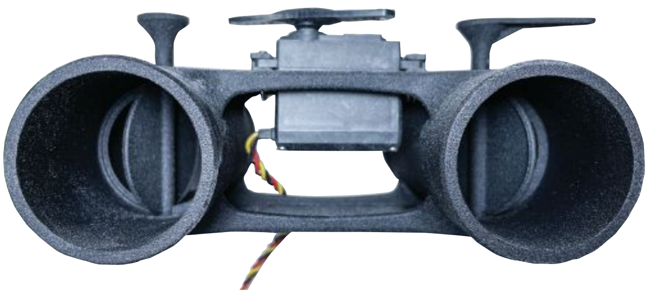
Higher volumes can be accomplished today with some careful planning. One of the company's key AM customers, for instance, is an industrial equipment manufacturer for which Aerosport produces several part numbers. The customer orders up to 12,000 of one of these parts per year, but rather than produce batches on demand, Aerosport keeps about a three-month supply in inventory. With 3D printing, this inventory level is simple to maintain for these parts, because they are small enough to pack in around other builds and print continually as other builds allow.

But, even so, the company is now at a point that one more serial production job at the magnitude of this one will necessitate another Multi Jet Fusion machine, Combs says. There is room for up to six of these printers to stretch in a line across the AM wing, so space is not a challenge. What might be, however, is scaling the postprocessing and employee needs around this added capacity.

2. Competing on Cost

"The main fight that we have is cost," Combs says. For now, quantities above 30,000 parts are typically too expensive to produce through 3D printing, so Aerosport focuses on smaller

Parts in various states of finishing. Left: Depowdered Multi Jet Fusion parts. Center: Dyed MJF parts (see the dye station that Additive Aerosport developed on the next page). Right: Shot-peened MJF parts.



This air vent assembly was previously built by riveting aluminum components together, resulting in valves that didn't fully seal against the inner walls of the tubes. 3D printing enables this assembly to be printed in one go, and provides the ability to add a rim inside each tube to prevent leakage.

Aerosport Additive's homegrown dye station was the result of 3-4 months of development and features two temperature-controlled tanks designed for easy changeover between dyes.

volumes. At this scale, switching a part intended for injection molding to AM can often be cost-effective just by virtue of avoiding tooling, but the cost calculation has to account for all the pieces of the process. For example: Additive might make it possible to print in one piece what would otherwise be a complex assembly of molded parts, but the as-printed surface finish won't be as smooth. If that surface needs to be cleaned, vapor finished and painted to meet the customer requirements, then AM might turn out to be more complicated and costly than conventional injection molding.

Part of Aerosport Additive's strategy to reduce the cost of its 3D printed production runs is to plan builds that include a variety of parts — for instance, packing small parts for ongoing jobs in as "fillers" around other larger parts. The more densely packed the build volume, the lower the cost of all the parts in the batch (and the better the print quality — a boon to both manufacturer and customer).

Over the long term, AM will need to win by providing more complexity — and therefore more value — to the customer, without introducing extra work or cost. The components for the industrial equipment supplier, for instance, contain several undercuts that would have been complicated to mold, but add no difficulty to the printing. Consolidated parts that reduce assembly without adding other steps to the manufacturing process are another possible win. Aerosport Additive, for instance, produces an air valve with moving gates that can be printed in just one piece, replacing a riveted aluminum assembly.

"Where 3D printing can consolidate many parts down to one, that's where it really shines," Combs says. "Customers see you can build things that you can't build on a regular mold tool."

3. Educating Customers

Teaching clients and potential clients about AM is perhaps the most difficult long-term challenge Aerosport Additive is facing. In one case, an RFQ came in for an automotive assembly that could have easily been made additively except for the material. Aerosport recommended Multi Jet Fusion with one of the nylons available for this platform as an alternative that would meet application requirements, but the customer insisted on ABS. In the end, Aerosport machined the parts from ABS stock. Despite the recent advances of the technology and introduction of production-ready materials, additive still faces skepticism compared to the processes and materials that buyers are used to using.

"The assumption that injection molding is 'production' has been hard to overcome," Combs says.

The Right Person at the Right Time

Aerosport Additive won't necessarily have to overcome all of these hurdles alone. Industry advances in printer productivity and material selections will help in terms of meeting higher volumes and reducing costs. The company plans to add a second Envisiontec printer to support more applications of Adaptive3D's ToughRubber flexible material soon; these printers will bring greater throughput for DLP parts to advance the scale of these applications. And customer awareness is growing, which may help bring in more production work suited to this process.

The key now is finding the niches where this production option makes sense — and the discovery still entails some element of luck. "Getting the right fit is the biggest challenge," Combs says. "You've got to talk to the right person at the right time."

By Peter Zelinski, Editor-in-Chief

How Additive Shapes a Production Facility

Sintavia's purpose-built facility for powder bed fusion of aircraft components illustrates ways the plant is different when 3D printing is the operation.

Here is a truism that manufacturers working close to additive manufacturing understand: The best opportunities involve parts designed with additive in mind. But what if this principle extends farther, to the plant and process as well? In the way it combines material creation and part creation in one, and in the way it consolidates assemblies, AM represents a new way to organize production. The best opportunities for AM, therefore, likely involve facilities that were also designed with additive in mind.

Sintavia, the Florida-based AM serving the aerospace sector, illustrates this point. In 2019, the company completed construction on a facility focused on additive production. The 55,000-square-foot site in Hollywood, Florida, currently has 25 industrial 3D printers for metal parts. In fact, the focus is even more specific: Launched from an aircraft engine MRO business in 2015, Sintavia performs laser and electron beam powder bed fusion (PBF) of aircraft and rocket engine components. Brian Neff, the company's CEO and founder, says the fact that the company had no legacy in conventional aerospace part production has been an aid to its success.

"It's not like we had to burn our boats in traditional manufacturing to commit to additive and make it work," he says. "We never had those boats to begin with."

I recently visited the new Hollywood site. In comparing what I have come to expect in conventional production facilities to this one built for AM, there are many differences I see. They include the quiet of part-making relying on 3D printing; production oversight at a distance, through monitoring in the engineering area; an uninterruptible power supply recognizing the importance of keeping multiday and multiweek build cycles going no matter what; and a quality system tailored to AM production for which there was no template or roadmap. In addition, three other points I noted are as follows.

1. Building Design With the Future in Mind

Technology in additive manufacturing is still changing rapidly, Neff notes. This means the facility design has to anticipate that the machines used in just a few years might differ from the machines used today.

The most meaningful technology change he expects is the advance to larger PBF machines. This has to happen, he says. Machines with even larger bed sizes and work heights will expand the opportunities for AM into even larger structures, consolidating even more assembly work into one piece, while also increasing productivity by permitting more smaller pieces in a single build.

To accommodate the expectation that machines in the future will be bigger, the facility was designed with more floorspace and a much wider central hallway (for getting machines in and out) than what is needed for the dimensions of equipment today.

2. Machining as the Completion of the Process

Conventional operations play a vital role that can't be overlooked. For components as precise and complex as aircraft engine parts, 3D printing alone does not realize the part's ultimate value. Attaining completed parts ready for delivery is the work of postprocessing, particularly machining. The machine shop in Sintavia's facility occupies a relatively small percentage of floorspace, but Neff says its importance is clear because additive alone can't realize the tolerances needed.

Metalcutting requirements on any given part are slight, but crucial — and also challenging. CNC machine tools in the shop include four-axis and five-axis machining centers, as well as a multitasking turn-mill lathe. In contrast to the unattended nature of 3D printing through much of the rest of the facility, the work in this shop relies on skilled machinists able to program, set up and fixture machining cycles for the geometrically complex forms. Sintavia's advance will necessitate machining capacity increasing, Neff says.

3. Focused on a Purpose

In a sense, the "factory" is back. That is, "factory" meaning a manufacturing facility purpose-built for a given product.

One of the AM production areas at Sintavia. The room is quiet and clean, running for long periods without people present. At the front, the newly installed AMCM M4K machine from EOS prints parts up to 1 meter tall. The cables reaching upward connect to an uninterruptible power supply, enabling the facility to keep these machines running for two weeks in the event of a power outage.

Manufacturing has shifted away from factories over time. Original equipment manufacturers (OEMs) today tend not to make their products, instead performing final assembly of components and subassemblies coming in. Contract suppliers, meanwhile, serve many markets — any given molder or machine shop might do business in aerospace, automotive, medical and other industries all at once. But the Hollywood facility is something different. Sintavia is not an OEM, nor a general-purpose contractor. The facility here truly is purpose-built: a factory for turning powder metal into aerospace engine parts. It's a subtle point, but an important one: AM is far more than a different manufacturing process or operation; it is also an approach to production calling upon an altogether different type of manufacturer. AM

CNC machining centers in the facility's machine shop. Because metal 3D printing alone can't realize the tolerances needed, the expansion of AM will create the need for more machining capacity. Photo Credits: Sintavia.

By Stephanie Hendrixson, Executive Editor

3D Printing at the Turn of Iten's Century

This specialist in laminates, composites and plastics manufacturing is turning 100 years old in 2022. 3D printing in polymer will be part of the company's next hundred years, leadership says.

"What else can we make for you?"

The question aptly sums up the attitude toward winning new work at Iten Industries. The 100-year-old company with three plants in Ashtabula, Ohio, produces composites and laminates, in addition to cutting and forming these materials through pultrusion, stamping, machining and more. It creates its own tooling through an in-house shop and runs production on its own injection molding presses. Increasingly, the company is taking on product development for plastic parts, with the goal of winning the work to provide the tools that make the parts. With any job that does come, Iten asks the question: What else can we make for this product or customer?

▲ Devin Curtis opens the door of Iten Industries' first Juggerbot Tradesman 3D printer. The company is celebrating 100 years in business in 2022. Conventional manufacturing processes have brought Iten this far. Now, 3D printing will help drive it forward into the next century.

While the company often finds a way to add value to the customer's initial request through its capacity and expertise, until recently something was lacking. Product development was not as fast or easy as it could have been, and there were still cases where the cost of mold tooling couldn't be justified for smaller runs. The company was losing out on some "what else" work, and falling short on pursuing new opportunities.

Now the company is on its way to filling that gap. Recently added large-format industrial 3D printers have given Iten Industries one more way to serve its customers, as well as a pathway into new applications.

Imagineering in 3D Printed Plastic

As Iten Industries approached its 100-year anniversary, company leadership began to reflect on how to ensure the business'

▼ Iten Industries occupies three facilities in Ashtabula, Ohio. The new Imagineering Center is co-located in this building which also houses the tool room and other subtractive manufacturing capacity.

continued advance. "We had to shift to think about the future," says Ron Emery, director of business development. "If we want to continue to grow, what technologies do we need?"

3D printing was a natural answer to accelerate product development. But Emery also saw its long-term potential for plastic parts where a mold couldn't be justified, for bridge production as a mold is being built, and for serving inventors and startups lacking the capital for a full injection molding setup.

In 2020, Iten Industries established what it calls the "Imagineering Center," a space that is dedicated to 3D printing. (The name comes from the company's tagline: "'Imagineering' with plastic," Emery says.) And in 2021, it took delivery of its first 3D printer from Juggerbot 3D. This machine, the Tradesman Series F3-32, was the first of its kind ever sold. The large-format, fused filament fabrication (FFF) 3D printer offers a 3 by 3 by 2-foot build envelope. But its material compatibility is arguably more significant than its size: Where most FFF-style printers apply thermoplastics, the Juggerbot platform can support both thermoplastics and thermosets, even in the same build thanks to dual nozzles. "We mold both," Emery explains, citing this compatibility as key to the purchase decision.

Early Use Cases

The Juggerbot printer was still fairly new when I visited in 2021, but Iten already had some success cases to show, both from this machine and a personal 3D printer owned by Devin Curtis, quality engineer and the company's primary employee now focused on additive manufacturing (pictured on facing page).

The part shown to the right is one such example. Iten had been contracted to pultrude the tubes for a frame assembly, but saw an opportunity to help with the corners as well. Curtis used his personal 3D printer to create a design with less overhang than the original. The change enables these corners to be injection molded with a less complex tool than was originally considered, which saved cost for the customer and won the work for Iten. The company now produces the full frame assembly — a direct example of the "what else" principle in action, enabled by 3D printing.

Iten is now serving injection molding customers with this prototyping capacity, but also expects to pursue new applications with 3D printing. A second Juggerbot machine recently joined the Imagineering Center in February, aimed more at end-use part production. This model is bigger than the first, and utilizes a different material format: pellets, which means Iten can now print using the exact same materials it can injection mold. The material capability opens greater opportunities for initial runs with the 3D printer, as well as bridge production and even 3D printed production straight from prototyping — part of the plan for Iten's next hundred years. AM

▲ After winning the work to pultrude the straight pieces of a frame assembly, Iten asked, "What else can we make?" The question led the company to develop a more easily moldable corner piece that uses less material. This 3D printed prototype showcases the design that was ultimately injection molded.

◀ Iten Industries' Imagineering Center is now equipped with two Juggerbot 3D printers (including this Tradesman Series F3-32, first of its kind to be sold) and a small desktop printer.

By Stephanie Hendrixson, Executive Editor

Can AM Materials Challenges Be Solved With Design?

TPU manufacturer Lubrizol says yes: Production-ready materials are here, and 3D printing-enabled design has only begun to realize their capabilities.

"Our vision is a solutions house approach," says Ed Thomas, 3D printing business development manager for Lubrizol. "We need to be agnostic to material and 3D printing technology, to support our customers from sketch through finished product."

This is the kind of statement one might expect from a contract manufacturer, a company with engineering expertise and 3D printing capability seeking to develop work for production AM. To hear it from Lubrizol, a decades-old supplier of thermoplastic polyurethane (TPU) polymers — including AM grades — is striking.

But the intricacies of AM and 3D printing technologies have driven the company to take a different approach to serving this marketplace. In AM, it is no longer enough for a materials supplier to be *just* a materials supplier, the company believes. In fact, the best way to advance AM materials into applications may be to take that solutions house approach — to develop and implement materials in conjunction with technology and design knowledge, in service of specific end-use applications. It's a strategy that is serving the company well, and one that could be key to driving AM forward.

This shock absorber highlights the interoperability of various 3D printed materials as well as design possibilities with additive manufacturing. The part features a PA11 coil spring and multiple components produced in PA12, as well as panels that highlight different postprocessing techniques. The absorber was designed, manufactured, postprocessed and assembled at Avid Product Development. Photo Credit: Lubrizol.

Not Just Another Market for Thermoplastic Polyurethane

Headquartered in Wickliffe, Ohio, Lubrizol is one of the largest manufacturers of TPU in the world, offering this material in a diverse selection of grades and formats. Its TPUs are found in products ranging from sneaker outsoles to cable jacketing to flexible fabrics. The company first entered the AM space as a filament supplier in 2017, and in 2019 introduced its Estane 3D TPU M95A formulated for the Multi Jet Fusion 4200 series from HP. At the outset, 3D printing seemed like just another potential application for this class of materials, but the company has come to find that AM has different demand than other industries it serves.

Lubrizol's activities in the space today are wide-ranging. The company's 3D printing applications development takes place in Montmelo, Spain, and Brecksville, Ohio, as well as Loveland, Colorado, the site of contract manufacturer Avid Product Development, which Lubrizol acquired in August 2020. Building on its long history as a materials company, Lubrizol is now also a parts provider through Avid — a move it has not made with any other production technology, but one that it has found is necessary for advancing with AM.

"We saw no other way to maximize the value 3D printing can bring to the end user," says Peter Jung, 3D printing technology development manager. "We had the materials expertise, but we were missing design for additive manufacturing [DFAM] and large-scale 3D printing production capability."

The deeper Lubrizol got into AM, the more clearly it saw these gaps. The challenge it came to understand is less one of material formulation and more a question of how to apply these materials effectively with additive.

"The materials are suitable, but we had very little DFAM experience and that doesn't play to AM's strengths," Thomas says. "Our learning curve came in design."

The Design Learning Curve

In order to provide the best solutions for AM, it became evident that Lubrizol would need to get familiar with the additional challenges of production AM; the actual products and parts being made this way; and methods for achieving desired results through manipulating design. Rather than become an expert additive manufacturer outright, the company chose to pursue this expertise through the acquisition of Avid Product Development.

Why Avid in particular? Lubrizol evaluated a group of potential contract manufacturing candidates and ultimately chose Avid Product Development for its years of product development and production via AM, as well as its experience with a range of polymer 3D printing processes and ability to start from scratch to develop parts specifically for 3D printing. The company uses multiple 3D printing modalities, including stereolithography, digital light processing (DLP) and MJF. In Avid Product Development, Lubrizol gained an affiliate with insight not just into how to apply each process but how to optimize it through print parameters and part design.

It's this last point that is particularly interesting for both Lubrizol and its customers. Whereas other suppliers serving additive have approached materials as an R&D hurdle to be overcome with an expanding portfolio, Lubrizol has come to understand that there are viable existing materials with potential still yet to be unlocked through design for AM. In other words, there may be geometric solutions to problems that until now have been characterized as materials challenges.

Design Expands Material Applications

From Lubrizol's perspective, this design freedom is AM's untapped superpower. TPU alone can achieve an array of different characteristics from similar or even the same formulation just by manipulating elements such as lattice cell shapes or strut sizes, but it takes 3D printing prowess and exposure to real applications to learn to apply these principles. While new material formulations will continue to be developed for 3D printing, they will always need to work in conjunction with design as well as the production method.

One example that illustrates the material-design-printer dynamic is VarioShore TPU, a ColorFabb product that is based on Lubrizol resin. The TPU filament is an "active foaming" material that expands as it is printed, activated by the heat of the nozzle. Printing temperatures in the range of 200 to 250°C will cause the filament to expand up to 1.6 times its original volume and become softer; below this range, the material will not foam.

Prints using this material can vary in durometer across their geometry, delivering cushioning or flexibility in some areas but greater rigidity in others — meaning that just one filament can fill a variety of possible application needs.

In AM, design and material can work together to deliver a variety of results even within the same part — like the living hinge seen here. This custom packaging and electronics enclosure was designed, printed and assembled by Avid. The packaging is made from Lubrizol Estane 3D TPU M95A, a nonmarring material suitable for Class A surfaces. Photo Credit: Lubrizol.

The material is currently being applied by a ColorFabb spinoff to make insoles for diabetics, who require specific areas of support in their shoes. But this is not the only use for VarioShore TPU. The impact-resistant material could also be applied for prosthetic liners, crutch grips and other custom assistive devices, granting designers endless possibilities for customization through variable flexibility alongside 3D printing design freedom. The material exemplifies what can happen when material, design and printer work together: an incredible diversity of material properties in the same print, derived from a single material.

While VarioShore TPU is a newer product, Lubrizol sees other opportunities to apply existing materials in a similar fashion. Design capabilities can provide for customization of medical devices and footwear, for example. 3D printed TPU materials can replace high-density foams in protective gear and, by varying the lattice infill, even provide better shock absorption than conventional materials. Working closely with Avid Product Development and partner companies engaged in production work helps Lubrizol better understand production needs and when and how to apply materials like this, so that each new problem doesn't necessarily require a new materials solution.

"Many solutions that customers are looking for could likely be solved with design," Jung says. "We haven't exhausted all the existing material capabilities." AM

By Julia Hider, Senior Editor

3D Printed Baseball Mitt Inserts Are Ready for the Big Leagues

Fast Radius was able to use Carbon's DLS system for both prototyping and production of 3D printed, fatigue-resistant inserts for Rawlings' REV1X baseball glove.

Baseball is an American tradition and, although the game has changed over the years, the baseball glove has stayed much the same. Rawlings' new REV1X outwardly carries on the design of the traditional baseball glove, but it contains a number of hidden innovations, including the addition of 3D printed thumb and pinky inserts. In order to develop and manufacture these inserts, the company needed to find partners it could work with from the design and prototyping stages all the way up to full-scale production.

Traditional baseball mitts contain thumb and pinky inserts that are made out of foam. This foam requires a break-in period, and then it eventually degrades over time. Between the break-in period and the breakdown of the inserts, the gloves' performance can be inconsistent, so Rawlings wanted to create inserts with a different life cycle. This way, the feel and performance of the glove would be more predictable.

To replace the foam, Rawlings turned to Carbon to design 3D printed latticed inserts out of flexible polyurethane. Carbon, in turn, connected Rawlings with cloud-based manufacturer Fast Radius to produce the inserts. As the largest Carbon Production Network partner in North America, Fast Radius had the expertise and infrastructure to manage the project from prototyping to production. "We have a strong track record of bringing elastomeric lattice structure type applications to market and supporting them," explains John Nanry, Fast Radius co-founder and chief manufacturing officer.

Rawlings' new REV1X baseball glove contains a number of innovations, including the addition of 3D printed thumb and pinky inserts. Fast Radius used Carbon's DLS technology for both prototyping and production of the inserts.

"Carbon introduced us as a production expert on lattices, and we then partnered closely with Rawlings through their product development cycle and scaling to production."

According to Nanry, Carbon's Digital Light Synthesis system is a good fit for this application for three reasons:

- **Scalability.** Nanry says that the platform's speed and setup make it ideal for quickly scaling up to production. "It's very easy to go from one part to 10 parts to a hundred to thousands," he explains.
- **Materials.** The inserts required a material that was shock-absorbing and resistant to fatigue but still flexible. Carbon's FPU 50 had the right combination of flexibility to enable players to catch and handle the ball, and fatigue resistance to withstand the impact of baseballs that could be travelling over 100 miles per hour without breaking down, Nanry says.
- **Cost.** Nanry adds that, from a total cost perspective, this mode of production is competitive. While it is difficult to make a cost comparison because the inserts can't be made using an alternative process, Nanry says that Fast Radius "likes these applications" — where the value of the 3D printed part to the customer is significantly higher than the cost to make it.

The 3D printed inserts were designed to replace traditional foam inserts, which wear out over time. By designing a longer-lasting insert, Rawlings hopes to produce a glove that has a more predictable, consistent feel.

The inserts have lattices with varying thickness levels to conform to the player's hand and improve ball control. They were designed using Carbon's Design Engine, with manufacturability input from Fast Radius.

Design

Rawlings designed the inserts using Carbon's Design Engine, which automates lattice creation. The final design includes lattices with varying thickness levels to conform to the player's hand and improve ball control. At this stage, Fast Radius worked with the company to provide feedback on manufacturability and produce initial inserts for prototype gloves. Rawlings sent these gloves to players in the spring of 2020 to test and provide feedback. "There were several revisions," Nanry says. "That's the beauty of additive. You can revise and iterate so quickly at very low cost."

Once all of the revisions were made, Fast Radius created a build package, where it locks all of the build parameters so the process is repeatable and can be scaled to production. The whole design process, from the time Fast Radius first got involved to the point where it had a locked build package for the inserts, took about three months.

Production

Nanry says Fast Radius's biggest challenge in scaling up production of the inserts was establishing repeatability in post-processing operations. First, the inserts need to be washed to remove excess resin. "What's unique about this part is the lattice density and [the challenge of] being able to wash that in a consistent way," he explains.

Once washed, the inserts are baked. However, the company found that the parts were prone to curling up during the process, which Nanry refers to as a "potato chip effect." In order to counter this, the company designed custom jigs and fixtures to keep the inserts flat during the baking process.

With a locked build package and scalable processes in place, Fast Radius was able to expand production. Although the company was unable to share current production rates, Nanry says that production could eventually grow into the tens of thousands.

Nanry says that this project illustrates the potential of AM for existing products. "What's exciting to me about this application is that it really shows how additive can lead to a radical redesign to something that's as classic and stable as an American baseball mitt," he says. "It just shows the extent that companies that really embrace it can innovate.... The potential out there is just so huge." AM

By Peter Zelinski, Editor-in-Chief

Binder Jetting Is Also for Tooling

A portfolio of 3D printing solutions involving infiltrated sand and metal covers tooling needs for casting, thermoforming, molding and composites.

One notable exhibit at the Rapid + TCT trade show last year made a point that should have been unsurprising. With the proven, working mold tool on display in its booth, ExOne illustrated that binder jetting — the AM technology for which the company is known — can be used to make an injection mold. At the show, the company was sharing plastic ice cream scoops that had been molded with this tool, which was made of bronze-infiltrated stainless steel. North American Mold of Auburn Hills, Michigan, designed the mold; the company has partnered with ExOne to prove out binder-jetted tooling for both injection mold and blow mold applications.

ABOVE: This injection mold was made via binder jetting from 420 stainless steel infiltrated with bronze.

ExOne recently launched what it is calling its X1 Tooling portfolio, offering 3D printed tooling at reduced cost and lead time compared to conventionally made tooling for applications including molding, forming and composites layup.

Here is why the mold tool should have been unsurprising: Binder jetting has been making tooling all along. Sand 3D printing via binder jetting is now an established method of making complex tooling in fast lead times for metal casting. And technology developed recently for infiltrating and coating sand 3D printed forms extends the application range beyond casting to include various “hard” tooling applications as well. ExOne Chief Technical Officer Rick Lucas notes that this new development relies, in part, on metal infiltration, a proven capability that is a poor fit for many binder jetting applications involving production parts, but often a good fit for tools.

"Infiltration of one metal into another metal is a technique that allows us to achieve finer dimensional control during sintering," Lucas says. The added metal essentially fills space between particles of the primary metal, holding the resulting part's volume and dimensions as the metal particles fuse into a fully dense form during sintering. A part subject to 20% shrinkage during sintering might see less than 1% shrinkage with an effective infiltration material added. This is frequently not an acceptable solution for end-use parts. "Major OEMs seeing the promise of binder jet for production parts made clear: They needed the known, well-understood material properties that came from a pure alloy," Lucas says. Binder jetting found its successes in production parts in large measure because ExOne found different avenues to dimensional control for single-material components.

And the company has been focused on production because binder jetting delivers distinctive strengths here. Binder jet is a metal AM process with no phase change (that is, no melting and resolidifying), so material structure and stresses are controllable. In addition, binder jet's ability to nest parts in three dimensions means a single 3D build might produce a large batch of parts.

In part, it was COVID-19 that redirected the company's focus for the metal AM capability. ExOne CEO John Hartner says, "As the pandemic continued wreaking havoc on supply chains, we had more and more manufacturers ask us: 'Can you 3D print our tooling?'" The answer was yes. Indeed, the company was never far from recognizing a potentially expanded role for binder jetting for tooling — it has used hard tooling made with sand in its own production, and infiltration similarly offers a way to obtain precise hard tooling in metal quickly and economically.

Now, the new X1 Tooling portfolio arguably covers the broadest range of tooling needs of any AM capability. Among other additive processes, reinforced polymer 3D printing is effective for tooling for composites and laser powder bed fusion is effective for mold tooling. Binder jetting spans both these applications. With 3D printed sand, including infiltrated sand, the portfolio includes competitive tooling solutions for casting, composites (both layup and sacrificial wash-out tools) and thermoforming. In 3D printed metal, the portfolio includes solutions for plastics molding and robotic end-of-arm tools. In addition, the interest of larger manufacturers in 3D printed tools in H13 has led to fast-tracking the development of binder jetting in this tool steel. This capability is likely to lead to hard steel tooling for casting and other metal part molding.

The potential tooling size range is arguably broad as well, company representatives note. One part of the binder jetting process in metals is sintering, in which the 3D printed form is made hard and solid through its particles fusing together under heat. ExOne notes the fusing can be leveraged to increase potential size. To make a very large tool, sections of the tool 3D printed separately can be allowed to fuse into one within a large furnace.

The tool in this thermoforming operation was made by infiltrating and coating 3D printed sand. Photo Credit: ExOne.

By Julia Hider, Senior Editor

How Does 3D Printed Steel Compare to Traditional Steel for Injection Molds?

Westminster Tool tested the machinability of Mantle's 3D printed P2X material by designing a test block with thread-milled and hand-tapped holes, thin-wall pockets made with wire EDM, hard-milled ball runners and primary and secondary vents, and a soft-milled flange. When the shop ran the P2X block through these processes using P20 parameters, it found that the P2X performed comparably to P20. Photo Credit: Westminster Tool

According to tests performed by Westminster Tool, Mantle's 3D printing materials behave similarly to traditional steels and hold up well during molding, making them easy to incorporate into existing moldmaking processes.

The advantages of metal 3D printing for moldmaking are clear — it can save moldmaking lead time while also producing molds that (through features like conformal cooling) perform better than those made by machining. These potential benefits led Westminster Tool in Plainfield, Connecticut, to begin exploring various metal AM technologies in 2017 to use in its moldmaking work for the medical and aerospace industries. But, as manufacturing engineer Eddie Graff explained in a presentation at Amerimold 2021, the shop kept running into four shortcomings:

- **Tolerances.** Many of the systems the shop considered couldn't hold tight enough tolerances. This would drive up postprocessing costs, making 3D printing more expensive than machining.
- **Stability** or the ability to hold flatness. Molds need to be able to hold their shape during postprocessing, but Westminster found that internal stresses in 3D printed molds were causing movement, making them unable to hold flatness tolerances.
- **Porosity.** Porous materials can cause undercuts in the mold, preventing plastic parts from ejecting.
- **Cost.** The cost to buy metal 3D printing capacity in the form of laser powder bed fusion can be on the order of $1 million, out of the reach of an independent mold shop such as Westminster Tool.

In 2019, the shop entered a partnership with Mantle, a 3D printing startup whose system is specifically designed for moldmakers. Mantle's TrueShape technology is a hybrid process that combines a milling machine base with a printhead that extrudes a metal paste. The paste holds its shape well enough that it can print fine details. For use in its machine, Mantle has developed two materials, a P20 equivalent called P2X and an H13 equivalent.

As part of the partnership, Westminster worked on two R&D projects using Mantle's technology. The first involved material testing to determine the post-print machinability and stability of cavities produced using Mantle's materials, and compare their performance to traditional steels. The second project studied the feasibility of using a 3D printed core in a mold, including use of conformal cooling channels, tolerances on complex geometries and whether the cavities would hold up through a few hundred molding cycles.

For material stability, Westminster wanted to know if it could make the material flat, square and parallel. It tested this by performing grinding operations on the material and then checking for cupping and warpage. The tests were successful — the material held tolerances of 0.0001 inch after traditional grinding and less than 0.0001 inch after wet grinding. The shop also machined thin-walled geometries that were likely to warp due to internal stresses. These results showed that the blocks of material held a flatness of 0.0007 inch or better on all sides. According to Graff, this was the first time the shop had seen a 3D printed material whose stability was comparable to true steel, enabling it to predict part movement and achieve the tolerances required in moldmaking.

Next, Westminster designed a test to assess the material's machinability. This was important because the shop wanted to ensure that the 3D printed parts would fit into its existing machining processes. It designed a test block that included features and geometries common in moldmaking: thread-milled and hand-tapped holes, thin-wall pockets made with wire EDM, hard-milled ball runners and primary and secondary vents, and a soft-milled flange. Then the shop ran a P2X block through these processes using typical P20 parameters. Results showed that the P2X block's performance was comparable to P20 without requiring special parameters or attention. Graff notes that many of the machine operators said they would not have been able to tell that the block wasn't traditional P20 steel.

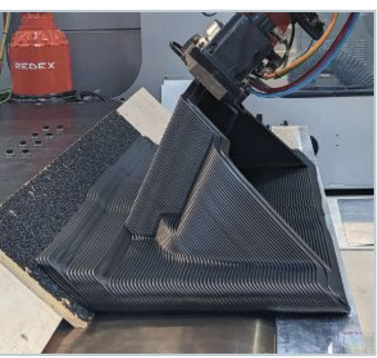
The second project was a core replacement test to study how a 3D printed cavity performed in a mold. For this test, Mantle printed a 3 × 3 × 2 inch P2X cavity. The cavity's design was chosen to be complex, but similar to the work Westminster expects to make on Mantle's machines. After printing, the shop did a full CMM inspection on the cavity, which showed that tolerances were within ±0.002 inch. Graff adds that since the initial trial two years ago, Mantle has continued to improve its tolerances. He estimates that the machine can hold tolerances of ±0.001 inch on a 3 × 3 × 2 inch block, while a 6 × 6 × 4 inch block could hold tolerances between 0.001 and 0.004 inch. These tight tolerances will reduce the need for postprocessing on 3D printed cavities. On this replacement cavity, Westminster estimates that it saved 20 hours of manufacturing time. 3D printing also enabled the addition of conformal cooling channels without added cost or lead time, which reduced molding cycle times by 10%. And, after running the 3D printed cavity for a few hundred cycles, Westminster determined that it was able to withstand the temperatures and pressures of the molding process.

Westminster expects to receive Mantle's first beta printer in early 2022. With this 3D printing technology, the shop will be able to integrate conformal cooling channels into molds without increasing cost or lead time. Reduced manufacturing costs will also enable Westminster to print mold tooling for prototyping, pilot testing and bridge applications.

Carbon's M3, M3 Max Designed for Faster, Larger, Smoother DLS Printing

Carbon's M3 and M3 Max DLS printers are said to provide an advanced end-to-end, idea-to-production platform when combined with Carbon's Design Engine and DLS materials. The M3 is designed for faster printing, simpler print experience, expanded design space and more consistent surface finish. The M3 Max offers the same benefits as well as a 4K light engine to enable double the build area with the same pixel size and density. The company says the M series works with a wide range of high-performance materials tailored for applications across industries such as automotive, life sciences, dental, consumer products and industrial. The printers are said to enable design teams to create high-quality prototypes with end-use performance quicker and more efficiently.

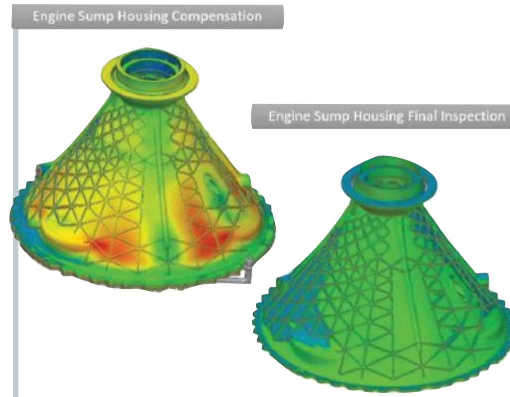
carbon3d.com



Thermwood Adds Angle Layer Printing to Large Scale AM Systems

Thermwood Corp. has added a third print orientation to its Large Scale Additive Manufacturing (LSAM) systems. Previously, the LSAM systems could print both horizontal and vertical layers, if equipped with the Vertical Layer Print (VLP) option, which is available on most Thermwood LSAM machines. The new addition adds Angle Layer Printing (ALP) to the VLP option, giving users the ability to print at a 45-degree angle. According to the company, each print orientation has advantages and limitations for a particular part design, but offering all three orientations on the same machine, for the first time, means maximum print flexibility. All print orientations use the complete LSAM printhead, including exclusive LSAM print features such as the patented compression wheel and thermal sensor layer automation.

thermwood.com



GE Additive's Amp Integrates Build Prep Tools in One Software Platform

GE Additive's Amp is a cloud-based, process management software platform that puts AM build preparation tools into one integrated software platform. The first two modules — Print Model and Simulation & Compensation — are now available in limited release for Concept Laser M2 machine users, with a wider release planned for the second quarter of 2022. Amp was developed and designed exclusively for GE Additive machine customers. From development to print production, Amp is said to offer a flexible, streamlined workflow so manufacturers can improve part production and significantly reduce trial and error needed to develop print-ready parts.

ge.com/additive

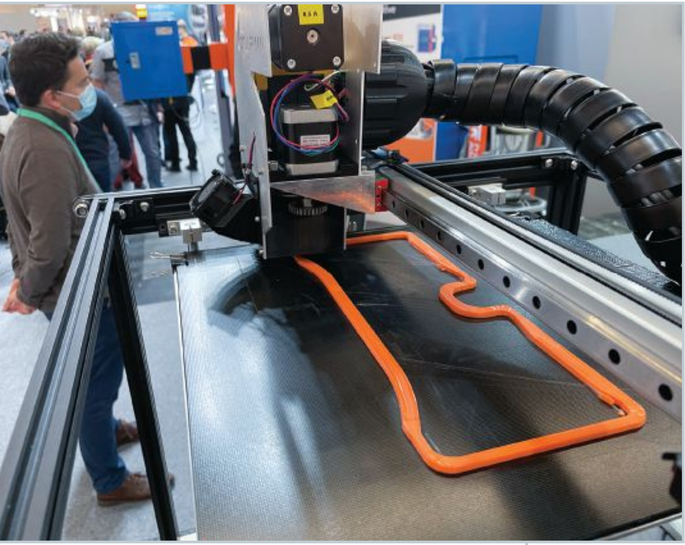
3D Systems, AMT Collaborate on SLS Solution for Efficient AM

3D Systems and AMT are collaborating on an industrial-scale, selective laser sintering (SLS) solution for delivering repeatable end-use parts. This SLS workflow combines 3D Systems' SLS 380, 3D Sprint, DuraForm materials and AMT's PostPro to enable cost-effective batch production parts with high levels of throughput, consistency, performance and yield. The SLS 380 is said to deliver high levels of repeatability, improved throughput and reduced operating costs for more effective, efficient digital manufacturing. The SLS printer uses a custom algorithm that manages eight separately calibrated heaters, together with an integrated high-resolution infrared camera that captures over 100,000 thermal data samples per second to manage, monitor and control thermal uniformity within the build chamber.

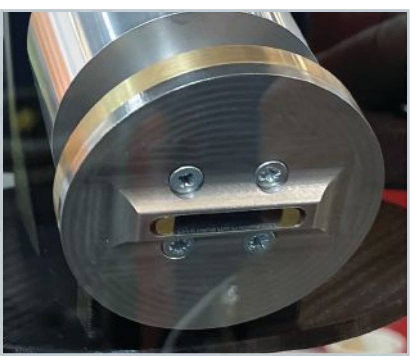
3dsystems.com

By Peter Zelinski, Editor-In-Chief

Faster FFF Build Rate With Variable-Orifice Nozzle



An FFF build employing real-time control over the layer width. The nozzle here can vary from 0 to 10 mm in deposition width.



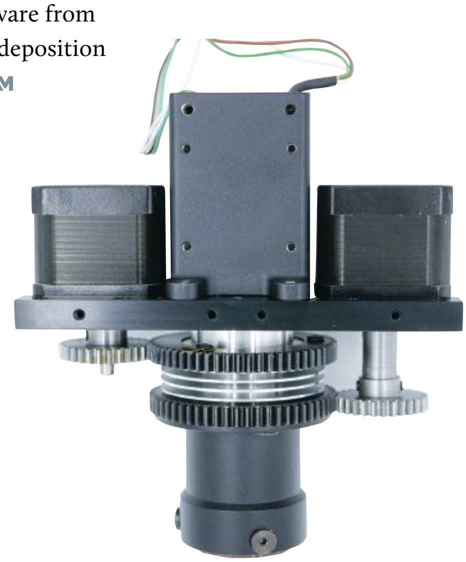
View of the variable-width opening. This photo shows the nozzle still under development that is capable of varying from 0 to 20 mm in layer width.

The cross section of the nozzle opening that deposits material in fused filament fabrication (FFF) is, in almost all cases, a circle. Faster deposition entails extruding through a bigger circle. Is this the ideal shape?

Sculpman, a startup founded in Belgium, is pioneering FFF through a rectangular nozzle orifice. The advance this makes possible is taking control of the width of the rectangle, varying it as needed throughout the build. That means *layer width* becomes a controllable variable just like *layer height*. Late last year at the Formnext expo, the company demonstrated filament-fed 3D printing with a nozzle orifice continuously variable from 0 to 10 mm. (See video: gbm.media/variablenozzle.) Larger nozzles are under development, including a pellet-fed version variable from 0 to 20 mm in layer width, offering layer height up to 4 mm.

The benefit this promises is faster FFF build speed without loss to quality. Disconnecting layer width from layer height in this way enables fast 3D printing and fine 3D printing in the same build. Wide ribbons of material can be deposited rapidly to build thick walls or solid sections, and then the nozzle orifice can narrow to print thin walls or small features.

"Ribbon" is an image Sculpman uses to describe the form of its material deposition, contrasting this with the "spaghetti" shape of conventional FFF. Printing in a ribbon form presents the new challenges the system has been developed to overcome. For example, the Sculpman nozzle features controlled rotation around its centerline, because the ribbon of deposition must be kept always aimed in the direction of the print path. (Spaghetti does not present this problem.) More significantly, the extruder's volumetric rate has to vary in coordination with the nozzle, changing so that the layer height stays fixed as the orifice width changes. Because of these additional axes needing control, software development has been at least as important as the hardware. Slicer software from Sculpman is part of the system, enabling deposition with this more complex set of motions. AM



LEFT: Control over the layer width speeds the build time of this threaded form. This part measuring about 155 mm long was printed in 2.25 hours with the variable nozzle. Printing it with a fixed nozzle small enough for the thinnest regions would have taken more than 10 times as long. RIGHT: Because the layer is a "ribbon," nozzle direction becomes important. Controlled orientation keeps the ribbon aimed along the print path. Photo Credits: Sculpman.