3dpbm | Insights

AM Post-Processing

The key to scalable, industrial AM

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3dpbm

About

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

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Hello

In this eBook, we take the opportunity to focus on the last (but not least!) stage of the additive manufacturing process: post-processing.

Across all AM technologies—from polymer extrusion, to metal powder bed fusion, to binder jetting—post-processing is a critical step for the production of high-quality, end-use parts. Post-processing solutions, as we'll explore in more detail, are especially important for enabling digital additive mass production (DAMP). To date, the AM industry has perceived post-processing as something of a bottleneck to achieving serialized, industrialized AM production. The good news is that we are starting to see robust, scalable and automated solutions for finishing 3D printed parts, across powder-, filament- and resin-based technologies.

In the following pages, we provide an in depth look at the different post-processing solutions that exist on the market today, from material handling and cleaning solutions, to debinding and sintering furnaces, to finishing, smoothing and coloring technologies. We also hear from post-processing specialist PostProcess Technologies about its journey towards sustainably scaling AM, and revisit an interview with Elnik Systems President Stefan Joens. Finally, we map out the most promising visions for an automated AM factory, being developed and realized by innovative companies like Siemens, GE and others.

Tess Boissonneault
Editor in Chief, 3dpbm

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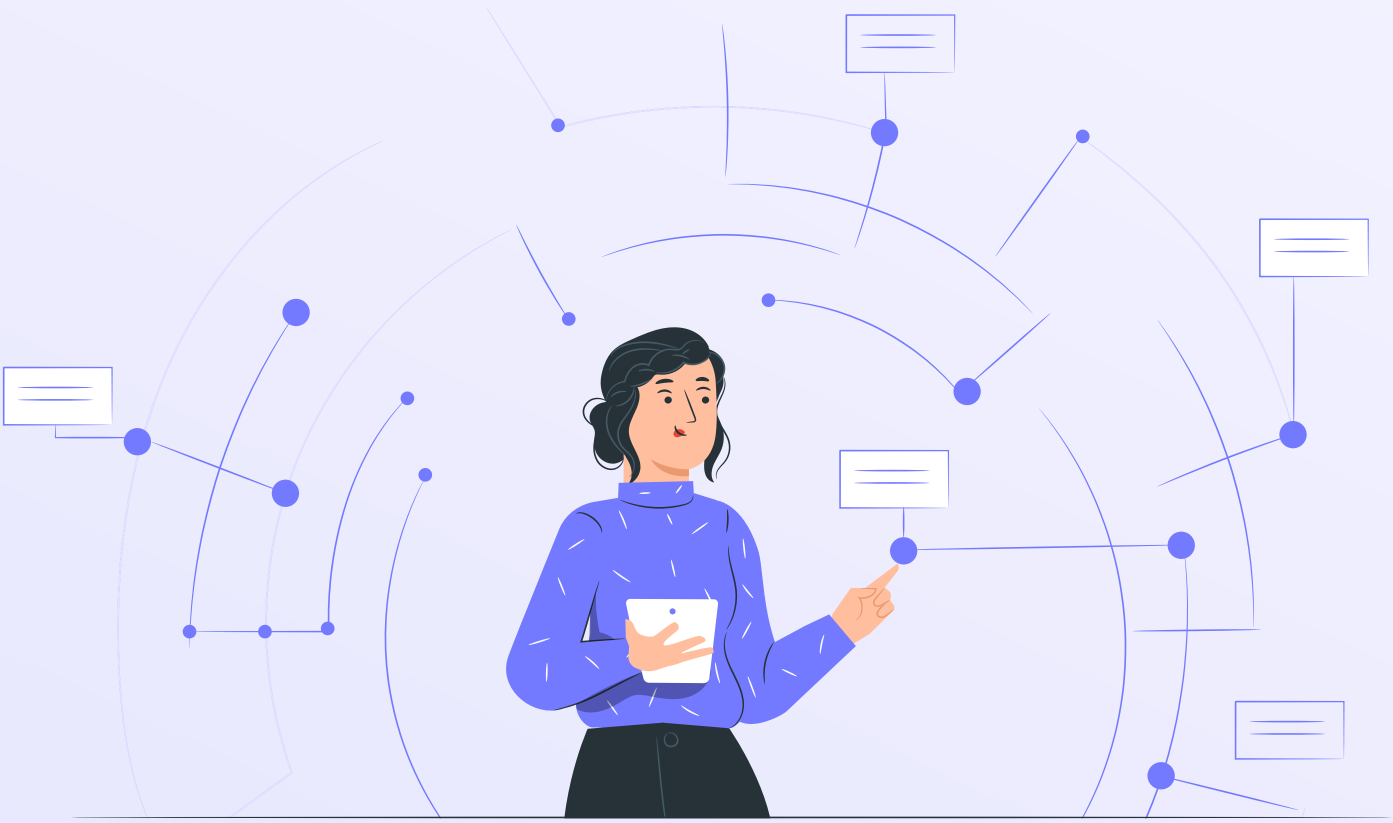


ANALYSIS

From start to finish

The end-to-end DAMP workflow cannot exist without advanced post-processing. We take a closer look at some of the most relevant products and opportunities.

Image: 3dpbm | AM Solutions

As additive manufacturing technologies experience greater use for batch, serial and mass part production, post-processing becomes increasingly relevant. Our main focus at 3dpbm is on digital additive mass production—a market for which we have coined the acronym DAMP—so the need to produce fully finished parts and the enabling technologies to achieve this via AM have always represented a key area of interest.

One of the biggest hurdles to greater adoption of AM in larger batch production was always a tendency to underestimate the impact to cost-effectively post-process large series of 3D printed parts. Post processing is a relatively minor concern on unique, ultra-high-value parts such as prototypes and tools. But when it comes to post-processing tens, hundreds and even thousands of parts in a few days time, these challenges grow exponentially.

Producing fully finished parts presents significant challenges in the polymer AM market and it presents even bigger challenges in metal AM and ceramics AM. So much so that even metal PBF technologies, where part sintering/fusion takes place during the printing process, ends up being more time-consuming in terms of their post-processing phase than binder jetting technologies, where debinding, infiltrations and sintering are all carried out as additional post-processes.

The segment for AM post-processes differs for each major technology but can be generally intended as including these main areas: Powder Removal and Sieving systems, Debinding and Sintering systems, Material and Parts Handling systems, Measurement and Inspection systems, Support Removal systems and Thermal Treatment/UV Curing systems.

Today there is a much greater awareness on the various post processes that are required in all AM technologies, both through specialized operators such as AM Solutions, PostProcess Technologies, AMT, Solukon and D-Lyte (among others), that focus specifically on automating AM post processing, and several other companies specializing in automated post processing solutions for injection molding and other traditional technologies, which are now looking more closely at the AM market.

In this analysis we will look at many of these companies and their capabilities. Some, such as AM Solutions, PostProcess Technologies and DyeMansion, span multiple segments. For a full list of companies specializing in the various phases of pre- and post-processing AM solutions, visit 3dpbm Index's dedicated section on Automation and Post Process companies here.

Material handling, cleaning and removal solutions

The first post processing step for all AM technologies is removing and cleaning excess materials. These can be either non-processed materials, such as loose powder or uncured resins, or processed support materials, including both metal and thermoplastic or photopolymer supports. The unprocessed material is removed by cleaning, and the main challenge is to re-use as much of it as possible, especially in the case of high-cost thermoplastic and metal powders. Supports, on the other hand, present a different challenge. Some are soluble and can be removed by baths of water or other solvents. Some—like metals or non-soluble plastics—require intensive work to remove, relying on saws, files or CNC machines.

Because its use is so widespread in DAMP processes such as binder jetting and high-speed PBF, powder sieving represents the primary business opportunity in this area and there are several third party suppliers of powder sieving systems for metal and plastics.

Most high-speed photpolymerization 3D printer OEMs provide their own first party cleaning systems. Carbon promises 70% labor savings per wash by placing the build platform from an M2 printer into the Smart Part

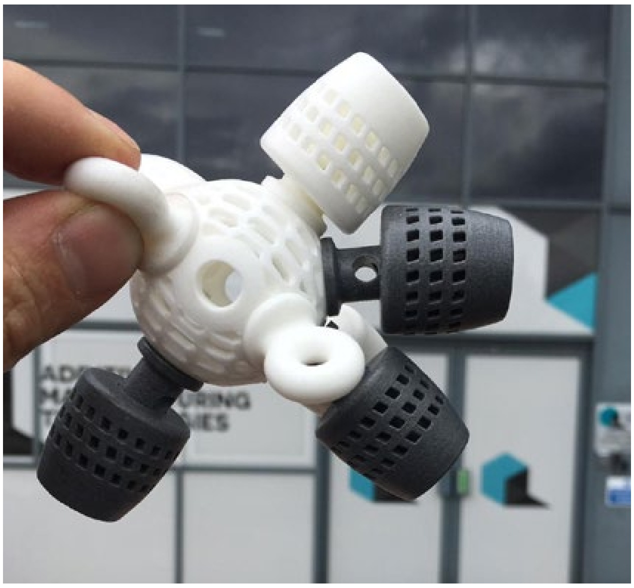
Because its use is so widespread in binder jetting and high-speed PBF, powder sieving represents the primary business opportunity in this area

Washer to let it run. Nexa3D introduced the xWASH to match the build volumes and process requirements of its NXE400 3D printer, supporting up to two NXE400 build platforms simultaneously for streamlined post-processing workflow, or the option of a loose parts basket for production flexibility.

Key companies

AM Solutions can be considered one of the leaders of the overall AM post processing market today. The company (part of the Rosler Group) offers a product portfolio that consists of its own equipment and

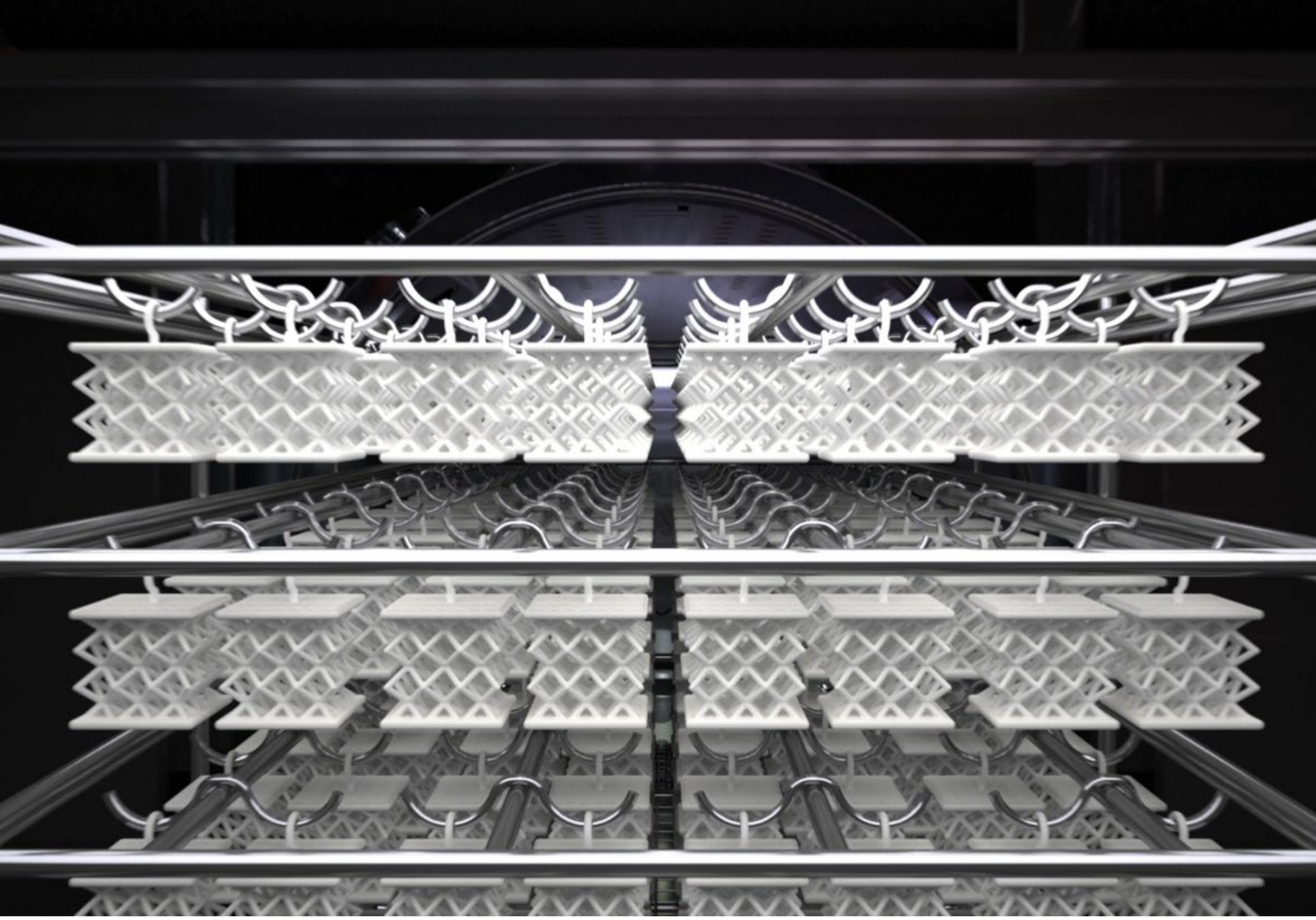
Image: AMT



process technologies and also equipment from external partners. Its powder sieving systems include the S1 and S3 platforms. The newest S1 is an automatic or optional manual shot blasting solution that enables the effective removal of residual powder after the printing. The constant rotation of the work pieces during the cleaning process ensures repeatable and consistent shot blasting results without damaging the workpiece surface. This applies equally to plastic and metal parts providing an excellent basis for subsequent manufacturing operations.

DyeMansion is one the most AM-focused companies in the post-processing segment. The company was born specifically with AM in mind and has grown through investments from EOS, one of the AM hardware market leaders. The company's newest cleaning solution is the Powershot Performance series, its first-ever system with Multi Belt, an integrated wide troughed belt, and is capable of processing full-sized build jobs (i.e. 1x EOS P396 or 1.5x HP Jet Fusion 4200/5200).

PostProcess Technologies' powder sieving solutions is the DECI Duo (also commercialized by AM Solutions), for powder removal and surface finishing of 3D printed parts, automated in a single, multi-functioning system. The Hybrid DECI Duo supports resins, thermoplastics and metals for all major AM processes (SLA, SLS, DMLS/Binder Jetting, MJF, SLS and more). Its technology is based on Thermal Atomized Fusillade (TAF),



With investments from EOS, DyeMansion is one of the most AM-focused post-processing solution providers on the market today.
Image: DyeMansion

in which two perpendicular, single-axis jet streams of compressed air, detergent and suspended solids provide targeted blast sequences while utilizing 360° part rotation for maximum surface exposure.

AMT is another company founded specifically to support the AM industry. Its PostPro series systems are equipped with an ionization unit that reduces static electricity, and therefore results in "dust-free" parts. Cyclone provides efficient and effective blast media and dust separation to ensure an optimal operating mixture, while the Ventilator system with high extraction rate prevents dust build up in the working chamber and enhanced visibility. The machines come with a quick-clean sealed dust bin to store waste dust and powder from the filter unit.

Solukon Maschinenbau (metal depowdering and sieving) is a leading supplier of depowdering systems for metal and polymer AM. The German company offers a full range of industrial powder removal systems. Solukon is an expert in powder removal of tough-to-handle materials, such as copper, and its systems can handle reactive materials such as titanium and aluminum under safety controlled inert conditions.

Farleygreene (metal depowdering and sieving) has brought to market the Sievgen 04 system, a highly automated, ultrasonic sieve for recycling/processing metal powders, developed specifically for AM. The unit opens up to reveal the sieve at the heart of the process, allowing unhindered cleaning access and minimizing turnaround times between batches or material changes.

The Desktop Metal Studio System 2 integrates its own debinding and sintering processes.
Image: Desktop Metal

Russel Finex (metal, depowdering and sieving) provides its AMPro range of systems, which are designed to recover, reuse and recycle additive manufacturing powders and ensure that powder is quickly and safely qualified for use. All units are designed to ensure a controllable and repeatable process to promote optimum sieving efficiency, and minimal operator involvement, from small, low maintenance batches of powders to full production scale.

Guyson, a US-based post processing specialist, offers several advanced solutions for metal AM material handling, starting with the Euroblast Ex Range of Atex Blast Systems, which has been certified for use in potentially explosive atmospheres caused by fine powders of materials such as plastic, aluminium, titanium and Inconel, used in the aerospace and medical AM sectors. The company also developed the C600-AM Dust Collector, which features options to minimize risks. These include an explosion relief valve, explosion isolation valve, secondary HEPA filtration, waste bin balance pipe— which enables dust collection in a plastic bag (located in the collection bin hopper) that can be quickly sealed on removal, minimizing dust in the open atmosphere— and a waste bin level sensor. In addition, the Guyson Powder Recovery System was the first to be developed specifically for EBM.

Debinding, sintering, thermal treatment and curing, HIP/CIP

With the growth of metal binder jetting technologies, post-process sintering in a kiln or industrial furnace has become much more relevant in AM. However, even

PBF and DED processes, where particles are welded or sintered during the AM build process, still require some—or even extensive—thermal post-processing or pressure treatments such as annealing (the process of controlled heating and cooling of a material to remove stress, or change properties such as hardness, strength or ductility) and HIP/CIP (hot/cold isostatic pressing). In particular, the HIP process solves issues like residual stresses, internal porosity, heterogeneous and anisotropic microstructure in metal in order to achieve the required material performance within demanding industries such as aerospace and medical implants.

Almost all binder-based processes (including bound material filament extrusion processes) also require a debinding step, which represents the connecting link between material handling and part post-processing. In other words, the 3D printer creates a green part, which must then undergo either a solvent bath (such as acetone) or heat treatment to remove the binder. The resulting part is then placed in a furnace—such as those used in CIM and MIM production—for sintering. This ideally results in a fully dense component.

Because AM is such a specific process, working with highly complex geometries and unique requirements, hardware manufacturers have been developing and offering their own sintering solutions. For example Markforged (Wash-1 and Sinter-2) and Desktop Metal (Studio System 2) offer their own debinding and sintering systems for their bound metal extrusion and binder jetting 3D printers. Admatec also offers a Debinding furnace and Sintering furnace for its ceramic-slurry-based stereolithography 3D printers.

At the same time, high level industrial applications may require industrial-grade furnaces that can handle advanced materials and complex parts. HIP and heat treatment systems for metal 3D printed parts represent a key short-term opportunity to capitalize on the widespread adoption of metal PBF. As binder jetting processes are expected to become the driving DAMP technologies, sintering systems have been identified as the key long term business opportunity in this area.

This is true for polymer technologies as well. Hot PBF processes, including both laser and heat-based inkjet processes (such as MJF/HSS/SAF), need to undergo controlled cooling, which can last several hours, while resin-based processes also require treatments to complete the curing reaction.

Elnik Systems (debinding and sintering furnaces) was founded in 1969 and manufactures some of the most advanced metal injection molding (MIM) first-stage debinding and second-stage debinding/sintering furnace equipment. Its MIM 3000 Sintering Furnace is a one-step debind and sinter furnace. This means that it is also the ideal furnace sintering tech for AM processes. The MIM 3000 provides a cost-effective alternative to the two-furnace technology then being used. Now that a new era of adoption for bound metal additive manufacturing systems is about to begin, there will be a growing need for sintering parts in a furnace. Few companies can boast as extensive an experience with these systems as Elnik.

Image: Markforged

Xerion (debinding, sintering furnaces, AM systems), based in Berlin, is a company that specializes in industrial sintering furnaces and other thermal treatment products for metal and ceramic manufacturing. In 2018, Xerion ventured into additive manufacturing with the Fusion Factory, a compact production line for bound metal and ceramic filament AM. The system has three modules that combine the process steps of printing, debinding and densification or sintering (the final heat treatment to produce a purely metal and dense component) into one plant. With additional AM modules, the system can be expanded for industrial series production. The system is also available as a stand-alone Debinding and Sintering System, the Fusion Factory Compact.

Carbolite Gero (heat treatment, annealing) specializes in advanced heat technology in the design and manufacture of laboratory and industrial ovens and furnaces ranging from 30 °C to 3000 °C. In addition to the wide range of standard products, the company develops customized equipment for complex heat treatment processes in aerospace, engineering, materials science, medical, bioscience and contract testing laboratories globally. Specifically for metal PBF additive manufacturing, Carbolite Gero's General Purpose Chamber furnaces offer heat-treatment solutions with precise temperature uniformity in an inert (typically argon) atmosphere to ensure the sintered part is not contaminated by oxygen molecules which can alter the chemical and physical properties (porosity) of the final component. Various sizes are available (Laboratory Furnace CWF 13/65 or Industrial Furnace GPC 13/131, 13/200, 13/300, 13/350 & 13/405) with capacities for between 1 and 4 build plates.

Quintus Technologies (HIP/CIP) is the first name that comes to mind when thinking of hot isostatic pressing systems for additive manufacturing. Today, HIP is a proven technology to enable metal additive manufacturing for demanding industries such as aerospace, medical implants, energy and automotive, addressing issues such as lack-of-fusion between layers, gas pores originating from the feedstock and residual sintering porosity that act as stress concentrations and crack initiation points in the material. HIP for metal AM has been shown to give dramatic effects on the material's fatigue performance (up to 100 times fatigue life). Quintus' HIP systems are equipped with Uniform Rapid Cooling (URC) and optional Uniform Rapid Quenching (URQ) furnaces that provide high cooling rates up to 4,500 °C/min (8,100 °F/min). This technology provides decreased cycle time and higher productivity. The high cooling rates enable conventional heat treatment steps to be integrated into the HIP cycle. These steps include solution annealing, ho- mogenization, quenching, ageing, tempering, stress relieving etc.

The equivalent of heat treatment in polymer photopolymerization processes is the curing process. Today, there are many options available for all types of machines, even the most affordable. For example, in the lowest price segment, **AnyCubic** introduced the Wash and Cure Station 2.0 Station at just over $100. This enclosed system supports both washing and curing of resin printed models, preventing the cleaning agent from splashing and ensuring more safety and protection. The internal platform even rotates 360° to ensure even and complete curing.

On the professional, high-speed photopolymerization side, **Nexa3D** offers its own xCURE plaform for post-curing to maximize material properties, improve parts strength and provide consistent mechanical performance. The system combines heat and dual wavelength light to post-cure printed parts using a combination of material-specific prescribed sequences in a controlled chamber, accommodating parts as large as 16 liters.

Third party systems are also becoming increasingly available. One of the first was introduced by **Wicked Engineering**. The New England company was founded in 2016 by owner and President Paul McGarr and was the first to the market with a full-featured post-curing

Quintus Technologies' QIH48 M URQ press is based on the company's patented Uniform Rapid Cooling (URC) and Uniform Rapid Quenching (URQ) technologies.
Image: Quintus Technologies | Pankl Racing Systems

device for the prosumer SLA market, the CUREbox UV post-curing chamber. The company had acquired a Formlabs SLA 3D printer and realized there were no proper UV post-curing devices available at a price point that made sense. What started as an internal development project turned into a business opportunity.

Finishing, smoothing, polishing and coloring

And we finally get to the finish line: part finishing. Once material handling is complete and a part has been cleaned and treated, it's time to make it look like a final part, ready for use. In order to do this, a part needs to be smoothed, polished and/or colored. Unless, that is, you like the rough surface with layer lines, which is actually starting to be increasingly appreciated for certain types of applications. Nevertheless, most parts need to look like they have come out of a factory not a 3D printer and there are several solutions on the market that can do this rapidly, proficiently and, most importantly, through a digital, automated workflow.

AM Solutions is again one of the leaders in this area both through its own Rosler systems and other systems from third party providers (discussed below). The Rosler systems are defined by the M line of products, including M1 and M1 Basic, M2 and M3. The M2 is meant for fully automated, high productivity surface finishing of 3D printed metallic and plastic components, leveraging the high energy of the applied centrifugal to allow a higher material removal rate. The M3 was designed for post processing 3D printed components made from plastic or metal, whenever these components are delicate, have a complex geometrical shape and require extremely gentle processing.

DyeMansion was founded specifically to bring automated surface finishing and coloring to the AM industry. The company debuted with the DM60 systems using innovative DeepDye Coloring (DDC) technology along with over 170 RAL and standardized colors. The system's fully automatic cleaning program allows flexible use and fast color change. In 2019, DyeMansion introduced the Powerfuse S for surface smoothing: it is based on DyeMansion's VaporFuse Surfacing (VFS) technology, a closed-loop, automated process that is capable of achieving smooth, high-gloss surface finishes for parts. This makes the parts water repellent and easy to clean, with surface quality comparable to injection molded parts.

PostProcess Technologies also offers several support and resin removal solutions for mass part finishing under the DEMI brand (also marketed by AM Solutions). The DEMI 400 and DEMI 800 both support automated removal of supports and resin for most polymer 3D printing technologies (FDM, SLA, DLP, DLS, PolyJet, and more). Leveraging patent-pending Submersed Vortex Cavitation (SVC) technology, the systems use a rotating motion while the part is immersed in fluid and ensures even exposure to the induced mechanical

Hirtisation is a chemical-electrochemical process for removing support structures and partially melted powder particles from metal AM parts.
Image: RENA Technologies GmbH

The Hirtisation process has been specifically developed for the post-treatment of 3D printed metal parts and is compatible with all common metals

agitation. The latest DEMI 4000 system is a large-scale software-driven 3D post-printing solution for high-volume photopolymerization production, leveraging proven submersion technology.

GPA Innova, based in Spain, also rapidly moved to address the metal AM finishing requirements offering a rapidly growing number of solutions that leverage its DLyte electropolishing technology. The company's offer ranges from the most basic DLyte Desktop (and Dental) ultra compact solutions to more professional solutions such as the Compact and Pro series. The company's latest product, the DLyte 10.000, was developed for automated machining of large metal workpieces in series. The modular system can also be integrated into a production line. The machine works with DryLyte technology, a patented form of surface finishing of metals by ion transport with free solids. It is a dry electropolishing process that uses no liquid as electrolyte and does not create micro-scratches on the surface, respecting the part's tolerances.

In 2020 German company **RENA Technologies** acquired **Hirtenberger Engineered Surfaces** to offer one of the largest finishing solutions for DAMP (digital additive mass production) currently on the market, based on the proprietary Hirtisation process. Specifically developed for the post-treatment of 3D printed metal parts, Hirtisation is compatible with all common metals and alloys and all metal AM technologies. The process is based on a combination of electrochemical pulse methods, hydrodynamic flow and particle assisted chemical removal and surface treatment. The treatment media used in this multi-step process are material-specific and guarantee a gentle surface treatment. There are no mechanical processing steps involved. RENA's giant H3000 and H12000 industrial finishing line are fully automated solutions that integrates into the AM process chain, targeting large manufacturing businesses. A single H12000 is able to finish the output of up to 25 3D printers with cycle time of less than an hour through parallel processing.

Guyson, a US-based company, is another major provider of finishing (and other post processing) solutions for additive manufacturing, delivering virtually any type of surface finish required. The varied range of machines is available for smoothing over product striation lines, removing excess or loosely adhered ceramic or metal particles from laser melted parts. Guyson's Powder Flush system is designed specifically for removal of residual Additive Manufacturing (AM) powders from medical implant trabecular structures, aiding the interlocking human bone growth into the implant. The company also provides Benchtop Ultrasonic Baths for safe, fast and effective ultrasonic cleaning on polymer parts enabling a more paint or coating receptive surface by removing the smooth shine and replacing it with a finely controlled textured surface that improves subsequent adhesion. ◆

SPOTLIGHT

Scaling sustainably in AM: the critical role of post-processing

PostProcess Technologies addresses bottlenecks in scaling AM sustainably

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Image: PostProcess Technologies

It is no coincidence that additive manufacturing as a production method and sustainability as a mission are taking on increasingly important positions in the manufacturing world. As we write, more and more industrial players are embracing sustainable practices, focusing on waste reduction, streamlined operations and energy efficient products. In many cases, additive manufacturing is factoring into this more sustainable vision, unlocking new possibilities on all fronts.

Despite the growing appeal of additive manufacturing to meet sustainability and efficiency goals, there is still ample room for improvement, especially when it comes to scalability, automation and post-processing (also known as post-printing). One company in particular is at the forefront of solving these three challenges, which have created a bottleneck for industrialized additive manufacturing. Based in Buffalo, NY, PostProcess Technologies is seeking to unlock scalability for additive manufacturing with its automated finishing solutions.

Post-printing, the forgotten step

As additive manufacturing adopters think about scaling up their 3D printing production, the first thing that comes to mind—understandably—is increasing the number of 3D printers. Manufacturers also usually upgrade to more sophisticated design and workflow software programs to match the increased production rates. Where adopters tend to have a blindspot, however, is the crucial post-printing step. This creates a significant hurdle when it comes to scaling production.

Traditionally, post-printing methods have relied largely on labour-intensive tools, like sand blasters, water picks, razor blades and dunk tanks. While these manual methods are suitable for prototyping and low-volume applications, they don't quite cut it for higher production volumes because they are time consuming, expensive and often hazardous. As PostProcess highlights, "it is important to keep in mind that larger companies with sustainability agendas will only adopt additive at scale if the processes expedite their eco-conscious goals, rather than introduce new waste and safety concerns." And that's not to mention the issue of human error involved with manual post-processing.

Interestingly—as revealed in a 2020 trends report by the company—it is the printing technologies that are most suited to scalable production—powder bed fusion and vat photopolymerization—that are most inhibited by the post-printing bottleneck. A mere 25% of the study's respondents said that today's post-printing methods were suitable to match the scale of 3D printing they are planning for the future. Fortunately, hope isn't lost for the other 75%.

Where digitalization comes in

The first step to bridging the scalability gap between additive manufacturing (including the design stage) and post-printing is digitalization. The strategic use of software can connect all steps in the AM process, helping to solve not only scalability issues but also safety and sustainability concerns. In other words, a fully digital, automated workflow is key to unlocking scalability and AM's full potential.

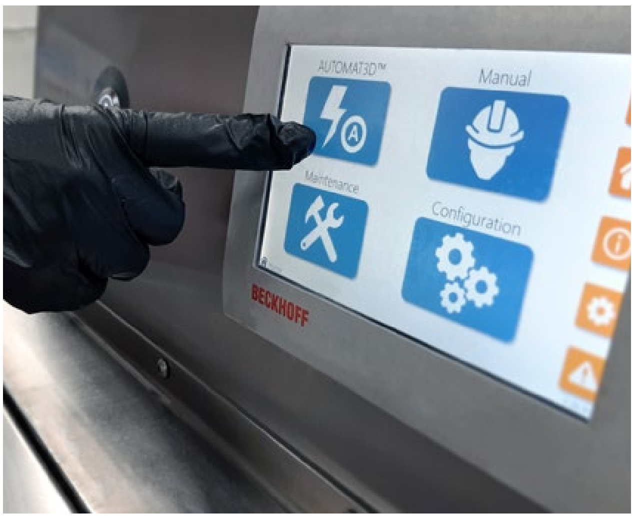
3D printed SLA parts, before and after post-processing.
Image: PostProcess Technologies

By combining software, hardware and chemistry for automated support removal, surface finishing and resin removal, PostProcess has forged a path towards lights-out 3D printing

PostProcess Technologies was the first company in the AM industry to fully connect the AM digital thread with automated post-printing solutions. By combining integrated software, hardware and chemistry for automated support removal, surface finishing and resin removal, the company has forged a path towards lights-out production for a number of 3D printing technologies.

Today, PostProcess has five proprietary finishing technologies: Suspended Rotational Force (SRF), Submersed Vortex Cavitation (SVC), Thermal Atomized Fusillade (TAF), Volumetric Velocity Dispersion (VVD) and Variable Acoustic Displacement (VAD). All of them are driven by software that closely controls each process' energy source and optimizes finishing for various part sizes and geometries. The software is also highly automated, with built-in presets based on data from hundreds of thousands of parts that enable operators to simply "press play and walk away."

Through a user-friendly interface, the software intelligence within each solution is key to enabling a fully digital, automated workflow.
Image: PostProcess Technologies



PostProcess' digital software solution also integrates preventative maintenance alerts, which identify when maintenance will be required, helping to reduce downtimes and cut back on repair costs. Overall, the digitally driven post-printing solutions developed by PostProcess are designed to improve efficiency by shifting away from manual finishing steps towards more automated, intelligent solutions. This not only clears the path for scaling AM production but also facilitates greater sustainability, especially—as we'll see—when it comes to vat photopolymerization technologies.

Addressing the hazards of resin removal

One of the biggest problem areas identified in PostProcess' 2020 Post-Printing Trends Survey was related to the safety of post-processing for resin-based 3D printing. Vat photopolymerization requires the use of solvents for part finishing, which are made from

PostProcess has developed special detergents that are more sustainable and effective than solvents like IPA for resin-based 3D printing.
Image: PostProcess Technologies

combustible materials with low flashpoints, like isopropyl alcohol (IPA). The solvents also generate fumes that can be hazardous to 3D printing technicians, as well as volatile organic compounds (VOCs), which are harmful to the environment and require proper handling.

To address the concerns surrounding post-printing for resin processes, PostProcess developed special detergents for its full stack automated finishing solutions that are more sustainable and more effective than solvents such as IPA. The resin removal detergent is characterized by a higher flashpoint, lower vapor pressure and better longevity than other solvents, which in turn reduces the frequency of waste disposal. Further, the detergent can be distilled after it is saturated with resin with up to 90% of the original detergent suitable for reuse.

Swedish product design service Splitvision has seen the advantages of PostProcess' resin removal solution first hand. The company adopted PostProcess' technology as a more ecological alternative to IPA solvents for finishing parts 3D printed on 3D Systems' Figure-4 platform. "It can be a very tedious job to fully clean the resin off of these features [intricate crevices and small slots] with a traditional solution like isopropyl alcohol," explained Lukass Legzdins, R&D Director, Splitvision. "Even if the printer used is efficient and several parts can be manufactured in one run, the unit cost still does not go down much, since so much time is needed to clean each part individually. Apart from being time-consuming, the work environment also gets compromised by the strong smell from the IPA. Not to mention, we were always concerned about the fire risk posed by IPA."

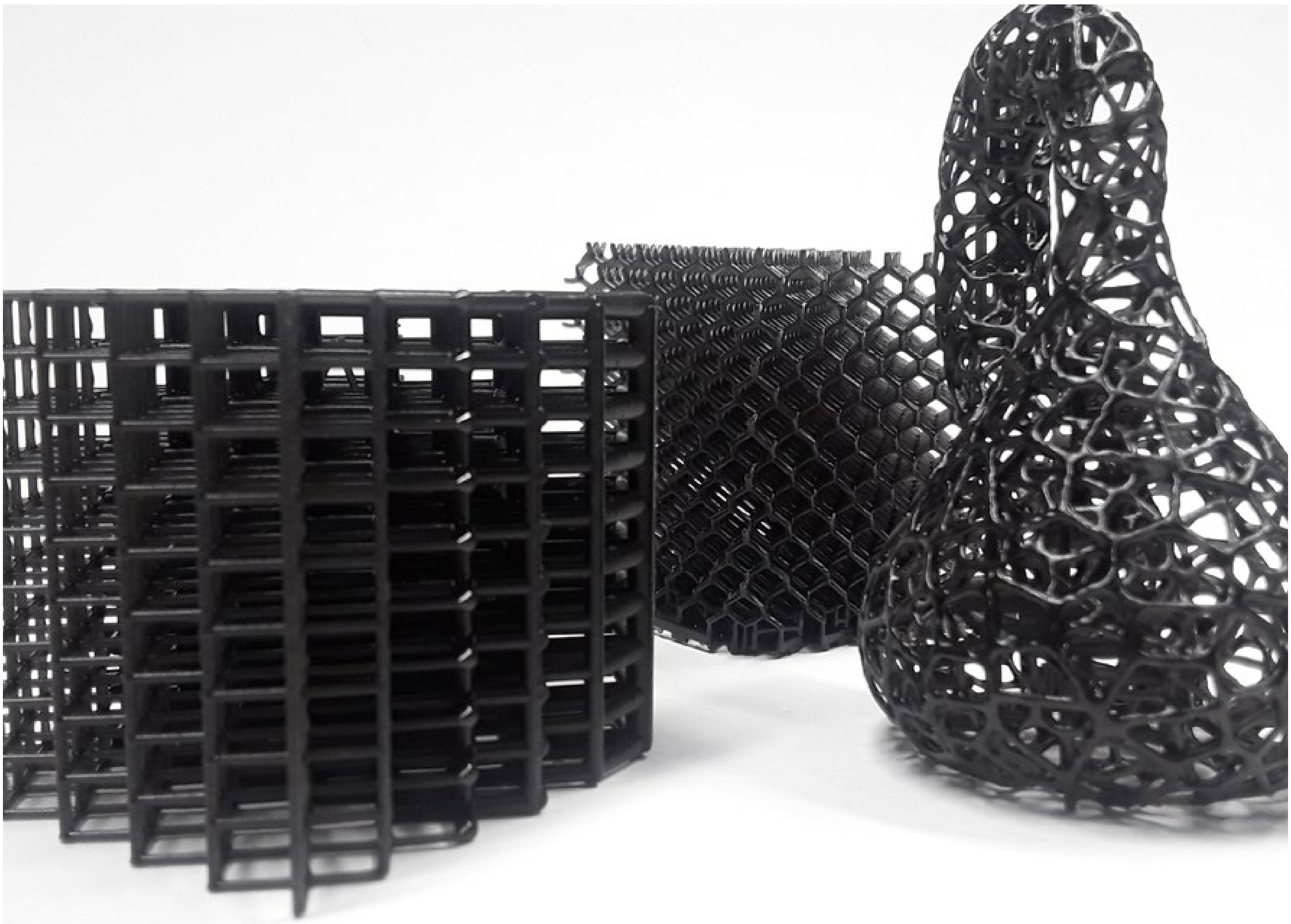
PostProcess' solution has enabled the Swedish company to streamline part finishing, reducing costs and turnaround times, since many 3D printed parts can be finished at once. Crucially, it has made post-printing safer for Splitvision employees and the environment, by eliminating the fire risk and hazardous vapors and particles associated with IPA resin removal.

A more efficient, sustainable future

If 3D printing presents a clear way towards more sustainable manufacturing, then post-processing must be a part of the conversation. A critical step in the AM workflow, post-processing should not hold back scalability or industrialization. It should also not hinder the inherent sustainability that makes AM so appealing to manufacturers.

PostProcess Technologies is one of the leading companies actively pushing post-printing forward, bringing solutions to market that emphasize scalability, digital connectivity and, importantly, sustainability. As the company succinctly concludes: "A common post-print platform which users can implement across their AM operations improves productivity and growth for the company and industry as a whole. There is no future for AM without sustainable, scalable, digital post-printing." ◆

Swedish product design service Splitvision has adopted PostProcess' resin removal solution to streamline its 3D printing workflow.
Image: PostProcess Technologies



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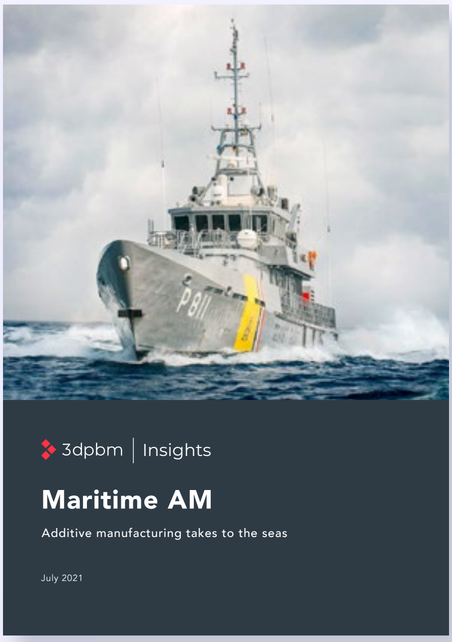

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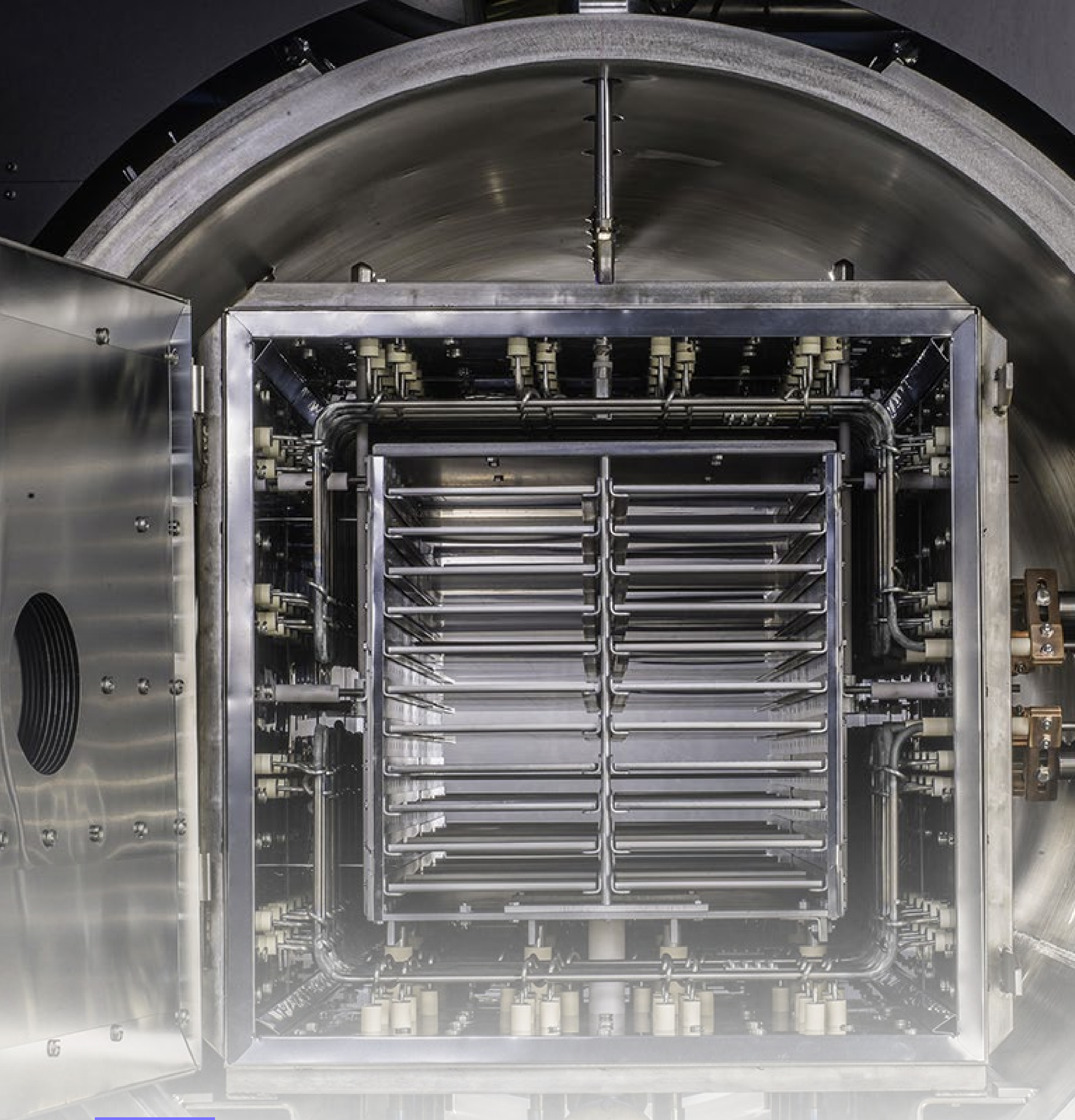

INTERVIEW

Getting to know furnace sintering for AM

Interview with Elnik Systems President Stefan Joens

3dpbm

Image: ELNIK Systems

Founded in 1969, Elnik Instruments, Inc. was established in Germany as a wholly owned subsidiary of W.H. Joens & Co. GMBH to market the company's line of temperature controllers, recorders and programmers. These instruments were designed for use on industrial furnaces, vacuum furnaces and a variety of plastic extrusion and injection molding machinery. Today, Elnik Systems manufactures some of the most advanced metal injection molding (MIM) first-stage debinding and second-stage debinding/sintering furnace equipment. Its MIM 3000 Sintering Furnace is a one-step debind and sinter furnace, enabled by some of the most sophisticated technologies available. This means that it is also the ideal furnace sintering tech for AM processes.

Elnik began to focus its efforts on the manufacture of complete vacuum furnace systems in 1982, serving clients such as Raytheon Corporation. By 1986, demand for custom vacuum furnaces was increasing at a rapid pace. A new company, Elnik Systems, was formed to meet this growing demand. In 1992, a 'one-step' debind and sinter partial pressure furnace was developed to meet the needs of the MIM market. The MIM 3000 provided a cost-effective alternative to the two-furnace technology then being used. Now a new era is about to begin, with the adoption of bound metal additive manufacturing systems in many segments of industrial production. These AM technologies need to sinter parts in a furnace as a post-process and few companies can boast extensive experience with these systems as Elnik.

In 2019, ExOne started collaborating with Elnik Systems improve sintering profiles for metal parts 3D printed on its binder jetting systems. Standard profiles are now based on metal type, as well as part features, including size, mass and other geometric elements. The companies developed an interface to automatically load or select, sintering profiles. We had the opportunity to interview Elnik Systems President Stefan Joens, who explained in great detail how his company is going to cater to this growing market demand and develop a greater understanding of the entire sintering process.

3dpbm: Can you explain your offer of furnace sintering products?

Stefan Joens: 25 years ago, Elnik developed its MIM 3000 line of furnaces, which are used to thermally debind the backbone or secondary binder in a traditional MIM part and continue on to sinter the part in the same furnace. Before this system was developed, MIM required a three step process to remove the first-stage wax, second-stage binder and presinter and then sinter, using three different pieces of equipment. Additionally, in the early 2000s we also developed a catalytic debind oven to remove the first-stage polymer from BASF Catamold or other POM based feedstocks. We also offer a solvent debind oven to remove a wax-based first-stage binder.

3dpbm: Are the products used for additive manufacturing the same as those used for MIM?

SJ: Most of the AM industry growth we see is coming from binder jetting. These technologies will only need to have our MIM 3000 series unit to remove their binder and perform complete sintering in one step process. The process of binder jetting creates a part similar to a MIM Brown part. This is the result of performing the first stage of binder removal on a green MIM part. Our MIM 3000 series furnace fits this processing demand perfectly. Since the processing requirements are 1 for 1, it makes transitioning our efforts and support to this industry very simple. We make graphite versions of our furnaces as well for any ferrous-based metals that don't require refractory metal or hydrogen processing environments.

3dpbm: Have you seen a surge in interest since new bound metal (binder jetting, bound metal filament) technologies were introduced to the market?

SJ: Yes, the interest in our equipment is high. We have been the leader in the furnace industry for debind and sinter processing for 25 years. Our ability to not just make highly functional equipment that lasts but really our motivation to educate our customers and help them every step of the way is driving our success. We have a sister business called DSH Technologies, which is an in-house service business that manages processing experimentation, toll contracts and R&D work with the metal part making industries, using Elnik equipment to carry out the work. These are all full-sized equipment, not small laboratory items. We have helped a lot of companies that are currently in the AM industry get started. DSH offers Elnik's state-of-the-art equipment without the need for CapEx until the customer is ready.

3dpbm: How does the demand of your products from AM users compare to the demand of your products from MIM users?

SJ: The systems are functionally identical. We have made a few modifications to the standard MIM 3000 unit to offer the AM industry the ability to process larger parts than normal MIM parts. Over the last two years, our sales have been about 50/50 MIM and AM. Although the interest in our organizational equipment has heavily been outweighed by AM over the last couple of years.

Image: ELNIK Systems

3dpbm: What should AM companies that are now introducing binder jetting technology in their workflow consider when evaluating a furnace sintering system?

SJ: One challenge that any new part maker faces is that there are some companies pushing furnaces into the industry with the "Easy Button" recipe builder. These systems often do not have the capabilities to provide processing environments that are ideal for all metals being offered into the AM industry, especially stainless steel, which is what most AM equipment developers are starting out with.

Through DSH, we have learned about a lot of the issues that some customers have faced with this approach. We have a lot of experience in the processing industry and feel that it is important to properly provide all customers with the right information to make the right decisions. There is no "EASY BUTTON" to process metal bound parts via MIM or AM. Our mission at Elnik and DSH is to help keep the information transferred clean, clear and understood.

3dpbm: Have you had a chance to evaluate metal binder jetting and metal filament extrusion technologies? Which do you think are more effective and functional?

SJ: Each technology has pluses and minuses. Binder jetting will lead the way with production capability and more MIM-like part results, but it is difficult to build or fabricate enclosed structures without trapping powder within the cavity. This is where extrusion based printing wins in terms of part geometry flexibility. But then you are limited in surface finish quality without some form of pre- or post-processing rework. The winner comes down to what the objective for part development is and where the parts will be used.

3dpbm: Can your products be used with any of these technologies from any manufacturer? Or do they need machine parameters from AM hardware producers?

ELNIK Systems' furnaces offer a high degree of control, with temperatures ranging up to 1650°C and a range of gas atmosphere options.
Image: ELNIK Systems

SJ: Our furnace has the capability to process any known metal with any known binder on the market today. The furnaces we make are highly flexible in their use and offer a lot of processing variability control. A user can operate up to 1650°C temperatures under a variety of gas atmospheres (depending on the partial pressures) or vacuum environments. They also have the capability to mix gases or switch gases during the same furnace run. The systems can operate under hydrogen, nitrogen, argon or vacuum environments. All program parameters are developed into an Excel Spreadsheet. The use of Excel makes programming very easy and provides any equipment user or company engineer the ability to work on program development without having to be in front of the furnace. They can do this from the comfort of their own home or office.

3dpbm: How do your products compare with those offered directly by the AM hardware manufacturers such as Markforged and Desktop Metal?

SJ: This topic links back to the statements above: our furnaces are industrial in design, they offer the full range of processing capability with argon, nitrogen, pure hydrogen, vacuum, and up to 1650°C temperatures, which is higher than most competing systems currently on the market. Our furnaces are made typically in all metal zones, which allows for processing in every environment, at any pressure up to almost atmospheric.

What is particularly interesting is that the material the AM industry is starting with—stainless steel—is best processed in full hydrogen to achieve the results most

The majority of ELNIK Systems' equipment has integrated H2 gas processing capabilities, with built-in interlocks and safety systems.
Image: ELNIK Systems

customers are looking to achieve. Yet many new and competing systems on the market are not offering this capability. The reason is that dealing with pure H2 gas is a safety risk and a liability for many customers. On the other hand, about 90-95% of our equipment leaves our floor with H2 gas processing capability. Our systems have gone through extensive reviews and evaluations to ensure we are safe to operate with H2 gas within the explosive limit. We have a lot of interlocks and safety devices built into the equipment to ensure the system is safe for use by the operator.

We also believe that to get started in the metal part making industry it takes some real knowledge of processing requirements and guidelines to achieve the end results one is targeting. While these companies are offering their end users a starting spot, we believe that the abilities we have at DSH to not only begin the experimentation on the best equipment in the industry, we also provide invaluable education of the process along the way. So once the part maker is ready to take off, they can make educated decisions about what systems they need in place and how they can start the projects successfully. We feel the value of performing R&D or lite-toll processing work with the support of DSH for those starting out in the additive manufacturing industry is a much wiser investment in an AM part maker's future than the costs of any furnace equipment in the industry today. And the education learned along the way is priceless.

“The need for a lower cost piece of equipment is there and it is something that we have been discussing, but we need to ensure it still maintains the Elnik standard of quality”

3dpbm: How does this reflect on the system’s price?

SJ: We have been asked numerous times to make a $100K furnace that has the capability to do all the same things our current furnace can do. However, our current equipment has almost that much worth of H2 safety features alone, so that is just not possible. The need for a lower cost piece of equipment is there and it is something that we have been discussing, but we need to ensure it still maintains the Elnik standard of quality and performance. Elnik does not choose components for its equipment based on price but rather quality and longevity. In the interim, as mentioned earlier, DSH is the greatest offer for any AM part maker that wants to have access to equipment with functionality that Elnik offers.

3dpbm: Is it true that furnace sintering is a more repeatable and predictable process than laser sintering during the AM phase?

SJ: I have not heard this statement before. Each AM process offers its challenges and benefits. In laser sintering, you are building a part via a process similar to welding. You have to deal with splatter effects, tension in the part during the build (which is later removed during an annealing process), structural supports and the build plate that all have to be removed post-build. And your surface finish is less than desirable for most applications. But you can use these processes to fabricate some very intricate parts. With any furnace demanding process, like binder jet or metal filament-based 3D printing, you can get some very interesting parts printed. However, much like in the MIM industry, the engineer designing the part needs to understand the process the part needs to go through. This means they have to understand the part will experience pretty uniform X+Y shrinkage and a greater Z shrinkage (directionally from the printer). So how the part is printed and how the part is later staged in the furnace for processing needs to be taken into account. MIM has demonstrated the repeatability of the process and has really dominated in its applicable markets for years. The AM industry needs to perform enough experimentation and data analysis to reach this same level of consistency. The processing side is certainly challenging, but only without the right in-house support and team to get the work done.

If you don’t have the capital or manpower to get the work done in-house, this is where our sister company, DSH Technology, really shines. We help part makers from the ground up. Build the foundation of knowledge needed so that one day they can take over the process, bring it in house and excel in their respective industries they are trying to enter.

3dpbm: How do users of your products deal with part shrinkage, dimensional stability and maintaining tolerances?

SJ: The real answer to this question is looking at the science of it all. Not only does the printing process have an effect on the part throughout the process, but the binder used, the metal particle sizes and distributions can all impact the results of the parts. Let alone the type of furnace, the accuracy of temperature control, the environment used to remove the binder material. There are a lot of factors. But it is all manageable when you understand what you are trying to manage. The printing companies are doing a pretty good job gathering print analysis data and we are hoping to see some real results in terms of guidelines for printing based on total geometry.

As for the furnace side, each individual part can technically demand a specific program. But that is not really practical. The additive manufacturing industry is looking for flexibility and reduced variability. So in our systems, the functionality of the equipment lets the user develop recipes based on the largest or thickest part in the furnace during the run. This means that, so long as the metal and binder are the same, you can process a variety of parts all in the same run and not worry about part orientation or location to optimize gas flow. A good processing facility will still need to have an in-house Process Metallurgist (or have access to one), not just a material science expert. Again, another plug for where DSH can be of assistance.

We offer Block times of support to any customer throughout the world. They don't have to be an existing Elnik or DSH customer either. We are looking to educate the world on process metallurgy. We have a dream of developing a DSH University to allow material science students and people that want to learn more about the process side of this industry to spend time with us either via an internship, temporary employment or even long term employment. There is a lack of education being provided to teach our specific technology and our goal is to help future companies have the right candidates in-house to get the work done!

3dpbm: Will some of this be eventually done at a software level during part design or through the software managing the sintering process?

SJ: As for software managing the furnace process, there is currently nothing available in the market that is reliable. There are variables that need to be considered in terms of processing parameters that are generally not available during the printing design process. Perhaps something may eventually be developed. The real challenge is realizing that any solution provided will be a conservative approach to processing. And anyone interested in deep diving process optimization will need to analyze this with a good process metallurgist.

3dpbm: Do you think that AM will eventually grow in size to compete with MIM and other formative processes?

SJ: It certainly can. It will require good repeatable results driven by valid scientific data analysis and demonstration of what works and what doesn't. MIM has limitations as well and groups like MPIF, EPMA and other private technical organizations have done a really good job providing technical standards to help part makers rely on a benchmark. This is still at the starting phases in the AM industry. The faster this gets up and running, the sooner companies will know where they stand. Like the MIM industry 30 years ago, the AM industry is in its "Wild West" phase. The leading companies or those that really want to have a voice in this process need to get involved with technical boards to help drive this process further. The biggest challenge they face right now is knowing where to start, a bit like drinking from a firehose. Taking the lead from some MIM part makers and getting some insight from the MIM tech boards might be a good avenue to press on.

The casting industry should be mindful of the AM industry. AM opens the doors to higher part complexity, wider metals range and can really make a dent on that industry. The machining industry should also begin to bring this process in-house. AM will allow them to develop really challenging pieces that only need minimal machining to be in line with their customer requirements. ◆

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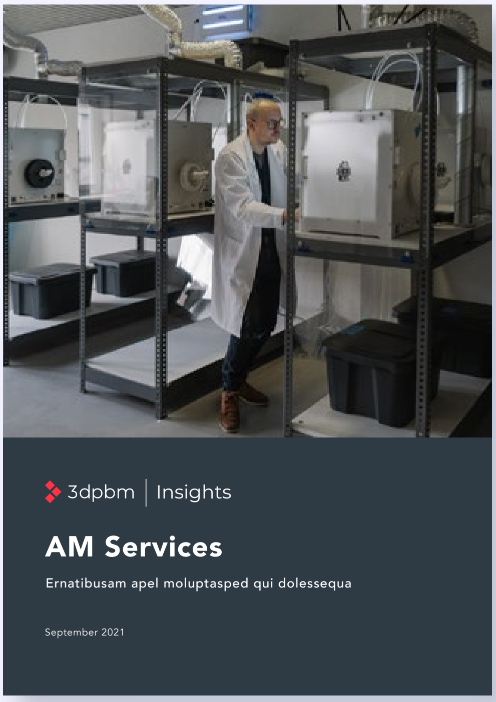

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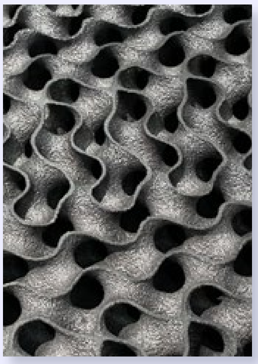

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MAPPING

Another step in AM factory automation

Most AM companies' visions for the automated factory of the future continue to evolve. Here's how.

3dpbm

Image: Siemens

As AM evolves towards becoming a digital additive mass production (DAMP) process, most large 3D printer manufacturers have announced and displayed their vision for automating production in an additive manufacturing-based factory.

These include key additive manufacturing hardware OEMs as well as large machine tool manufacturers, which can leverage extensive experience in factory automation, adding the "AM engine" as an additional tool for directed energy deposition within hybrid manufacturing. The integration of powder bed fusion (PBF) technologies within the automated factory presents a greater order of magnitude in terms of additional complexity, as it is, by definition, confined to an enclosed powder bed.

The GE vision for the automated AM factory is very much based on the M LINE FACTORY metal PBF systems, forming the core element of the "AM Factory of Tomorrow," which also envisages linking up with traditional manufacturing methods in the post-processing of parts. The concept consistently implements the basic idea of "Industry 4.0" with a focus on delivering a "smart factory." Consistent automation, interlinking and digitization of all processes ultimately allow the economical series production of additively manufactured metal parts.

The new machine architecture is essentially characterized by decoupling "pre-production," "production" and "post-production." This includes, among other things, flexible machine loading and physical separation of the setting-up and disarming processes. This becomes possible thanks to a consistent modular structure of handling stations and build and process units that, in terms of combination and interlinking, promises considerably greater flexibility and availability. It will also be possible to handle the present diversity of materials better and more economically through a targeted combination of these modules. GE Additive's largest AM factory in Ohio, the ATC, holds more than 90 3D printers, including six of the largest metal printers in the world, the XLine 2000, and has begun introducing the MLINE systems in 2019. The site employs over 300 designers, machinists and engineers and belongs to GE Aviation, although about half of the employees come from GE Additive.

The new approach also envisages dividing the material storage facility, the processing unit and the unit for collecting excess material into individual modules. These modules are independent of one another and can be controlled individually. Simulated production scenarios have in fact shown that this space can be reduced by up to 85% compared to the possibilities that exist at present. In addition, the laser power per square meter of area used has increased seven-fold.

As the leading provider of design, process optimization and PLM software, Siemens' vision for the AM factory of the future encompasses and enables the concepts brought forth by several partnering hardware manufacturers, including EOS (for metal and polymer PBF), Stratasys (for polymer and composite material extrusion), HP (for polymer MJF) and ExOne (for metal binder jetting), among others.

With the recently expanded Siemens Materials Solutions facility in Worcester, the company has set the goal of moving 3D printing out of the laboratory and onto the factory floor. From the start, as a key part of Siemens' AM strategy, Siemens Materials Solutions set out to solve complex printing engineering challenges and focus on high-end prototypes and serial production for customers across the Power Generation, Aerospace, Automotive and Process and Tooling sectors. The company's offer covers the complete AM value chain: from digital solutions to design & manufacturing and AM services. The company has just installed four more EOS M400-4 at the Worcester facility, bringing the total fleet (which includes the new facility in Orlando, Florida) to 34 machines. The initial target of 50 printers, announced with the opening of the new Worcester facility, is getting closer.

eos

EOS worked together with automotive manufacturer Daimler and aerospace tier-1 supplier Premium Aerotech on the NextGenAM project for AM implementation in large-scale serial manufacturing.

The objective of the project is to advance the automation of the entire industrial AM process. The NextGenAM additive production chain is highly scalable and is fully automated. No manual work is required at any stage of the process, from the print file preparation to central powder supply, to the AM build process, to heat treatments and quality assurance. Even the part removal process has been automated with the mechanical separation of parts from the build platform.

The full system comprises an EOS M 400-4 quad laser printer as well as a driverless transport system and robots that ensure the seamless production of parts from start to finish. The system is controlled by a centralized, autonomous control station that networks all the elements of the AM system. Once order data is sent to the control station, it automatically prioritizes the build requests and initiates builds on the networked additive manufacturing system. The control station also enables users to monitor the manufacturing process remotely and compiles quality reports once the production is complete. The data needed for the production of a digital twin can then be assessed, allowing for complete traceability.

voxeljet

There are many different approaches to direct metal additive manufacturing—from laser powder bed fusion to binder jetting. However, there are also non-direct options that offer some very real solutions for production applications. One of the most influential proponents for non-direct metal AM is German company voxeljet, a specialist in industrial sand and polymer binder jet 3D printing.

Today, voxeljet's binder jetting technology plays an integral role in the production of metal parts by creating molds or patterns which can then be used in metal casting. This process, called Additive Casting, is a dual approach that combines the benefits of 3D printing with the time-tested reliability and quality of casting. 3D printing for metal casting today is a fairly well established and certified process, which has been in use for over two decades in the automotive, aerospace, engineering, heavy industry and art sectors, among others. Compared to other metal AM processes, additive casting also offers certain advantages, including fewer size limitations, broader material diversity and lower costs. In regards to the latter, compared to Direct Metal Laser Sintering (DMLS), where powder costs range from about €300 to €400 per kilogram, a 3D printed sand mold costs approximately €5 per box liter and casting steel costs between €6.50 to €32 per kg.

Image: voxeljet

In terms of size, voxeljet's binder jetting systems can build molds and patterns up to 4,000 x 2,000 x 1,000 mm, enabling the production of large components—or several smaller components. For even larger metal parts, molds can also be printed in several pieces and assembled before casting. To date, the size of direct metal 3D printed parts has been more limited in scope. Looking at materials, additive casting gives customers the freedom to choose between hundreds of metal alloys. Alloys can also be tailored to meet specific part properties in special cases. Notably, materials which are notoriously challenging to 3D print directly, such as magnesium, can be used, especially for applications which require lightweighting, like in aerospace.

HP expects automated assembly will arrive soon, with industries seamlessly integrating multi-part assemblies including combinations of 3D printed metal and plastic parts. As automation increases, HP proposes a vision from the industry for a more automated assembly setup where there is access to part production across both metals and plastics simultaneously. This could benefit the auto industry by enabling manufacturers to print metals into plastic parts, build parts that are wear-resistant and collect electricity, add surface treatments and even build conductors or motors into plastic parts.

HP's Multi Jet Fusion systems were developed to be highly automated in combination with the post-processing units for part cooling, powder handling and powder recycling. The newest HP Jet Fusion 5200 Series 3D printing system comes with a new cooling module, which further streamlines and automates the production process. The low-cost cooling unit essentially sits on top of the build unit and once the printing process is complete, the still-hot parts are automatically transferred into the cooling boxes so that the build unit is liberated for the next job.

Image: HP

3D SYSTEMS

3D Systems' vision for the metal AM factory of the future centers around the latest DMP 8500 Factory Solution metal PBF system, which the company describes as "the first truly scalable, automated and fully integrated metal additive manufacturing solution."

The DMP 8500 is a modular solution, in that it is made up of several different systems that make up an automated workflow, supported by 3D Systems' 3DXpert software solution. Each module is designed to maximize efficiency by optimizing utilization. Customers can configure a custom metal AM factory for the scaled production of precision metal parts by choosing the right combination of modules to optimize their specific production application.

The Printer Module (PTM) is capable of 24/7 operation. It is the heart of the repeatable, scalable automated solution. Its 3DXpert-driven three-laser scanning system and fast bidirectional recoater enable the rapid printing of large, seamless parts. The Removable Print Module (RPM) is an integrated unit for building parts and transporting them, as well as powder, to other modules. The parts and powder are sealed during transport and the design enables full powder traceability. The Powder Management Module (PMM) extracts unused metal powder from build platforms, recycling the powder and preparing the RPM for the next build. The Transport Module (TRM) is designed to efficiently move the Removable Print Module between modules. The Parking Module (PAM) has an inert environment for storing Removable Print Modules until they are ready to move to a free slot on a printer or powder management unit, enabling a continuous production cycle.

At the core of 3D Systems automated AM factory vision for polymer part manufacturing is the Figure 4 platform, which is intended to transform the production of mass-customized and complex end-use parts while meeting durability and repeatability requirements of production environments. Built to be scalable, modular and fully automated, the platform allows customers to tailor configurations and select materials to address specific applications. Configurations range from single-print engine machines to fully automated, high-volume production systems with 16 or more print engines, automated material delivery and integrated post-processing.

Desktop Metal

Desktop Metal's automated factory vision revolves around its Production System. Powered by Single Pass Jetting technology, the Production System is a metal 3D printing platform envisioned specifically for mass production, with speed, quality and cost-per-part that are able to compete with traditional manufacturing processes.

The Production System, which is designed to print a broad range of alloys, including reactive metals such as Ti and Al, enables the use of metal powders that are 80% lower cost than laser powder bed fusion metals, delivering parts at 1/20th the cost.Designed around the MIM chemistry and powder supply chain, the Production System allows access to a large and established ecosystem of low-cost, high-quality alloys with a mature supply chain and well-studied controls.

Carbon

Carbon SpeedCell is a system of connected manufacturing unit operations that enables repeatable production of end-use parts at any scale. The M and L Series printers, along with the automated Smart Part Washer, are part of a series of modular offerings that allow a wide range of industries to design, engineer, make and deliver end-use parts with a single manufacturing workflow. The system is driven by a proprietary automation software that brings hardware and materials together into an easy-to-use system. The built-in DSM physics engine optimizes each print for speed, accuracy and repeatability. The data-centric approach enables the implementation of a predictive service and dashboards that allow users to monitor their printer fleet.

Carbon also uses a proprietary cloud-based Finite Element Analysis tool to help customers re-imagine their parts outside the boundaries of injection molding. As in any connected device, the software is also continually improving with one-click updates. SpeedCell achieves superior production workflow and output by integrating multiple key operations, including part printing and part washing, to facilitate cost-effective part production. The system also features multiple Carbon Connectors, which enable hardware extensibility to support additional system capabilities in the future. ◆

Image: Carbon

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