MANUFACTURING

additive

3D ADEPT MAG

Dossier
WHAT ARE THE KEY PERFORMANCE INDICATORS FOR A GOOD (METAL) AM PRODUCTION?

Software
DOES YOUR SOFTWARE ENABLE PRODUCTION?

AM Shapers
AM IN THE MILITARY FIELD: THE STORIES OF **AIRBUS HELICOPTERS** AND **PRATT & WHITNEY**

Materials
TECHNICAL CERAMICS: CURRENT ADVANCEMENTS & LIMITATIONS IN MULTI-MATERIAL 3D PRINTING

3D PRINTING

N°5 - Vol 6 / September - October 2024

Edited by KEYMAR Solutions - ISSN : 2736-6634


Messe Frankfurt Group
mesago
formnext
19 – 22.11.2024
FRANKFURT / GERMANY
Shape the future of manufacturing
Demand for more complex, customized parts is rising fast. Product cycles are shortening, traditional supply chains are evolving, and the importance of sustainability continues to grow.
Additive Manufacturing offers you the solutions to meet these challenges and inspire your customers.
Stay ahead of the competition! Visit Formnext, the international expo and convention for Additive Manufacturing in Frankfurt am Main.
Where ideas take shape.
Secure tickets!
formnext.com/tickets
Honorary sponsor
VDMA
Working Group
Additive Manufacturing

Edited by KEYMAR Solutions

Graphic Designer
Martial Y. , Charles Ernest K.

Editorial team
Kety S., Cameron Constanzo, Yosra K., Martial Y.

Proofreaders
Jeanne Geraldine N.N.

Advertising
Laura Depret - Laura.d@3dadept.com

Periodicity & Accessibility:

3D ADEPT Mag is published on a bimonthly basis as either a free digital publication or a print subscription.

Publishing house:

3D ADEPT is a publication of Keymar Solutions

KEYMAR SOLUTIONS

Questions and feedback:

KEYMAR Solutions SRL
VAT: BE0681.599.796
Belgium -Rue Borrens 51 - 1050 Brussels
Phone: +32 (0)4 86 74 58 87
Email: contact@3dadept.com
Online: www.3dadept.com

Table of Contents

The “job to be done” theory

As far as I can recall, innovation has been both a top priority and a major source of frustration for leaders. In an industry like AM, it’s hard not to find a company where innovation is not part of the growth strategy. Although they are aware of the importance of innovating, companies don’t always know if that innovation will be able to deliver the desired performance.

I may not know the ins and outs of each company’s profile but a conversation with a marketer I admire made me realize the importance of the “job to be done” theory to deliver results. This theory of innovation is based on the economic principle that people buy products and services to get “jobs” done, i.e., to help them accomplish tasks, achieve goals and objectives, resolve and avoid problems, and to make progress in their lives.

This means that when we purchase a product (understand “solution”), we’re essentially «hiring» it to perform a specific task. If it does the job well, we’re likely to choose it again the next time we face the same task. But if it fails to meet our expectations, we «fire» it and search for a better option. Interestingly, this theory can be applied to everything.

While this theory of innovation may be obvious to apply by AM technologies’ providers, I would like to draw your attention to what it may look like for AM users. Let’s take the example of the military field, a sector where it has always been difficult to discuss the use of AM applications – for obvious reasons, one will realize that most companies in this field have limited the use of AM to one or two applications – mostly spare parts.

In this edition of 3D ADEPT Mag, the stories of Pratt & Whitney as well as Airbus Helicopters reveal how they have found other “jobs to be done” to leverage the technological advantages AM can bring to the military field.

These stories as well as other dossiers all aim to help you answer one single question:

What jobs do you need AM to do?

Kety SINDZE
Managing Editor at 3D ADEPT Media
KETYS@3DADEPT.COM

EDITORIAL


Powerful metal powders –
for powerful AM

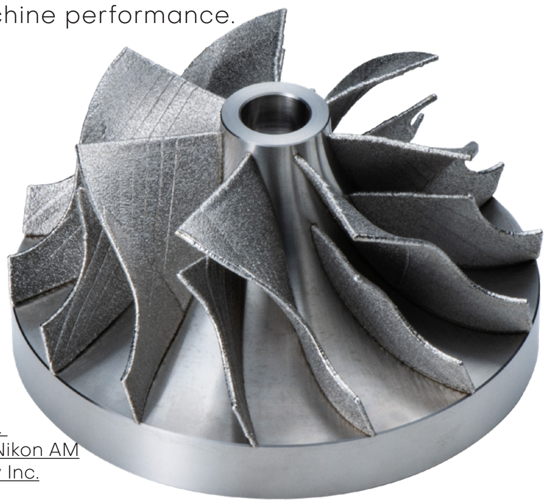
What are the key performance indicators for a good (metal) AM production?

With a 30-year-plus pedigree in the industry, Additive Manufacturing continues to evolve. While it is clear to many that it is no longer just a solution for rapid prototyping, preconceptions regarding its usefulness as a production technology often need to be reassessed. As we evolve in a context where attention is shifting to higher-volume applications such as mass customization and the fabrication of standard parts, production losses due to process variability and inefficient machine use may be common concerns – leading AM users to ask themselves a million-dollar question: ***what are the key performance indicators for a "good" (metal) AM production?***

Given the economic constraints of the current times, many assess the value of AM by its ROI – return on investment. It is not a bad thing in itself, as it may help determine the number of parts machines can produce or how much production has increased during an average workday, thus facilitating calculation of the cost-benefit. The problem is it can be difficult to define AM based on the numbers of ROI for a simple reason: AM doesn't function the same way as the other machines on the floor.

AM users therefore need another approach to assess the success metrics of AM. This dossier is **at the intersection of general business considerations and manufacturing needs of industries**.

With a focus on four metal AM processes (DED, Cold Spray AM and Material Extrusion), this dossier aims to help AM users assess the manufacturing capabilities of AM; assess a technology production candidacy regarding mass production as well as discover the metrics that enable a user to determine a machine performance.



Impeller.
Credit: Nikon AM Synergy Inc.

The constant comparison with traditional manufacturing: is it still worth it?

In general, and for a long time, assessing the metrics of success of AM has been done in comparison with traditional manufacturing. This somehow makes sense when one knows the key advantages (design freedom and flexible and rapid fabrication) AM brings compared to traditional manufacturing processes (acknowledged for their ability to allow mass production or large economy of scales).

The truth is, talking about production and AM does not necessarily refer to mass production. *"When talking about production and additive manufacturing, especially in metal AM, we do not necessarily always think of mass production. Production can involve a wide range of conditions from initial proof of concept (POC) and prototyping to custom or small batch production, low-rate initial production (LRIP), full rate production, and mass production,"* **Dr Behrang Poorganji, CTO of Nikon AM Synergy I nc** explains.

Making a clear comparison with casting and forging, **Herbert Koeck**, Managing Director at Titomic explains:

"Unlike casting and/or forging foundries that can require larger economy of scales to justify tooling investment and parts production, cold spray additive manufacturing (CSAM) in certain geometries can offer an alternative source for near net parts. CSAM can be setup for mass production, although the investment in CS has the added advantage of versatility, where one day the machine is producing as a titanium caster, and the next day running as copper foundry."

However, this comparison may not always be applicable when one realizes that AM often comes to enhance existing processes, making them more efficient and effective. Furthermore, AM is sometimes a victim of its own success: the more the technology advances, the more complexity it brings to other areas of the manufacturing chain, even when the process reduces industrial costs, shortens lead times, or enhances the sustainability of manufacturing.

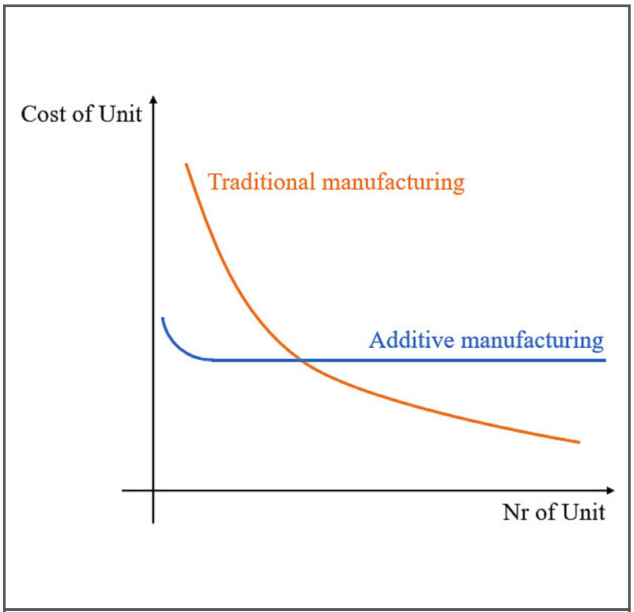
These considerations make the definition of AM evolve among its users, and **often lead to a comparison between AM technologies themselves**.

With over twenty different metal 3D printing processes, the metal AM landscape is probably the most diverse field of manufacturing. While the application often determines the choice of the technology, **laser powder bed fusion** remains the most widespread technology. For obvious reasons, we decided to focus three other metal AM processes that are gaining momentum in the market.

That being said, for those who are looking to take their first steps in AM, there is no clear communication about the **appropriate use and scope of each technology**.

If we were to evaluate the appropriate use and scope of traditional manufacturing processes, we would have considered features such as **cost and price**, as well as other considerations related to **mass production and the global supply chain**. These considerations may include labor, energy, material feedstocks, production support, research, design and engineering amortization to name a few.

(Cost indicates manufacturing efficiency, whereas price is a customer-oriented measure that ideally reflects the value of the product.)



Legend: This figure shows a comparison between the cost trend of AM and traditional techniques as production volumes increase. Source: An overview of the impact of additive manufacturing on supply chain, reshoring, and sustainability

Clemens Lieberwirth, CTO at AIM3D GmbH

In the case of metal AM, *"the first question we should ask ourselves is why we would choose AM for mass production and consider using a global supply chain for that purpose. Are we considering cost, functionality, performance, lead time, environmental impacts and sustainability, security, etc. as our decision factors in choosing AM?*

Cost efficiency, materials availability and materials properties, design complexity (where AM provides tremendous advantages), precision and quality requirements, and scalability all factor into the suitability of mass production. High-demand products experiencing a strained supply chain using conventional manufacturing processing technologies could be strong candidates for mass production using metal AM and implementing a global supply chain. IP considerations are also important when thinking of leveraging a global supply chain in metal AM," **Poorganji** outlines.

For **Clemens Lieberwirth**, CTO at AIM3D GmbH, *"there is no good business case for mass production with AM – but talking about small series production, there are three indicators in my opinion:*

- *Series Size – depending on part size/complexity up to 10.000 pcs/year*
- *AM-optimized product design (depends on AM process) – part size, wall thickness, overhangs, smallest details, and internal channels should be tuned to the specific AM process to get the best result concerning quality and cost*
- *Independency in terms of material choice and production location. Systems that have open material policies allow the best cost & quality performance and make the production line crisis-safe"*

So, a comparison between traditional and AM processes may be interesting but it is no longer a must to determine the key performance indicators of a good AM production.

Moreover, we may link conventional manufacturing with mass production, but one thing we should keep in mind is that the value of Additive Manufacturing does not lie in replicating what mass production already accomplishes, but in excelling where mass production falls short or struggles to perform effectively.

The question of standardization

It would have been difficult to not mention the question of standardization when one knows that manufacturing strategies that rely on traditional manufacturing processes champion standardization. Indeed, some products – especially those that are mass-produced or certain industries, give more value to standardization whereas this value seems diminished with AM which favors customization.

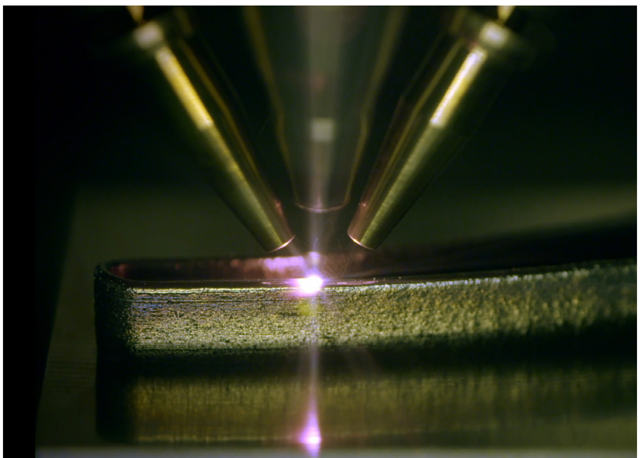
"For high-rate production in aerospace and defense, ISO/ASTM recognition assists in achieving consistent results as a product transition from development to full-scale production that require collaboration of larger teams," Titomic's expert outlines.

On another note, there are only **7 AM process categories** established by ISO/ASTM (the International Organization for Standardization). For those who are new to AM, these categories include material extrusion, material jetting, powder bed fusion, sheet lamination, binder jetting, direct energy deposition (DED) as well as VAT photopolymerization. This does not prevent AM users from using metal AM processes that do not fall within these categories.

The question is: does it matter? Experts have different opinions on the topic:

"Recognition under a globally used standard such as ISO/ASTM joint standards for AM is highly important, but whether it is absolutely necessary or not depends upon the industry and products. There are other standards and specifications such as SAE AMS, AWS, MIL that are necessary in certain contexts for specific products/industries. Standards are critical in assuring quality when it comes to repeatability and reliability of the process. They also establish a common language in building trust and credibility, and understanding risks, as well as in satisfying specific regulatory compliances defined by agencies such as the FAA, FDA, NASA, etc. by defining requirements and establishing certification processes," Nikon AM Synergy Inc's expert said.

"I [don't] think it absolutely matters now. The standards are in part very general and try to merge different technologies, that have different technological principles of action. There are still many customers that are confused by the amount of different AM technologies and that cannot differentiate what is suited for one process or another. Standards that are mixing these processes won´t help with that. But of course, more enlightenment and suiting standards could also help with that in the future," AIM3D's CTO argues.



Credit: Nikon AM Synergy Inc.

So, what performance indicators should one consider for an AM production and for a 3D printer?

In this dossier, metrics of success and key performance indicators are used interchangeably to qualify an AM production and a machine performance. For an AM production, we believe that if an AM process has been able to deliver value through customization, enable complexity at low cost and in small volumes, allow on-demand manufacturing, and ensure amortization – it's already a win.

Some technical considerations may emphasize this:

"In metal AM production, there are several key indicators of production success. Part quality, repeatability and reliability of the build process, cost effectiveness and production efficiency, lead time/ on time delivery, as well as sustainability with regards to reducing waste and being able to reuse and recycle materials are among these indicators.

When it comes to AM machine performance assessment, equipment uptime, reliability, ease of use and available services and maintenance are essential factors. Other critical considerations include machine throughput, build volume, printing resolution, process automation (especially in serial production, or when skilled operators are not readily available), and in-process monitoring integration for machine health and quality assurance purposes," Dr Behrang Poorganji outlines.


Dr Behrang Poorganji

Taking example on their technology, Titomic's **Herbert Koeck** points out:

"Process consistency is of high importance and is measured in several ways by Titomic. A primary metric for Titomic's systems is powder velocity and material deposition. With high deposition rates, Titomic produces large, strong titanium parts at 5kg per hour, depending on the application."

Before highlighting the performance indicators of their industrial 3D printers, let's note that Nikon AM Synergy Inc. brings its expertise as a manufacturer of DED technologies. The company recently unveiled a Lasermeister DED repair solution which attracts customers looking for the highest quality and precision to repair critical parts such as turbine blades or complex and expensive molds and dies. One of the main features of its DED solution is its compact size and automation capabilities with integrated scanning, geometry compensation and tool path generation for the repair of complex parts. This will enable extremely low scrap rate, as well as highly efficient and repeatable processing, independent of machine operator skill level.

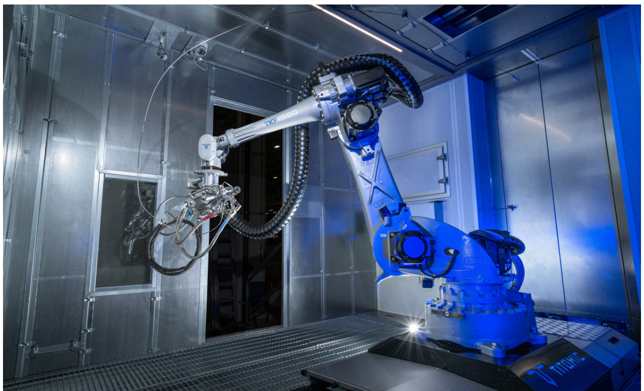
Credit: Nikon AM Synergy Inc.

Poorganji describes their 3D printer's performance in light of the value benchmarks below.

Value benchmarks	Answers
Does it help to achieve wall thickness?	Nikon DED Lasermister repair systems are very capable of delivering thin wall thicknesses and high-resolution features, down to 500 microns (0.5mm). Our next-generation high-throughput machines have even finer capabilities down to 200 microns resolution (0.2mm)
What's the minimum and maximum part size feasible?	Our current generation system can produce up to 400mm tall parts with approximate cross section of 300 X 200mm. Our next-generation DED system will have capabilities for up to 650mm parts.
Build rate	Our current generation DED repair system can deliver 2-5 cc/hr. For our next-gen DED system, we are targeting +100cc/hr.
In-process quality assurance	We have in-process monitoring in our DED system for both the melt pool and powder feed rate.
Inspection and quality controls	Our DED repair solution is integrated with pre and post-3D optical scanning for dimensional accuracy. We at Nikon are also benefiting from our non-destructive Nikon X-CT inspection.
Finishing and post-processing?	Our DED repair system's high resolution and fine material deposition enables very smooth surfaces as well as minimized heat affected zone (HAZ) and thermal distortion. Using our Nikon DED repair solution can thereby reduce time and cost at the post processing step.
Materials?	We have parameters for a variety of materials and our system is compatible with both reactive and non-reactive powders. As a few examples - we can process Steels, Ti alloys, Ni alloys, Cu alloys, and Nb alloys.
Quality sensitivity (Does it require specific tools to control defects for instance?)	Standard microstructural characterization, mechanical and physical material property, and standard non-destructive testing (NDT) are the conventional tools we use.

Titomic's cold spray technology excels at creating large parts from pure titanium to a near-net shape. Titomic develops the world's leading cold spray solutions to meet customer demands. From low-to-medium pressure portable systems, to high-pressure Titomic Kinetic Fusion® Additive Manufacturing Systems, Titomic's engineered cold spray solutions provide a robust platform for cold spray implementation across the R&D, industrial, and government organizations, including applications in defence and aerospace.

Titomic's High-Pressure TKF-1000 Cold Spray System is a modular cold spray system designed for prototyping and R&D, as well as small-scale production. With advanced robotics and control systems, industry-leading build rates, and state-of-the-art hardware.



Credit: Titomic. High-Pressure TKF-1000 Cold Spray System

Herbert Koeck describes their 3D printer's performance in light of the value benchmarks below.

Value benchmarks	Answers
Does it help to achieve wall thickness?	Yes. Wall thickness is dependent on the material, the cold spray parameters used, and the geometry being built (i.e., flat vs rotational parts). For example, Titomic has achieved wall thickness in CP-Ti of 75 mm.
What's the minimum and maximum part size feasible?	The maximum limitation is either residual stress limits or post processing limitation such as the heat treatment size available. The minimum does depend on the geometry and cold spray system used. With a plum diameter ranging from 3 to 12 mm, parts that a derived from near net casting or forgings can be well suited to cold spray.
Build rate	A reasonable build rate is 1 Liter per hour. For higher stressed materials this is dialled back to 0.5 and 0.25 Liters per hour. Titomic can produce titanium and other parts at rates of 5kg/hour, depending on product application requirements, including optimisation of material properties.
In-process quality assurance	Titomic carefully records all cold spray parameters, such as power feed rate, gas temperature, and pressure.
Inspection and quality controls	Non-destructive testing techniques can be used, such as ultrasound, to inspect parts for defects. Titomic conducts further inspection with its on-site laboratory and machine finishing facility.
Finishing and post-processing?	Titomic parts can be used as sprayed in some applications. Otherwise, the as-sprayed part is directly machinable. As parts made with cold spray are near-net-shape, they may require machining to remove 5-10% of material to bring the part to final tolerance. Once complete, the part may require heat treatment, depending on the final desired outcome or part application. Titomic has found very strong results in the use of hot isostatic pressing, with parts showing significant strength-to-weight values.
Materials?	Most metals that can be powdered can be cold sprayed, however, if a powder has a high strength-to-density ratio, it can be difficult to build with as it required a high particle velocity and therefore can be highly stressed during deposition (for example carbon steels). Titomic's cold spray process excels at manufacturing and coating with copper and its alloys, titanium and its alloys, tantalum, stainless steels, and Inconel In718 and 625.
Quality sensitivity (Does it require specific tools to control defects for instance?)	

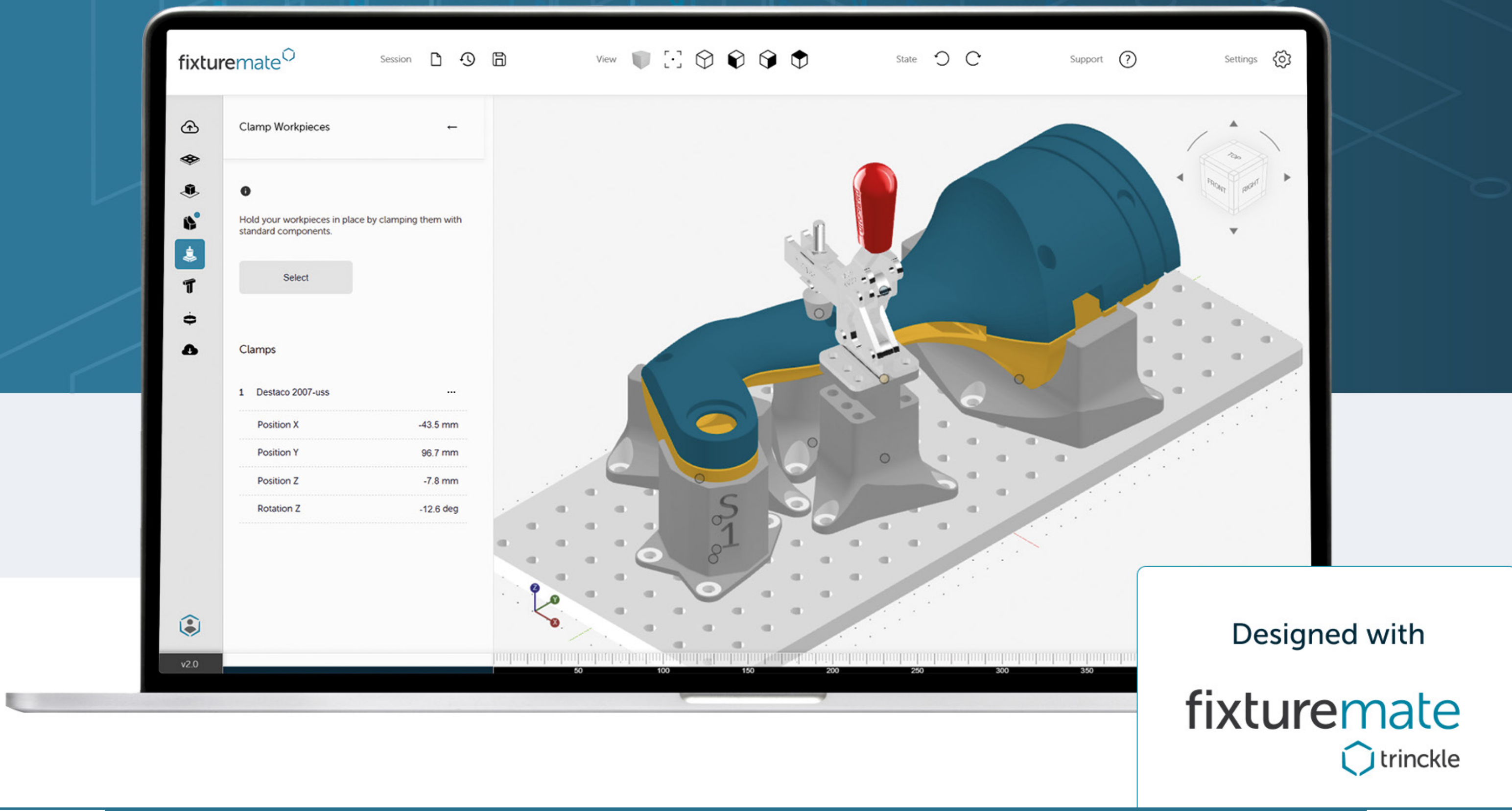
AIM3D GmbH has developed a multi-material 3D printer that prints products made of metals, ceramics, plastics and reinforced plastics based on standard injection molding granules without costly machine conversions.

Clemens Lieberwirth describes their 3D pellet printing technology's performance in light of the value benchmarks below.

Value benchmarks	Answers
Does it help to achieve wall thickness?	Yes, it helps to achieve wall thicknesses.
What's the minimum and maximum part size feasible?	Minimum part size ~ 0,125 cm³ (Size of a tooth) Maximum part size ~ 500 cm³ (Size of a palm)
Build rate	~ 60 -250 cm³/h
In-process quality assurance	Process parameter control (temperature, movement, extrusion, nozzle clogging)
Inspection and quality controls	Visual inspection, weight, dimensional measurements
Finishing and post-processing?	Deburring, Debinding, Sintering, cutting threads, sanding polishing if needed
Materials?	Stainless steels, low alloy steels, nonferrous metals like titanium, copper, brass, ferromagnetic alloys, hard metals, ceramics …
Quality sensitivity (Does it require specific tools to control defects for instance?)	Depends on use case

In a nutshell…

While a good production with conventional manufacturing processes depends on its ability to ensure mass production and meet supply chain requirements, a good production with AM depends on many metrics that involve the machine performance, its ability to deliver value through customization, to allow complexity at low cost and in small volumes, as well as the ability to allow on-demand manufacturing. Moreover, given the current economic context of the market, broad accessibility, speed, entry costs and low production costs per unit, are also performance indicators that play to the strengths of AM. They reveal that the more AM evolves and is being utilized, the more performance indicators are identified on the road to success.



Does your software enable production ?

While many Additive Manufacturing (AM) users rely on AM for prototyping purposes, the ultimate dream remains to achieve (series/ high-volume) production in a repeatable and viable way. As we prepare for Formnext 2024, we can't help but recall that last year at Formnext 2023, most AM users looking to achieve production with AM, continuously asked software companies the same question: "Does your software enable production?" – A difficult yet pivotal question when one realizes that the AM software landscape is complex and often not well understood.

First and foremost, in the wide range of AM software solutions that can be used along the process chain, we have been able to identify:

- Software solutions used for part identification and application screening
- Software solutions used for production planning – Different categories fall into this group: Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), and Product Lifecycle Management (PLM). Industrial additive manufacturing (AM) operators also rely on workflow software to manage extensive fleets of various printers across multiple production sites. In such cases, AM workflows need to be seamlessly integrated into the broader supply chain.
- Software solutions that can support different tasks of the actual manufacturing process. These tasks include the design, simulation, pre-processing, distribution, manufacturing, inspection, or quality assurance (QA) to name a few.
- Software solutions that support different areas of the manufacturing chain. This includes software solutions related to data preparation, in-process monitoring and analysis. While some solutions handle basic tasks like tracking machine parameters and monitoring data systematically, others focus on assessing print quality layer by layer by analyzing data from cameras or other sensors. These solutions have become practical for operators, particularly in production environments where similar parts are printed in larger quantities, to monitor quality throughout the build process.
- Other peripheral software solutions related to quote and order management, LCA solutions or IP protection for 3D printing files that can still support AM users.
- Software-driven workflows formalized into secure, end-to-end systems. Such platforms tackle every link on the AM production chain.

As you can see, the AM software landscape is large and complex. These categories do not always fit together in an AM workflow. However, depending on the user's profile and production requirements, each of these categories can play a small role in achieving production with AM.

THE QUESTION IS: HOW ?

To answer this question, we have invited 4 companies with different expertise as key contributors to this dossier.

- trinckle 3D GmbH, a company that focuses on streamlining and simplifying the design process, making it accessible even to those with minimal CAD experience. As per the words of **Dr Ole von Seelen**, Chief Commercial Officer, "This accessibility is key to enabling production at scale. By reducing design times by up to 95% and making the design process accessible to non-CAD experts, [trinckle]'s software not only facilitates the creation of production-ready designs but also empowers companies to scale their AM operations efficiently. This capability is essential for moving from prototyping to full-scale production, making [this] software a critical enabler in the AM production ecosystem."
- Phase3D is a company that provides real-time inspection solution that uses structured light and data processing to help customers reach production faster. "In-situ inspection is a growing area in the software space for AM. The greatest challenge is high-quality input data that can be traceable and does not rely on AI-trained models," Noah Mostow, Business Development Manager at Phase3D explains. The company that has decided to address this in its core business, provides unit-based measurements of the entire build process to identify anomalies and predict build failures in real-time.
- Formware that provides a CAM package, print job preparation of 3D print files. The company also provides a lot of highly automated algorithms and an SDK.
- And RWTH Aachen University - Digital Additive Production (DAP) **Chair provides** a wide range of digital solutions, including design automation algorithms, data preparation tools, and cybersecurity solutions for secure data sharing within distributed supply chains. Their data preparation tools are key in streamlining the transition from design to efficient production. In terms of cybersecurity, the Chair has developed software that streams manufacturing information, enabling design owners to utilize the production capabilities of a service provider without having to share their 3D designs. This streaming approach fosters a more connected production network and lowers the barriers to entry for additive manufacturing.

Moritz Kolter, Chief Engineer of the Digital Additive Production unit

Interestingly, since achieving cost-efficient high-volume production and industrialization in AM requires a comprehensive digital end-to-end workflow that covers each process step from ideation to delivery, **Moritz Kolter,** Chief Engineer of the Digital Additive Production unit, believes that all software solutions that can support the different tasks of the actual manufacturing process from design to QA are of paramount importance.

For Kolter, and in general, *"the barriers we face are more commercial than technological. First, certification remains a significant yet time-consuming and expensive process. By integrating quality assurance with printer OEM software, we could significantly enhance our digital capabilities, allowing for certification through in-situ monitoring. This approach could reduce both costs and the need for extensive external quality assurance testing.*

Second, cybersecurity and intellectual property protection are still significant issues. These concerns limit many advantages associated with additive manufacturing (AM), such as innovative supply chain strategies. […]"

When focusing exclusively on software solutions that can support different tasks of the actual manufacturing process from design to QA, Dr **Ole von Seelen**, Chief Commercial Officer at **trinckle 3D GmbH**, said:

" The most crucial software category to achieve production in additive manufacturing (AM) is the ***design automation and optimization category.*** *This is because the design phase directly impacts the entire production process. Effective design automation allows for faster iterations, optimized structures, and cost-efficient production, which are critical for scaling up AM. Without robust design software, the other stages, such as simulation, processing, and quality control, would struggle to deliver the efficiencies needed for mass production. […]"*

"In the design automation category, one of the primary challenges is balancing ease of use with the complexity of design requirements. Many AM users are not necessarily CAD experts, yet they need to create intricate designs that meet specific industrial standards. Another challenge is the need for iterative design processes, where multiple adjustments are often necessary before achieving the final product. This can be time-consuming and demands a high level of precision. Our software aims to address these challenges by automating repetitive tasks, reducing the design time significantly, and allowing users to achieve high-quality results with less manual intervention," he adds.

For **Noah Mostow**, *"without in-situ inspection, AM is producing parts without knowing the quality until time-consuming, expensive post-inspection is completed. This is not a scalable process nor does it meet true production standards, at least for critical or near-critical use applications"* – hence the importance of real-time QA or in-situ inspection software to reach production.

According to Mostow, three main challenges hamper in-situ inspection: the fact that the data is too large to process or be used; the fact that outputs were not based on true, objective units and were subjective, and the fact that providers did not create a production-ready product. For this reason, Phase3D provides digestible data to facilitate the decision-making process. *"Like any other form of manufacturing, data is the backbone to an efficient production process,"* Mostow said.

In **Elco Jongejans**'s view, achieving production with AM software should involve a level of automation. Whether one deals with one-off items, small quantities or applications that are more evolved to production lines like jewelry production, the dental industry or the hearing aid industry, *"the advantage of AM is that you can print 1000 unique items with the same effort as 1000 similar ones. So, there will always be some kind of manual/software labor involved. The generation of the 3D model (scanning teeth, CAD design of a jewelry piece or wax filling an ear canal) will take up most of the work. And this is hard to automate fully. The CAM part, converting the models to a 3D print file is already optimized and highly automated,"* Jongejans explains.

Elco Jongejans
Director at Formware B.V.

The importance of cloud-based platforms

Industrial Metaverse, smart services, and digitalization are key trends in the manufacturing industry into which AM seamlessly integrates. A key tool in efficiently implementing these concepts is the cloud. It is gaining in popularity due to its ability to process, store, and enable data sharing in real-time, irrespective of the location.

Dr **Ole von Seelen**, Chief Commercial Officer at trinckle 3D GmbH

According to **Dr Ole von Seelen**, *"Cloud-based platforms should be relied upon when scalability, collaboration, and flexibility are key requirements. For companies looking to scale their AM operations across multiple locations, cloud-based platforms offer centralized control, easy access to data, and the ability to collaborate in real-time across different teams. Additionally, cloud solutions are ideal when integrating third-party applications, such as quality control or workflow management tools, as they provide a more seamless integration process. Cloud-based platforms also allow for quick updates and scaling without the need for significant infrastructure investment, making them a practical choice for expanding AM workflows."*

"From what we have seen in the market, some companies have built their own software or at least a custom version of third-party software. I believe this is caused by certain functionalities missing due to the unique applications specific companies have, but also because the AM software landscape is still evolving. However, relying on custom solutions can limit scalability in operations. With the growing capabilities and flexibility of cloud-based software, there are compelling reasons to adopt these solutions," Moritz Kolter adds.

A few examples of solutions popped up in the market in recent years. They include for instance, the CO-AM platform from Materialise, or the **ProCloud3D platform**, developed by the German-Chinese consortium led by the Chair of Digital Additive Production (DAP) at RWTH Aachen University.

In situ powder supply and LPBF-similar cooling rates make the EHLA process interesting for investigation in the field of Rapid Alloy Development (RAD). © RWTH DAP / Irrmischer

The architecture of the ProCloud3D platform, for this purpose, is fundamentally based on the Open Vector Format (OVF), developed by the DAP Chair and the Fraunhofer Institute for Laser Technology ILT. Building on the OVF, a streaming protocol was developed to ensure efficient real-time transport of PBF-LB production data and relevant metadata for various PBF machines. The protocol includes both secure data transport and data encryption. With a high-performance nester developed by DAP, manufacturing jobs consisting of multiple parts can be automatically generated. In a cloud-based user interface, the functionalities are fully integrated and visualized. The next step consists in preparing the cloud-based platform for mass-market adoption in decentralized additive manufacturing.

The walls between AM and traditional manufacturing – from a software standpoint

Several companies are reluctant to fully integrate AM into their operations due to factors such as a lack of expertise, concerns over higher equipment costs, perceived complexity, material consumption, and overall resistance to change—these being the most common challenges. For this reason, certain companies prefer to explore a combination of AM and traditional manufacturing in their production to increase efficiency and reduce costs.

Kolter is one of the experts who believe in the complementarity of these manufacturing processes. Given the AM software landscape, he clarifies: *"AM requires a different mindset regarding product design, supply chain setups, and the establishment of effective workflows. To successfully integrate AM, manufacturers should first determine the strategy for its use and then consider the necessary adjustments to the existing manufacturing process chain. Attempting to implement AM in isolation can lead to missed synergies and create friction within an organization. For instance, if a company engages in high-volume production using AM for only a few different components, there might not be a need for an AM-specific MES."*

In this vein, we can only agree with **von Seelen** who believes 5 key steps should be considered to reach production using AM software: education and training; pilot projects, design-automation-adoption, integration with existing workflows and scaling up gradually.

For Dr Ole von Seelen, pilot projects allows one to start with low-risk applications which can demonstrate quick ROI; while investment in design automation software not only streamlines the design process but it also helps in *"reducing the complexity of transitioning from traditional to additive manufacturing."*

As you can see, the approach to integrating a software solution includes a few steps similar to the implementation of a 360° AM strategy. No matter how complex this transition from traditional manufacturing to AM is, one should be aware of the specific jobs that only certain AM software solutions can do and the specific ones that can be done for conventional manufacturing operations.

In the end, software supports every stage of the AM production and serial production cannot be achieved without it. As the demand for more complex and precisely engineered products has grown, so has the sophistication of software solutions. That's why continued investment and maturation of 3D printing software can only increase AM's competitiveness with established, conventional supply chains.

Directly from the facility: Another logo variant of the ProCloud3D project manufactured via stream using the developed cloud-based platform. © RWTH DAP.

ECKART TLS broadens its metal powder portfolio for AM

The company **ECKART TLS**, based in Bitterfeld, Germany, is a key producer of metal powders for additive manufacturing (AM). The company specializes in Electrode Induction Melting Inert Gas Atomization (EIGA) and crucible-based gas atomization techniques to produce high-quality metal powders.

Originally founded in 1994 as **TLS-Technik**, the company specialized in Titanium and Zirconium alloy production using the EIGA technique. Over the years, **TLS** optimized its atomization processes, establishing itself as a leader in high-performance alloy powders. In 2021, **ECKART**, a firm with over a century of experience in metal powder production, acquired **TLS-Technik**, resulting in the formation of **ECKART TLS**. **ECKART** itself is a world-leading producer of metallic pigments with over 100 years of experience in producing metal powders and an atomization capacity of over 20 000 kg of aluminum per year.

Current Portfolio

ECKART TLS can produce several hundred tons of AM powders per year, specializing mainly in Titanium alloys such as Ti6Al4V and CP-Ti, Copper alloys such as pure Copper or CuCrZr, and Aluminum alloys such as AlSi10Mg or the patented high-strength A20X alloy.

Innovation / Product Development

ECKART TLS is focused on advancing its product portfolio to meet the evolving needs of the AM industry, as well as other specialized industries. In 2023, the company introduced new high-strength Titanium alloys into its standard portfolio, namely: Ti6242, Ti6246, and Ti5553. These alloys offer enhanced mechanical properties under certain conditions and have the potential to partially replace Ti6Al4V in specific AM applications. Additional examples include materials like Zirconium alloy Zr705 and the high-strength bronze alloy CuAl10Fe5Ni5, with the latter being particularly suited for Directed Energy Deposition (DED) applications.

The flexibility of the EIGA process, which allows for the atomization of round bars of any alloy composition with melting points up to 2500 °C, enables **ECKART TLS** to produce spherical powders from a wide range of materials. This versatility makes it possible to rapidly adapt to new material requirements as industry needs develop.

In addition to bringing new materials into the market, a recent advancement by **ECKART TLS** is the development of **coarser Ti6Al4V powders** for Laser Powder Bed Fusion (LPBF), also known as Selective Laser Melting (SLM). All gas and plasma atomization techniques produce a broad particle size distribution, typically ranging from a few microns to several hundred microns. Given that LPBF is the largest market for high-quality spherical Titanium powders, and that 15-53 µm or 20-63 µm are the commonly used particle size fractions, a significant fraction of the as-atomized powder is not currently used for LPBF.

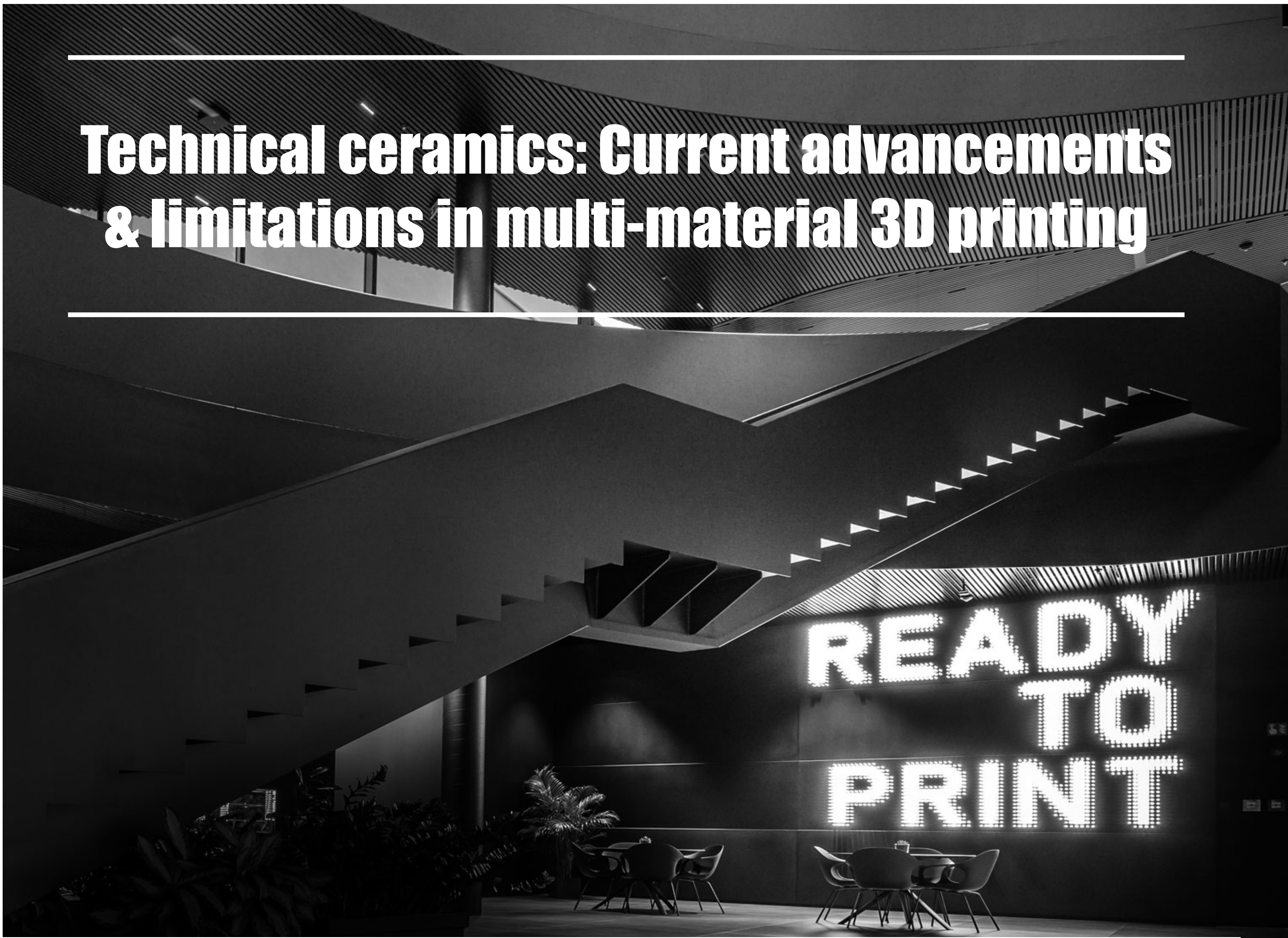
"Like all established titanium powder producers, we face the challenge of unavoidably producing high-quality by-products, especially coarser Ti6Al4V powders with particles larger than 50 µm, for which there is limited global demand. By utilizing coarser fractions, such as 50-80 µm, for certain LPBF applications, not only can excellent part properties be achieved, but we can also improve the sustainability of metal additive manufacturing. Equally important, using these powders allows us to develop entirely new applications for the AM of Ti6Al4V, as these coarse powders are available at significantly lower costs", says Dr. Moritz Roscher, Global Head of Additive Manufacturing & Metal Powders at ECKART.

Future Outlook

As demand for AM powders continues to grow, **ECKART TLS** is planning an expansion of production capacity for its materials. With the projected increase in demand from key customers in aerospace and medical sectors, **ECKART TLS** is preparing to further scale its output with additional EIGA machines, thereby positioning itself as a key player in the global AM market for the long term.

SCAN FOR MORE INFO

Technical ceramics: Current advancements & limitations in multi-material 3D printing



The smaller, the more complex and the more refined certain functional ceramic devices are, the more difficult they are to manufacture using traditional processing. In the wide range of manufacturing techniques that exist, multi-material 3D printing happens to be one technique that provides the ability to incorporate multiple material constituents without an intricate process or expensive tools. The question is, with the wide manufacturing landscape of ceramic 3D printing, what AM processes are ready to deliver commercial-ready applications?

One appealing argument of multi-material 3D printing is the ability to use multiple materials at the same time to fabricate an object. As explained in this dossier, this means that from product development, prototyping, and internal tooling, to low-volume production parts, this manufacturing method can bring a significant return on investment – if well performed. While both industry and academics still fail to find common ground in the way multi-material 3D printing should be defined, let's recall that to avoid any confusion, at 3D ADEPT, we consider multi-material 3D printing as a "specific procedure/technique" that defines the type of AM process one leverages; a procedure that can be applied to several types of AM processes.

With a key focus on **technical ceramics**, the present dossier aims to help AM users understand:

- The ceramic 3D printing processes that could be leveraged to deliver viable multi-material 3D printing applications
- The types of technical ceramics that could be combined in multi-material 3D printing
- The key applications that one can see thrive in the market
- The limitations that AM solutions providers should address to foster the adoption of multi-material 3D printing

What ceramic 3D printing process for multi-material 3D printing?

A research on multi-material 3D printing of functional ceramic devices reveals that most functional ceramic devices, such as multilayer ceramic capacitors, multilayer ceramic substrates, filters, chip antennas, power dividers, and duplexers, can be manufactured by a high-temperature cofired ceramic (HTCC) process or low-temperature cofired ceramic (LTCC) process. The problem is that not only do these processes require multiple steps – up to 9 different manufacturing stages from material preparation for ceramic tapes and functional pastes to post-processing, but they are not ideal for rapid prototyping and low-cost manufacturing of miniaturized, thin, refined, and highly integrated functional ceramic devices.

Additive Manufacturing (AM) can address these challenges through multi-material 3D printing. While taking into account that AM technologies are made up of direct and indirect solutions, Dr.-Ing. **Uwe Scheithauer**, Group Manager, Additive and Hybrid Manufacturing at Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, explains:

"With indirect technologies, the starting material is deposited over the entire installation space and then selectively consolidated (e.g. Binder Jetting, Powder Bed Fusion, Vat Photopolymerization), whereas with direct AM technologies (e.g. Material Jetting, Material Extrusion), the material is deposited and consolidated only where it is needed.

For the realization of multi-material components using AM, direct technologies have the advantage that there is space for the deposition of a second material directly next to the deposited material without having to remove unconsolidated first material first."

The examples of AM processes mentioned by **Scheithauer** are in the list of the dozen AM processes identified in a recent dossier on the current manufacturing landscape of ceramic 3D printing.

This implies that *"multi-material printing can be carried out with all known 3D printing processes for technical ceramics"*, **Stefan Waldner** from D3-AM GmbH notes.

"However, unlike metals and plastics, ceramics currently need to be processed using indirect methods, meaning that the green parts still need to be thermally processed/sintered after printing.

In MEX [material extrusion], different extruder heads can be used for different materials, while in DLP, there are approaches that involve working with different material vats, where the part is dipped from one vat to another and exposed, allowing for the production of highly precise parts. In SLA, there are approaches where the base material is cured by laser, and various materials are combined using dispenser systems. Even in the binder jetting area, there are R&D-level approaches to selectively apply different powders and bond them with a binder applied by inkjet printheads.

*These are all ways to create multi-material green parts, though they often involve compromises in terms of **material waste, cleanability, productivity**, etc.*

*The **most suitable process for multi-material 3D printing may be material jetting** (or a hybrid version of it), where droplets of the object material are applied voxel by voxel via inkjet printheads, theoretically allowing for an unlimited number of different materials to be applied. However, it is important to emphasize—and this is likely the main reason why multi-material applications are still rare today—that while printing two different materials with different properties is technically feasible with manageable effort, co-sintering (i.e., sintering two or more different materials together) is a significant challenge in materials science. Currently, it is primarily mastered by various R&D institutes,"* he adds.

If we only look at material jetting, one can understand that multi-material 3D printing of certain components can easily be utilized by following the same approach of conventional 2D ink jetting – the main difference being the fact that functional inks are deposited with multiple jetting heads in multi-material 3D printing.

With FDM 3D printing, the main parameters to consider include the filament (mainly its thermal, mechanical, and rheological properties and diameter), the process (temperature and speed), and specifications related to the 3D printer (the number of extrusion heads, the nozzle diameter, and the gear force). However, some of the limitations encountered with FDM are seen during the fabrication of complex structures. They include low resolution and poor surface finish, weak bonding between adjacent sections, and slow build speed.

Interestingly, in the list of VAT photopolymerization (VP) processes that exist, SLA – one of the oldest processes – is one of the processes that has been enhanced to enable multi-material 3D printing.

This year, 3DCeram for instance, the developer of ceramic 3D printing systems based on SLA, introduced **Hybrid Printing** on the M.A.T. (Manufacturing Additive Technology) through 3DCeram Sinto Tiwari in Berlin. The system includes a dual pellet extrusion head and addresses demands from universities and research centers. It enables multi-material 3D printing by allowing the simultaneous use of different materials in the printing process.

D3-AM GmbH's AM system – Credit: D3-AM GmbH

The M.A.T. can achieve multi-material 3D printing with Fused Filament Fabrication (FFF). *"The materials involved are silicon nitride (Si3N4) blended with electrically conductive molybdenum disilicide (MoSi2) for the conductive components, and a similar material with lower MoSi2 content for electrical insulation. This process allows the production of complex heating elements with a combination of electrically conductive and insulating ceramic materials, achieving high-temperature performance and corrosion resistance,"* the **team** explains.

While 3DCeram's Hybrid Printing system has only been mentioned as an example, it should be noted that each AM process comes with a series of specifications (developed by the manufacturer) that can enable multi-material 3D printing.

What is pivotal to achieving multi-material 3D printing is the different materials that can be combined during the manufacturing process.

Technical ceramics that can enable multi-material 3D printing

The term "technical ceramics" is often used interchangeably with the terms "engineered ceramics, advanced ceramics, precision ceramics, and high-performance ceramics". This prevents any confusion with "traditional ceramics" that are made from naturally occurring materials such as clays.

Despite their exceptional strength-to-weight ratio and resistance to high temperatures, chemicals, and corrosion, technical ceramics have remained largely underutilized due to the difficulties in manufacturing them with conventional methods.

Ceramics can be classified in various ways, one common method being the division into three categories: **oxides, non-oxides,** and **ceramic composites**.

Oxide ceramics encompass a variety of ceramic families, including alumina (aluminum oxide or Al2O3), zirconia (zirconium oxide or ZrO2), silica (silicon oxide or SiO2), yttria (yttrium oxide, Y2O3), and other metal oxide-based materials like silicates and magnesia. These materials are non-metallic, inorganic compounds that contain oxygen in their chemical composition.

Oxide ceramics can also be combined to form mixed dispersions, such as zirconia toughened alumina (ZTA) or alumina toughened zirconia (ATZ).

Non-oxide ceramics consist of families like aluminum nitrides (AlN), silicon nitrides (Si3N4), and various carbides such as silicon carbide (SiC). These are non-metallic, inorganic compounds that incorporate either nitrogen or carbon into their structures.

Ceramic composites, on the other hand, include materials where the matrix is ceramic (ceramic-matrix composites or CMC), metallic (metal-matrix composites or MMC), or polymeric (polymer-matrix composites or PMC).

According to **Waldner**, among the technical ceramics that are gaining momentum in the market right now, one counts: *"very pure oxide ceramics, mostly for highly complex chemical/thermal processes; as well as nitrides and carbides, especially silicon carbide, due to their excellent properties, with applications in aerospace, defense, and the semiconductor industry."*

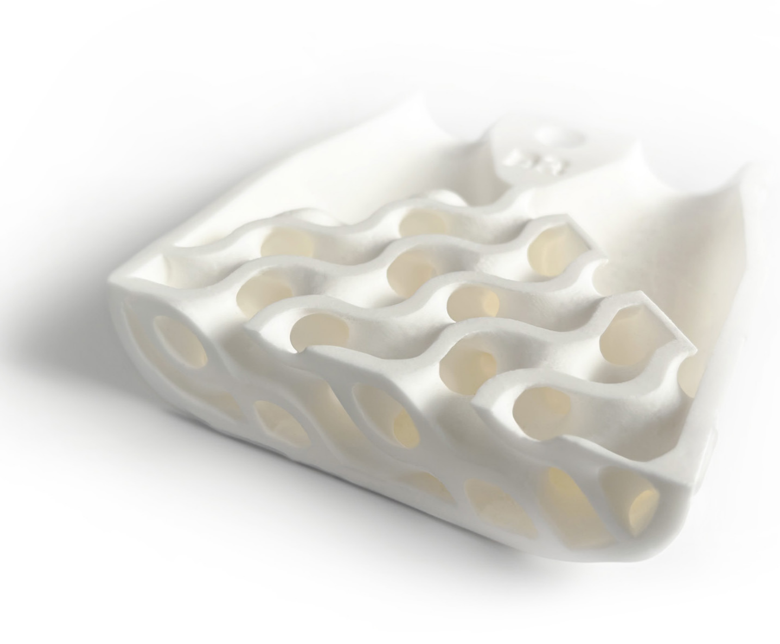
Speaking of materials that can be combined in multi-material 3D printing, he adds: *"combined materials can be used across various combinations, depending on the required properties of the final application such as temperature resistance, mechanical properties, insulation capability, conductivity, but also aesthetics, as seen in dental market where color gradients could be printed on dental crowns."*

The **3DCeram team** shares a similar view on technical ceramics that are gaining momentum in the market:

"Among technical ceramics, oxides and nitrides are gaining momentum in the market. For oxides, alumina is the most common, but zirconia is increasingly in demand, particularly for aerospace applications. The choice of ceramic materials often depends on the specific application."

For Dr. **Scheithauer** on the other hand, *"aluminum oxide will continue to be the workhorse – it has very good properties and relatively low costs. Zirconium oxide is particularly interesting for the medical sector, as are mixtures of Al2O3 and ZrO2. HAp and TCP are also highly interesting for the medical sector. AlN, B4C, SiC and Si3N4 have extremely interesting combinations of properties but require expensive, specialized infrastructure and know-how for thermal processing.*

For multi-material applications, the property combinations of electrically conductive and insulating (e.g. based on Si3N4 or LTCC), dense and porous (Al2O3, ZrO2) and multi-colored (ZrO2) are particularly relevant. We have already realized all these combinations with CerAM MMJ (a special MJT technology), in some cases also with CerAM FFF (MEX)."



credit: D3-AM GmbH

Applications enabled by multi-material 3D printing

We've said it several times: applications are what gives a specific technology its credibility. Whether we explore it with polymers, metals or technical ceramics, multi-material 3D printing remains appealing for its ability to use multiple materials at the same time to fabricate a part with different properties or functionalities.

Many OEMs and AM users are still exploring the range of applications that could be achieved using a multi-material (MM) 3D printing technique. With VAT photopolymerization-based 3D printing technologies for instance, MM 3D printing has great potential in sensors, actuators, robots, microfluidic devices, and scaffolds. Indeed, VAT photopolymerization processes can manufacture parts with high resolution, high accuracy, high throughput, and a good surface finish, which is not always the case for MJ, DIW, and FDM.

This is something **the 3DCeram team** confirms as they explain – speaking of their hybrid process:

"For example, the hybrid process is particularly useful in the electronics and sensors industries. Its flexibility allows for increased electrification density in electronic devices. Additionally, the hybrid process is a suitable method for rapid prototyping of ceramic PCBs, LTCC (Low-Temperature Cofired Ceramics), and HTCC (High-Temperature Cofired Ceramics). This approach can significantly reduce both the time and cost of developing innovative applications. For instance, the hybrid process has been used to create electrical paths on alumina, as shown in benchmarking results.

"With the M.A.T. printer, we have worked on several project involving multi-material 3D Printing, like combining different kinds of zirconia – black and white ones, which is used in the luxury industry.

A conformal embedded coil in an alumina hybrid process is particularly innovative for electromagnetism applications like an embedded coil in an alumina part. The picture below shows a benchmark adapted to this application. The small metallic solenoid is embedded into the alumina part by additive manufacturing. The current resolution is close to Ø0.5mm but it can be improved by a more precise dispensing system.

The hybrid process opens new applications like the bitter coil. The technology is well adapted to the future challenge of transport electrification (magnet wheel motor). Indeed, the bitter coil is complex even impossible to manufacture by conventional manufacturing process. The 3D printing process can manufacture some devices with perfect customization to optimize performance," the team adds.

In the long run, the expert from **D3-AM GmbH** also sees the greatest applications of multi-material 3D printing in the combination of insulating, conductive, and functional materials, enabling complex heaters, drives/actuators, sensors, and other applications that are, in some cases, not yet imaginable today. However, in the medium term, the medical field can also benefit from this technique – the dental industry especially, *"where color gradients can be digitally applied,"* he adds.

Limitations and future outlooks

Despite its obvious advantages, multi-material 3D printing with technical ceramics is slowing down due to several limitations. These limitations may be related to the process used or the materials themselves.

In FDM 3D printing, for instance, thermoplastic polymer filaments with high solid content are required to manufacture metal and ceramic parts given the low shrinkage after sintering. However, the dramatic increase in stiffness and brittleness adversely affects the production and printing process making it difficult to achieve repeatable 3D printed parts.

While he sees inkjet 3D printing as the most suitable approach for ceramic multi-material printing – given the technology's ability to build a part with different materials drop by drop, **Waldner** also recognizes the technology's limitations: The *"need to have access to inkjet printheads and ink supply systems capable of reliably handling and depositing abrasive ceramic materials drop by drop."*

"D3 currently demonstrates this reliability in single-material ceramic printing, but as of today, there are still few reliable systems available for multi-material

Credit: D3-AM GmbH

material jetting. Regardless of the type of technology used to manufacture multi-material components, it requires the right mindset from engineers to fully exploit these possibilities and to conceive and develop corresponding applications. I am convinced that machine learning will significantly enhance this capability in the future and help shape new, currently unimaginable applications," he adds.

For the expert from Fraunhofer IKTS, the main challenge of multi-material 3D printing with technical ceramics is *"the sintering route and the necessary co-sintering of the different materials. (Complex material development and adaptation (shrinkage) as well as limited material combinations that can be combined in terms of shrinkage technology)." "[Not to mention that] the identification of suitable material pairings and the adaptation of shrinkage behavior through the pre-treatment of powders is extremely complex"*, he adds.

The team of 3DCeram on the other hand explains that *"co-sintering presents a significant challenge. During the post-processing phase, materials with different thermal expansion rates (CTE) or sintering conditions may lead to internal stresses, and cracking of the 3D printed part. Achieving a cohesive final structure requires that the materials have compatible sintering behaviors. This makes the process highly complex and often limits the range of materials that can be used together.*

Another limitation is the risk of material contamination during the printing process. When different materials are deposited in successive layers or sections of the part, cross-contamination can occur, affecting the integrity and properties of each material. To address this, 3DCeram has introduced a nozzle that blows air to clean the groove before depositing the next material. This prevents cross-contamination between materials and helps maintain the purity of each layer."

So, what future do we foresee for multi-material 3D printing of technical ceramics?

Despite the aforementioned limitations that still need to be addressed, experts remain somewhat optimistic about the future of multi-material 3D printing with technical ceramics.

Dr. **Uwe Scheithauer** foresees a future where the proportion of ceramic parts will increase. This increase will come along with the rise of shaping processes and the reduction of post-processing costs; new material properties as well as the reduction in the total number of process steps required to produce complex, multifunctional components thanks to MM(J) printers.

That being said, we can't help but agree with Waldner when he said that multi-material 3D printing will remain a niche compared to the overall AM ceramics market. *"In the long term, this could change substantially, with improved printing systems, additional material systems, and AI-supported engineering significantly accelerating growth,"* he concludes.

Credit: D3-AM GmbH

Editor's notes

To discuss this topic, we invited three key contributors to share key insights into this dossier.

Dr. **Uwe Scheithauer**, Group Manager, Additive and Hybrid Manufacturing at Fraunhofer-Institut für Keramische Technologien und Systeme IKTS. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. As a research and technology service provider, the Fraunhofer IKTS develops advanced high-performance ceramic materials, industrial manufacturing processes as well as prototype components and systems in complete production lines up to the pilot-plant scale. In addition, the research portfolio also includes materials diagnostics and testing. Dr. Scheithauer has been a speaker at various ceramic-dedicated conferences and has been involved in several publications – one of the most recent ones being "Additive manufacturing of ceramic single and multi-material components–A groundbreaking innovation for space applications too?". The expert believes that ceramic materials will be used in applications where there is no other alternative such as aerospace and energy. He makes use of CerAM MMJ (MJT) – $Al2O3$, $ZrO2$, stainless steel, $Si3N4$; CerAM FFF (MEX) - $Si3N4$, as well as CerAM VPP (Lithoz LCM) – $Al2O3$ (dense/porous) as part of its multi-material 3D printing projects.

Stefan Waldner from D3-AM GmbH. D3-AM GmbH is a spin-off of the Durst Group, a world-leading manufacturer of digital printing and production technologies. The company has developed LABII, a hardware system for technical ceramics based on Micro-Particle Jetting process (MPJ). This development has allowed D3 to address the limitations of conventional inkjet systems, enabling the direct printing of water-based, highly concentrated suspensions with almost any particle size and distribution. D3 already uses a second inkjet-printed material for support structures in its LABII printing system. However, in the medium term, the focus remains on single-material 3D printing of high-performance ceramics using a proprietary inkjet technology. With regards to this topic, the D3 engineering team has gained significant experience in inkjet multi-material printing for graphic applications, with up to 12 different colors per machine, due to their background in 2D printing within the parent company, Durst Group. This multi-material expertise could become also relevant for D3 at some point with its Micro Particle Jetting technology.

The team at 3DCeram. If you're a regular reader of 3D ADEPT, you may know this French manufacturer who specializes in ceramic 3D printing based on SLA technology. The company is currently helping its clients move from experimental phases to fully industrialized solutions. This approach mirrors what they have already achieved with SLA technology, where they successfully transitioned to large-scale production, notably the printing of very large parts. *"As the technology continues to evolve, we expect to see more widespread applications of technical ceramics in industries such as aerospace, electronics, and energy, driven by the need for high-performance, durable materials. The focus will likely shift from research to practical, scalable solutions, making multi-material and high-precision ceramic 3D printing a standard in advanced manufacturing,"* the company said.

Last but not least, the current focus of their developments is geared towards the industrialization of the process. Rather than concentrating solely on multi-material capabilities, we are directing our efforts towards multi-plateau systems, which allow for increased productivity and efficiency in large-scale production. The use of large build platforms, combined with advancements in AI, is driving significant progress in optimizing workflows and expanding the industrial application of ceramic 3D printing. This shift towards multi-plateau setups will be key to meeting the growing demand for higher volume and larger parts in various industries.

New developments in 3D printing polymers: Encapsulated carbon black particles for Selective Laser Sintering

Based on the principle of building up a structure layer-by-layer, selective laser sintering (SLS) has been an ideal manufacturing technology to benefit from the many qualities of polyamide 12 (PA12). In fact, PA12 powders specially designed for SLS have been on the market since 1996. Created by Evonik, PA12 3D printing powders have been setting new standards in quality and useful features – helping expand the applications and possibilities of industrial 3D printing at scale.

The latest feature in PA12 for powder bed fusion technology is **INFINAM® PA 6013 P** and **INFINAM® PA 6014 P**. Developed by Evonik, the SLS powders possess a relatively substantial amount of carbon black embedded inside the core-shell particle. The production of these powders is an engineering feat.

Evonik's INFINAM® polymer powders for 3D printing.

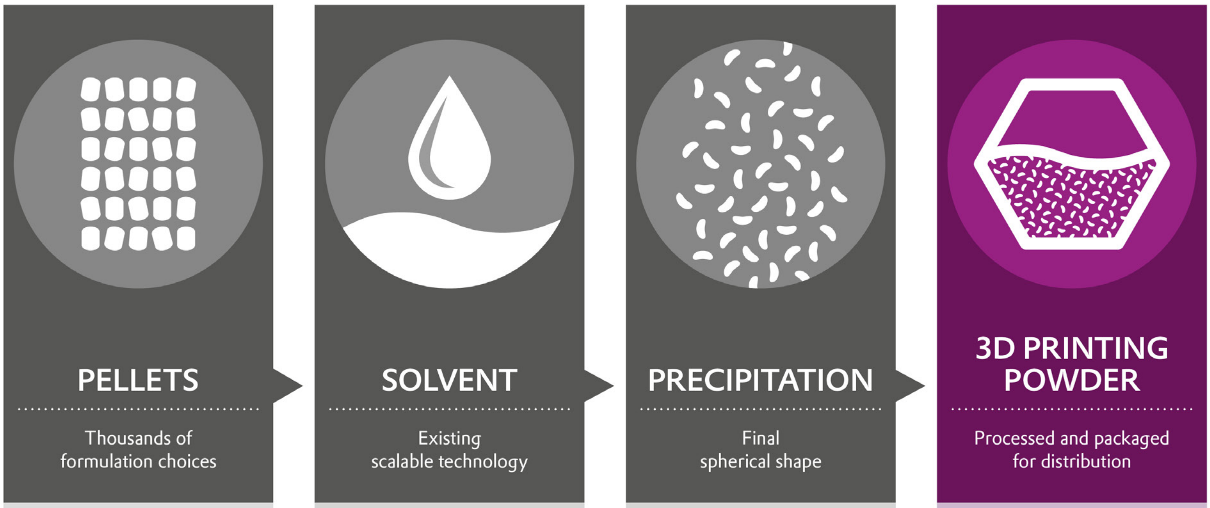
A specially developed production process

In order to create these novel powders, Evonik uses a special precipitation process they engineered. This enables a substantial amount of carbon black to be added into the PA12 polymer core-shell particle. Contrary to other existing carbon black powders, in which carbon black is dry blended or compounded, the special precipitation process allows for encapsulation, and (subsequently) for the PA12 particle to contain a comparatively higher amount of carbon black while maintaining good processability in SLS.

Precipitation is generally considered the ideal production process for powders used in powder bed fusion techniques, like SLS. In addition to enabling encapsulation, the precipitation of PA12 yields particles with the most preferable shape, and high flowablility, which are ideal for even sintering.

As the resulting new product contains both a PA12 shell and carbon black core, the powder possesses an interesting combination of characteristics.

Research and further development of INFINAM® in Evonik's application technology center.



INFINAM® powders are made through a special precipitation process, engineered by Evonik.

PA 12 – the gold standard of polymer powders for SLS

Pioneered by Evonik in the 1990s, polyamide 12, or PA12, has been continuously developed for the last 30 years to remain the ideal polymer-based SLS powder. A long-chain semicrystalline thermoplastic material, as PA12 powders are an ideal material for 3D printing elements used in prototypes, complex engineering projects, or low-volume customized applications. Taking it a step further, the material is also ideal for 3D printing made-to-measure medical devices for permanent or temporary body contact.

Key characteristics that make PA12 the ideal SLS polymer powder include:

- High mechanical resistance
- High chemical resistance, especially to oil, grease and solvents
- Lower water intake
- Great impact strength
- Excellent surface resolution
- Easy processability

As such, the polymer performs well with applications in the aerospace, automotive and medical industries.

Embedded with a significant amount of carbon black at the particle core, precipitated PA12 powders have an additional set of benefits.

With traditional PA12 powders being a neutral white in color, the possibilities for further tinting are naturally infinite. This is typically done with a multi-step process of SLS printing, dyeing, and chemical smoothening to achieve the desired result.

When the desired color is black or a darker tone, 3D printing with carbon black encapsulated powders naturally eliminates the step of dyeing to achieve the final product. There are other benefits, however, that are due to the high ratio of carbon black at each tiny particle's core:

- True pigmentation uniformity, for small and very large parts
- Minimized visibility of surface scratches, abrasion, and wear
- Elevated resistance to ultraviolet rays
- More isotropic performance (optimized elongation in z-direction)

These additional properties serve especially well in products that are destined for use outdoors – especially those needing to withstand an elevated amount of exposure to heat and light, such as certain applications in the automotive and aerospace industries.

A look to future developments in SLS polymers

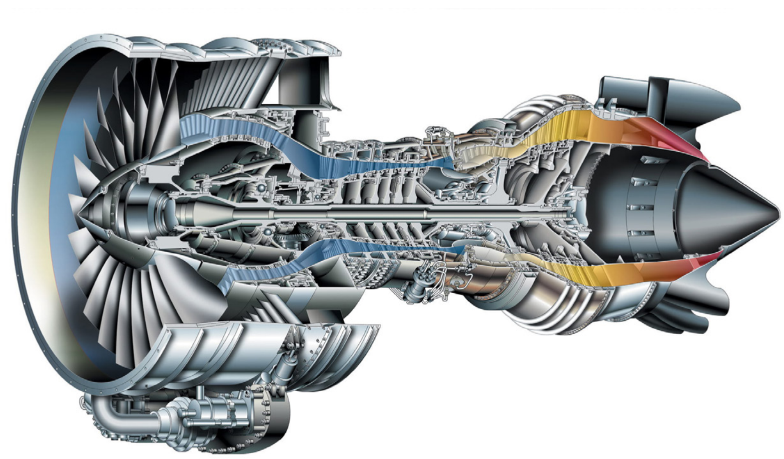
The carbon black encapsulated INFINAM® PA 6013 P and INFINAM® PA 6014 P powders are just the latest features available for 3D printing polymers. In fact, with existing properties ranging from excellent surface finishing to food contact compliance and high processability, INFINAM® is found in virtually all PA12-based 3D printing processes. Regarding sustainability, all INFINAM® products have a reduced carbon-emission footprint, as indicated by the RFP labeling in the product name.

Looking to the future, new developments in PA12 for SLS and other additive manufacturing technologies are currently in the works.

From 19-22 November in Frankfurt, Germany, Evonik's experts will be on site at **Formnext 2024**, the additive manufacturing world's hub for networking and information sharing among production professionals.

At the event, Evonik's top experts will present the latest details on the new carbon black encapsulated INFINAM® PA 6013 P and INFINAM® PA 6014 P powders, as well as showcase additional innovations and solutions for industrial 3D printing at scale.

Pratt & Whitney on the evolutionary journey that leads to the development of military engines with Additive Manufacturing



Many military aircraft, especially fighters, require engines with significant differences from commercial aircraft. They fly different flight profiles and perform various jobs. These differences continuously lead engine manufacturers to reassess priority and resources at the manufacturing level. Interestingly, with the wide range of technologies that can be leveraged to deliver the desired performance, Additive Manufacturing remains a technology of choice as it serves different purposes. A conversation with ***Pratt & Whitney's Jesse Boyer*** *sheds light on these purposes.*

Acknowledged for the design, manufacture and service of aircraft engines and auxiliary power units, Pratt & Whitney (P&W), a subsidiary of **RTX Corporation** (formerly Raytheon Technologies), also manufactures gas turbine engines for industrial use, and marine propulsion.

Like most advocates of Additive Manufacturing, Pratt & Whitney's first years as a user were dedicated to understanding and answering the 4Ws of the technology: what, why, where, and who. We were in the 1980s.

This meant *"what is Additive Manufacturing (at the time rapid prototyping), where do we think the technology could be leveraged and who are the key stakeholders,"* **Jesse Boyer**, Senior Technical Fellow for Additive Manufacturing at Pratt & Whitney explains. While answering the 4Ws is still pivotal along the adoption curve, the beauty of the journey lies in the way each user has made the most of the technology's maturation and the applications they achieve.

Pratt & Whitney's AM strategy: First steps and progression

35 years later after their first investments in SLA 3D printing, P&W's evolutionary processes reveal that if engine manufacturers haven't received the same headlines as other industrials, this doesn't mean they've been standing still.

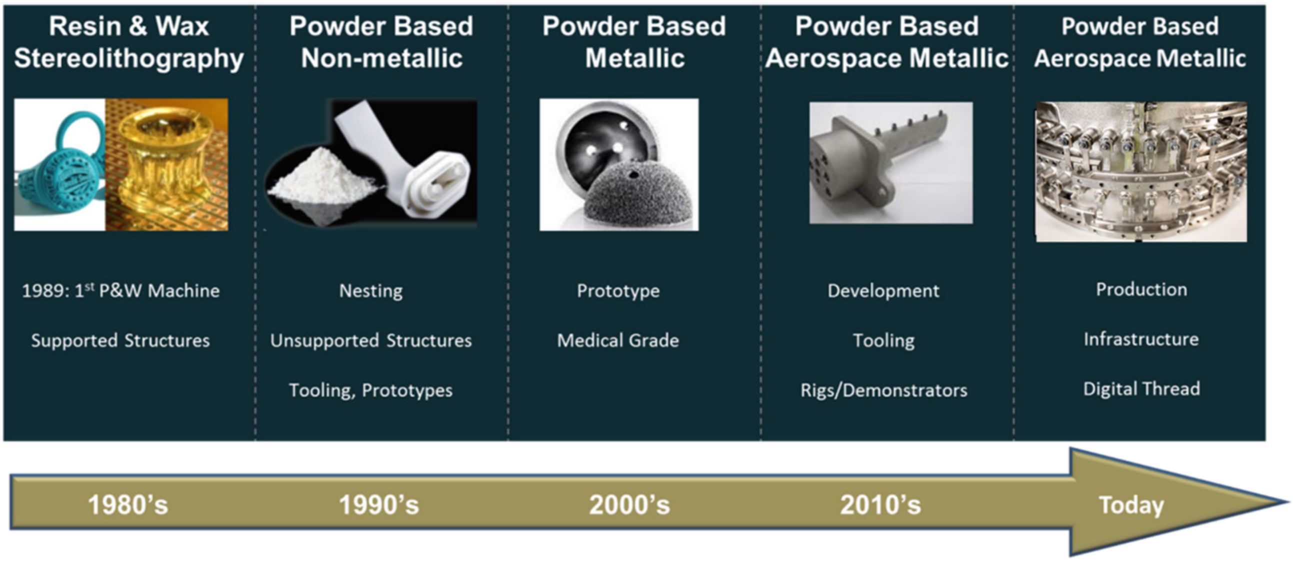
"In the mid-1990s we continued to expand our experience in plastics, polymers and wax into powder-based non-metallic components. The advances in powder bed fusion expanded the capabilities and knowledge with such things as nested parts and unsupported structures. Beyond using the technology for basic demonstration pieces, P&W was very innovative by utilizing these advanced materials throughout the shop floor for tooling, fixturing, and visual aids. In the early 2000s, we continued to monitor the progress of the metallic powders that were available and started our internal journey into metals. This journey was aided by our unique capability of manufacturing powder and the increased maturity of the available additive equipment," Boyer outlines.

What's interesting to note is, P&W's AM strategy is quite similar to most multi-national corporations exploring the technology at the time. This strategy can be summarized in two key steps: **First acquisitions of AM processes** and **establishment of dedicated AM production facilities/centers.**

VAT photopolymerization being the only AM process developed at the time for rapid prototyping, it made sense to see a first focus on *"non-metal adoption for design aids."* This is followed by the *"widespread use of non-metal AM for shop floor applications and tooling (VAT photopolymerization, Material Extrusion, Material Jetting, Binder Jetting, Powder Bed Fusion)"* and over time, *"the use of metal AM for non-production tooling, hardware and production repairs (Powder Bed Fusion, Directed Energy Deposition)".*


Jesse Boyer, Senior Technical Fellow for Additive Manufacturing at Pratt & Whitney

Today, P&W manufactures production metal 3D printed components using Powder Bed Fusion and continues to expand its Additive Manufacturing portfolio by methodically seeking other available AM processes.



As AM-dedicated facility centers are instrumental in the deployment and uptake of AM solutions, **RTX Corporation** established the **RTX Additive Manufacturing Process Capability Center (AMPCC)** in 2017 to accelerate the development and deployment of AM solutions across the entire corporation. Boyer notes: *"The team is co-located with the RTX Technology Research Center in East Hartford, CT. The mission of the AMPCC is as follows:*

- *Accelerate maturation & certification of AM materials and processes. This includes process control expertise to further industrialization of additive manufacturing at both RTX production sites and within the external supply chain;*
- *Establish a tool chain to enable design-for-additive to meet performance targets while minimizing producibility iterations;*
- *Demonstrate the effectiveness of developed techniques through prototype builds;*
- *Develop additive training curricula and deploy across RTX; and*
- *Act as an interface to external additive consortia, academia, industry and national labs.*

Over the past 7 years, AMPCC has grown to become RTX's primary development site for AM with a large inventory of commercial & experimental laser powder-bed additive equipment sourced from multiple equipment OEMs. Materials under development include titanium, nickel, aluminum and ultra-high temperature alloys.

In addition to the AMPCC, RTX has multiple facilities domestically (Florida, Iowa, Connecticut, North Carolina, Minnesota, California) and around the world (Canada, Poland, Singapore) to support various efforts utilizing Additive Manufacturing."

Legend: On the right, part made with a conventional manufacturing process; on the left, part made with an AM process. Credit: Pratt & Whitney

The use of AM in the development of military engines

We may have discovered P&W's AM activities through the manufacture of aero-engine MRO components, but the company has been quietly making strides in the development of military engines.

It's probably due to the sensitivity of the topic, but AM's impact in the military and defense fields has often been highlighted through the **production of spare parts or the deployment in remote environments.**

As one digs further, one realizes that AM has led to a myriad of applications in military contexts.

Boyer shares with 3D ADEPT a few of these applications:

"When it comes to Additive Manufacturing military or commercial, we typically look at four use cases. These use cases form the overall strategy for technology development and alignment of various initiatives, ***both at the product level and in the supply chain****. The use*

cases include:

Part Substitution/Part Adaptation

- *This use case applies when we have an existing part or component that we try to additively manufacture to address a casting, forging or conventional manufacturing concern. The advantage of this use case is a reduction in cost or lead time. Minimal design and material changes are required.*

Sustainment (Aftermarket applications/lifecycle agility)

- *This use case typically applies to a replacement or repair of a fielded part. The advantage of this use case is a reduction in lead time. In this use case, there are no design changes, but may possibly be a material change.*

Unitization (combining several parts into one component)

- *The advantages of this use case are supply chain optimization as well as an improvement in material usage, lead/assembly time, and cost. In this use case, there are some material changes and significant design changes.*

Optimized design (generative or design for purpose)

- *This use case fully leverages Additive Manufacturing design freedoms and is a clean sheet design for purpose.*

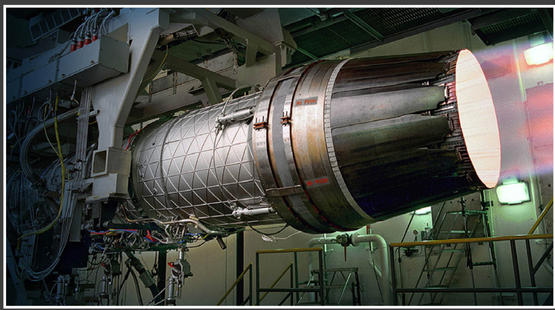
*For our military platform, we are very focused on **Sustainment** and how we can use Additive Manufacturing to ensure warfighter readiness, especially for our legacy applications. And **Unitization** and **Optimized design**, for use in our next generation propulsion systems that will potentially lower cost/weight and enable increased capabilities necessary for the advanced propulsion systems."*

Saving costs and time: Key examples of engines that benefited from AM

P&W has recently demonstrated three of these AM techniques (part adaptation, unitization and optimized design) in the development of the **TJ150 engine**.

Pratt & Whitney's GATORWORKS team redesigned the TJ150 engine to ensure quick iteration. They have been able to reduce the total part count from over 50 to just a handful. Within eight months, from concept to engine test, using their in-house AM technologies, they have been able to redesign and test the 3D-printed parts of the TJ150 engine. Needless to say, this production would have taken way too much time via traditional manufacturing processes as it would have included supply chain sourcing.

Another engine that benefitted from all the four use cases mentioned above, is the **F135 engine**, which powers the **F-35 Lighting II fighter aircraft**. P&W explained that in 2018, its team started collaborating with a supplier to 3D-print the Turbine Exhaust Case trailing edge (TE) box, which directs the flow of exhaust gases. In general, such boxes require the use of hydroforming, an advanced process where a high-pressure fluid bends metal plates into precise shapes that can withstand the forces of jet propulsion. Rather than outsourcing for casting and machining, the supplier relied on unitization, then 3D-printed and finished the unitized part in-house. To give you a rough idea of how much P&W saved, keep in mind that the



RTX's Pratt & Whitney delivers F100 engine in support of Poland's F-16 Fighting Falcon fleet. Credit: Pratt & Whitney.

potential savings on castings and moldings alone approach **$1 billion**.

When asked what technical challenges are related to the development of safety-critical parts, the Senior Technical Fellow for Additive Manufacturing at Pratt & Whitney answered **"confidence"** before adding:

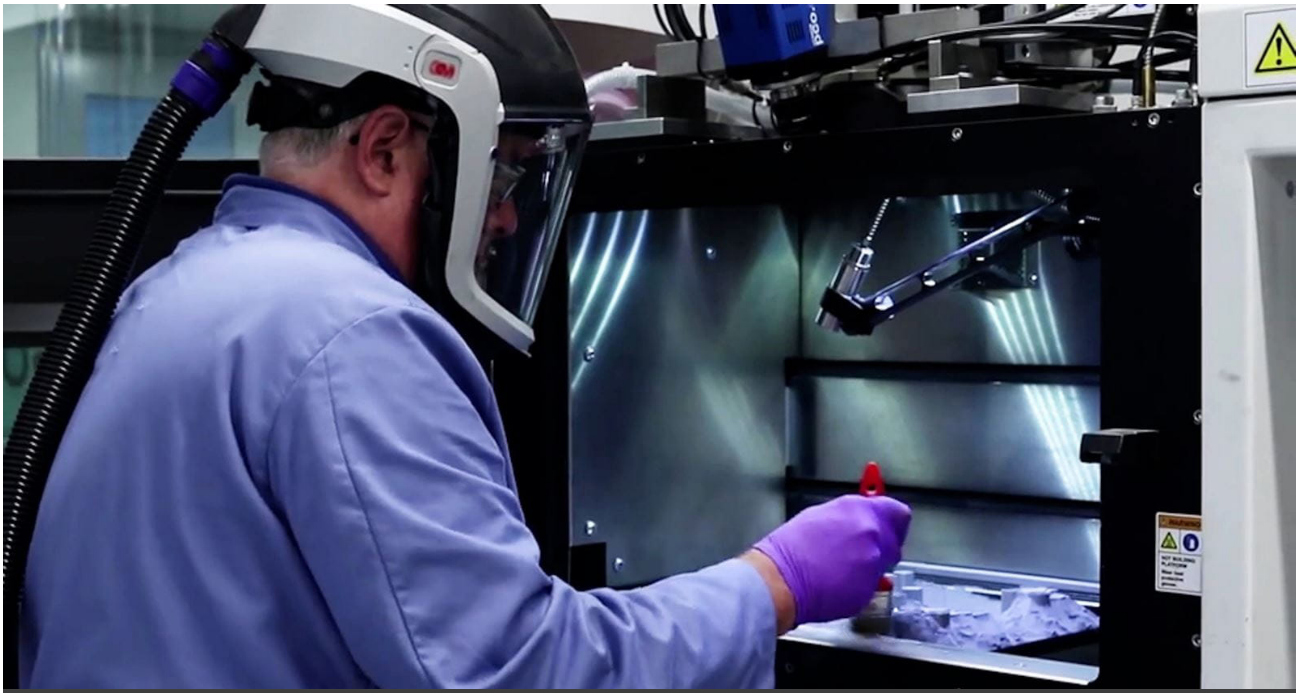
"The technical aspects to that [underlying challenge] are how to translate that confidence in how we communicate the components of variation, the impact of variation to the product, and develop tools (aka technology) that ensure that our processes are in control. Once we know these items, we can continue to develop Additive Manufacturing like many other manufacturing technologies for safety-critical parts."

On another note, since post-processing remains one of the most challenging aspects of the manufacturing process chain with AM and given the fact that it contributes to increasing the cost of the final part, we couldn't help but ask Boyer if it would be possible to reduce costs in post-processing through digitalization.

For Boyer, the good thing about AM is that it is already a "digital" process. While he didn't emphasize these opportunities at P&W, he did believe that "there are many opportunities in Additive Manufacturing to potentially apply digitalization from cradle to grave related to the entire process."

"Regarding post-processing, the largest opportunity is using digital tools to be predictive relative distortion, surface roughness, and defect generation to minimize things like machining and surface treatment and optimize processes such as inspection. Post-processing can "make or break" an AM application, so it is imperative to minimize/optimize that upfront in creating your manufacturing process to ensure the most cost-effective and robust application and digitalization is the tool for that," he adds.

Credit: Pratt & Whitney. Pratt & Whitney's F135 Engine Core Upgrade will deliver enhanced durability to the engine.



Legend: A technician operates a 3D printing machine. The face shield protects from the materials used, which can come in the form of fine powders. Credit: Pratt & Whitney.

Future outlooks: The next military engines that will benefit from AM and more

The story of P&W reveals that we still have a lot to learn from the use of AM in the military field. While the use of the technology in this field is still controversial, at 3D ADEPT, we would like to focus on how the technology highlights the beauty of engineering in its simplest form.

Currently, more than 7,000 Pratt & Whitney military engines are in operation across 34 armed forces globally. With AM [and other digital manufacturing technologies] onboard, I do not doubt P&W will keep establishing new benchmarks for performance and reliability. Moving forward, the team will explore opportunities regarding the **sustainment of legacy platforms such as the F100 and TF33**.

"We are progressing with unitized components on our small TJ150 platform and the F135 to provide cost savings and lead time improvements, and we are also utilizing Additive Manufacturing as a key enabler for unitized and optimized components in our advanced programs.

Currently, our Additive Manufacturing candidate parts compete with those that are optimized for conventional manufacturing. Those conventional designs have been rigorously tested for flight safety and certification – and our additively manufactured components undergo the same rigor. We see continued potential for Additive Manufacturing to be applied across our value chain. We have gathered extensive experience in a number of applications and are now at a tipping point for greater use. We are always looking to evaluate where the technology can be used in new products as well as supporting the sustainment of our legacy engine programs. And, although AM may not work for every application, it clearly compliments existing and advanced P&W manufacturing approaches. We develop these options to innovate and provide sound benefits to our customers. We also continue to support the regulatory bodies, standards development organizations, and various academic, government and industry groups to support the transition to production," Boyer concludes.

Editor's notes

I am one of those people who believe that to understand how efficient a company is, it's crucial to know the people who make the magic happen. In AM especially, there are different profiles that can help position a company at the forefront of its field. **Jesse Boyer** is one of them. He joined the AM department at P&W in 2015 and quickly spread the word about what's happening behind the scenes through his participation in AM-dedicated panels.

In his role as Senior Technical Fellow for Additive Manufacturing, like the other fellows at RTX, he is driven to grow in technical leadership, create product innovation, provide coaching and training to increase workforce capability, and capture knowledge for reuse and to share with others.

Fellows apply their technical skills and experience in organizing, leading, and guiding the resolution of top technical challenges and issues of importance to the company. More specifically, he is focused on the maturation, industrialization, strategy, and curriculum of Additive Manufacturing.

New dimensions of depowdering: The Solukon SFM-AT1500-S

Andreas Hartmann
CEO/CTO and co-founder of Solukon

In recent years, vertical industries such as aerospace, where high efficiency drives the way components are manufactured, have continuously pushed the boundaries of what is possible with Additive Manufacturing. At the same time, some 3D printers powered by laser powder bed fusion (LPBF) field have become a staple in the market for large-scale parts in record time, namely the NXG XII 600E system from Nikon SLM Solutions or the AMCM M 8K system from AMCM GmbH. For parts that are up to 1.5 meters high or parts that have built plate sizes of 820 x 820 mm and weigh at least several hundred kilograms, postprocessing must be automated. There is no other way to handle parts of this size.

Solukon: The depowdering system supplier for the largest formats ever since 2015

Solukon started back in 2015, the year it was founded, with a system designed for the largest machine on the market at the time, the Xline 2000R from Concept Laser measuring 800 x 400 x 500 mm. As early as 2020, Solukon impressively proved its depowdering expertise in the large-scale part segment when it launched the SFM-AT1000-S, a system that rapidly established itself as the market leader. The comprehensive experiences acquired since then have informed the development of an even larger system for metal parts. Solukon introduces the **SFM-AT1500-S**, a depowdering system that responds to the depowdering challenges in the heavy load segment at the highest level.

Which parts can the new depowdering system accommodate?

The SFM-AT1500-S is currently the largest metal depowdering system from Solukon. It can accommodate parts with dimensions of 600 x 600 x 1500 mm or 820 x 820 x 1300 mm with a maximum weight of 2100 kg, including the build plate – an immense intake weight for depowdering systems. This makes the SFM-AT1500-S the ideal depowdering system for heavy-duty requirements and dimensions.

Maximum capacity, minimum footprint

Space in production is in high demand yet often limited, especially where parts with enormous dimensions are produced. This is why the system is as compact as possible. With special drive technology, Solukon has succeeded in making the system very narrow. The structure is also arranged so flat that no platforms or stairs are necessary to load the parts. This makes the system unique in terms of its footprint and extremely safe and convenient when loading and handling particularly large components. *"The system saves space, is relatively easy to transport and easy to install since there is no time-consuming assembly work necessary. It's basically a plug-and-play machine"*, says CEO/CTO Andreas Hartmann from Solukon.

Adjustable vibration of massive parts: A special challenge

To make the powder flow, the massive parts must be made to strongly vibrate. However, the pneumatic vibrations must not be transmitted to the rest of the system, which is why Solukon developed a completely new decoupling concept. The part is made to vibrate optimally in any position, while the rest of the chamber is immune to the vibration. In addition, a newly developed, ultra-robust drive technology is used to move the parts, which can weight up to 2.1 tons.

Top Solukon quality for extraordinary requirements

Top machine quality, maximum safety with inerting for reactive materials and reliable cleaning results thanks to programmable 2-axis rotation are quality features that also apply to what is currently the largest Solukon system.

The chamber of the new SFM-AT1500-S is made of 100% stainless steel and the rotary table has four separately programmable compressed air lines for different configurations of vibrator, knocker and blower connections. Just like the SFM-AT1000-S, massive parts can be easily inserted with front-top-loading via crane. The SFM-AT1500-S is compatible with the SPR-Pathfinder® software, which automatically calculates the ideal motion sequence based on the CAD file of the part. Thanks to the integrated Digital-Factory-Tool, the depowdering procedure is fully transparent to users during the entire cleaning process. *"Digital features are also essential in the large-scale part segment. Smart software is the only way to depowder complex structures without human programming effort. Plus, continuous tracking is the only way to achieve real transparency,"* Hartmann explains.

Box fact and figures SFM-AT1500-S

Max. part dimensions	600 x 600 x 1500 mm or 820 x 820 x 1300 mm
Max. Part Weight (incl. Build plate)	2100 kg
Compatible printers	Every LPBF printer in the large part segment, e.g. NXG XII 600E; AMCM M 8K
Special features	Extremely compact footprint SPR-Pathfinder Digital-Factory-Tool New decoupling concept
Industries	Aerospace, new space, transportation, defense

Extreme amounts of powder require automated extraction

When depowdering the massive parts, significant amounts of powder accrue, and standard collection containers are too small. With the compatible SFM-PCU powder collection unit, the powder can be safely extracted and collected in a large container in a process monitored by sensors. Upon request, the SFM-AT1500-S machine can be made compatible with other manufacturers' powder conveying systems.

The next steps

The SFM-AT1500-S depowdering system is being launched at this year's Formnext at **booth 12.0, D71**. Immediately afterward, it will be delivered to two customers who have already purchased the first units. In the dynamic AM field, the boundaries of the feasible are nowhere near being reached. At Solukon, our mission is to always supply the right depowdering equipment for any extraordinary challenge. Thus, we keep discussing with leading aerospace manufacturers in Europe and the US.

SCAN FOR MORE INFO

Credit:
Solukon
SFM-AT1500-S

Credit: Airbus Helicopters

Frank Rethmann on Airbus Helicopters' AM journey : "Since 2017, we have produced more than 13500 shafts [using titanium 3D printing]."

I may have been blinded by the number of war films and thrillers that I have already watched, but I consider helicopters as one of the important inventions that changed the game for defense, warfighting, transportation, and disaster relief missions. This has led many governments to go the extra mile to propel the helicopter industry. That's the reason why, to be a consistent force to be reckoned with when it comes to defending a nation from the skies, helicopter manufacturers must also stay at the forefront of the technology. It takes a conversation with **Frank Rethmann** to understand what this journey looks like for **Airbus Helicopters**.

It's probably the same for other manufacturing fields, but when you're aware of the fact that helicopter manufacturers fall into two categories (those that can design, certify and manufacture new helicopter designs from scratch and those that can only manufacture extant designs under license), it is obvious to turn to a player of the first category to understand what an Additive Manufacturing journey looks like in this field.

As the world's largest helicopter manufacturer, Airbus Helicopters surprisingly embarked on its path toward AM industrialization in 2017. This might be a bit late compared to other industrial companies of the same league in the broader aerospace field, but it remained a strong start. Unlike other aerospace OEMs who started way sooner and who made their first steps in plastics 3D printing, in 2017 the technology was mature enough to explore industrialization with metal 3D printing – which is what Airbus Helicopters did.

FRANK RETHMANN

Head of Industrial Service Center 3D Printing at Airbus Helicopter

"We started our industrial application of AM in 2017 with the printing of shafts in titanium. In this first application, we took the existing design and reproduced the part using powder bed printing technology, achieving cost savings by improving the buy-to-fly ratio, meaning less titanium was needed to produce the part. Our strategy from the

beginning was not just to establish the printing capability, but to master the entire end-to-end process chain, and we have achieved this. Since 2017, we have produced more than 13,500 shafts. Last year, we bundled our AM activities in our ***AM TechCenter in Donauwörth*** *and significantly expanded our in-house capacity for this innovative process,"* Frank Rethmann, Head of Industrial Service Center 3D Printing at Airbus Helicopters told 3D ADEPT Media from the outset.

The 3D printing center at Airbus Helicopters' Donauwörth site integrates 3 industrial 3D printers for parts made of titanium, 5 3D printers for plastic parts, some

desktop 3D printers and a recently added metal 3D printer that can produce parts made of aluminum. *"The production area has doubled, with the latest expansion adding 500 square meters for Additive Manufacturing,"* Rethmann notes.

At present, and according to Rethmann, the 3D printing center can produce both metal and composite 3D printed parts. With their thermoplastic 3D printers, they can produce non-structural parts like air conditioning for Airbus Helicopters. In addition to series production parts, the 3D printing center also uses their laser powder bed fusion (LPBF) 3D printers to contribute to research activities to optimize titanium 3D printing and develop aluminum-based applications.

"Our ALM facility also allows us to quickly adapt to new situations and to produce parts for our helicopter prototype applications, such as the recently unveiled Racer demonstrator, or for our CityAirbus NextGen."

Although they do not use the same terminology as Pratt & Whitney **(read the article on pp 29 of this issue)**, Airbus Helicopters benefits from three advantages AM offers, its fellow manufacturer mentioned: **part substitution/ part adaptation, unitization and optimized design**.

"Compared with the conventional version, we save about 45 percent in weight and 25 percent in costs by so far integrating ten parts into one component. Around 3,500 shafts have been produced and the first of these have already been installed," I recall the Head of the Industrial Service Center 3D Printing department said during a presentation at Rapid.Tech 3D, an AM-dedicated event held in Erfurt.

On another note, *"We also work in close collaboration with the other divisions of Airbus to co-develop ALM new technologies and materials,"* Rethmann adds.

Challenges on the road: the case of the CityAirbus NextGen

The CityAirbus NextGen is an Airbus' **electric vertical takeoff and landing** (eVTOL) prototype that falls into Airbus' strategy to develop advanced air mobility services in countries around the world. Based on a lift and cruise concept, the prototype boasts an 80-km operational range and a cruise speed of 120 km/h – making it perfectly suited to a variety of flight operations.

In the aerospace field, there is only a short list of manufacturers – among which GKN Aerospace – who leverage AM to produce parts for eVTOL. As you may guess, the high-speed and long-range capabilities of some eVTOL designs make them suitable for rapid deployment of troops and equipment in remote or difficult-to-access locations hence their use in military applications such as transportation, and logistics.

For this reason, the team at Airbus Helicopters leverages the advantages of AM through new systems and new architectures. *"Design for ALM will help us foster the benefits of using ALM for weight and cost savings, i.e. integrating ALM in the early design phase. It is also an opportunity to improve offerings by reducing production and logistics lead times,"* Rethmann comments.

Among the new design elements that make for a robust and seamless architecture, and that could potentially require the use of AM, one counts the wings, the V-shaped tail as well as the eight electric-powered propellers that are part of the uniquely designed distributed propulsion system.

That being said, **qualification and certification of safety-critical parts** remain a big challenge on the road. While this is the case for many aerospace manufacturers, the team of Airbus Helicopters is lucky enough to be part of a broader corporation that has decades of experience in Additive Manufacturing.

"We are in close contact within Airbus and authorities to establish the routes to qualify and certify parts of increasing criticality where we believe the weight and cost savings compared to traditional manufacturing methods

Credit: Airbus Helicopters – CityAirbus NextGen *are very significant,"* the Head of the Industrial 3D printing center notes.

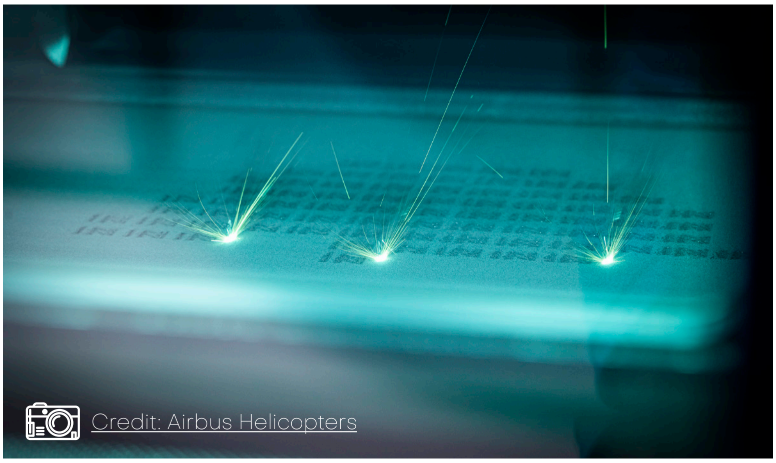
At the manufacturing level, one solution that could be explored to address this challenge is **digitalization**. Needless to say the topic is broad and can be applied across various steps of the manufacturing chain but in this specific case, Airbus Helicopters that recognizes its importance, will explore this solution in the *"process qualification and quality assurance process going forward."*

"Thanks to capturing data across the full process chain, we can use statistical process control to ensure the conformity of the parts", Rethmann points out, speaking of these steps of the post-processing stage. Speaking of the manufacturing process itself, he adds: *"Digitalization also enables us to further optimize the printing parameters , increasing our pricing capacity and reduce costs."*

Future outlooks

Airbus Helicopters has understood the 30:70 ratio principle. The biggest challenges that need to be addressed at the manufacturing level are in the downstream processing steps. But that's not all.

With sustainability at the heart of manufacturers' agenda, the OEM is aware of the advantages AM can deliver in this regard. As a matter of fact, Rethmann says AM allows them to not compromise their sustainability goals at the expense of cost or weight.


Credit: Airbus Helicopters

That being said, as per the words of our interviewee, by optimizing the buy-to-fly of the parts they produce, they use less raw material to make parts and consume much less energy compared to traditional forging and machining processes. However, the current focus remains to pursue "Design for ALM" (Additive Layer Manufacturing) to unlock the full potential of the technology for more and more applications, ensuring that they address the means to certify these applications.

"We must continue to work with powder material suppliers and machine manufacturers to further optimize the cost of parts. And we must continue our research into new materials and new applications. We believe that our ALM journey at Airbus Helicopters has been a great success so far and we look forward to the further business benefits this technology will bring in the future," Rethmann concludes.

INTERVIEW OF THE MONTH

GOING THROUGH ARKEMA'S ESG AND SUSTAINABILITY JOURNEY IN ADDITIVE MANUFACTURING

It's been a few years already that we continuously monitor sustainability activities in the AM industry. Last year, in the sustainability edition of 3D ADEPT Mag, we shed light on the fact that sustainability goes hand in hand with ESG – an acronym which stands for Environmental, Social and Governance; a framework used to assess an organization's business practices and performance on various sustainability and ethical issues. While all AM solutions providers are concerned, material producers are among the first companies that are leading the way in this journey – for obvious reasons. In the short list of material producers that have taken the leap in this journey, there is Arkema.

Arkema SA is a publicly listed, multi-national manufacturer of specialty materials, headquartered in Colombes, France. The company debuted in the AM market about 6 years ago, in 2018. The first steps the company took at the time included an expansion of its global production capacity at its Mont site in France for the manufacture of specialty powders, the launch of the platform "3D Printing Solutions by Arkema" to equip customers, partners and OEMs with industrial-grade AM materials including its N3xtDimension resins as well as several partnerships with the likes of LSS Laser-Sinter-Service GmbH, Prodways, EOS, and HP. Each of these OEMs leaned on the company's expertise in plastic materials development for their polymer 3D printing machines.

As part of its sustainability and CSR strategy, and just like most multi-national companies willing to play their part in the fight against climate change, Arkema has set ambitious goals to reduce its environmental impact by 2030.

"We're aiming for net-zero emissions by 2050, in line with the 1.5°C target of the Paris Agreement. We're working hard to cut CO2 emissions across the entire value chain, from production to delivery (Scopes 1, 2, and 3). These principles guide us in driving decarbonization and circularity in our material design, all while aligning with the UN Sustainable Development Goals (SDGs)", **Brad Rosen**, Global Business Director for 3D Printing, at Arkema told 3D ADEPT Media.

Its 3D printing division has always been quiet on its sustainability activities in the AM industry until 2023, when the company announced a landmark biomethane deal with ENGIE to further reduce the carbon footprint of its 3D printing materials.

That being said, given the material expertise of the company, it makes sense to see Arkema 3D printing business explore *"sustainable solutions that merge sustainability benefits with [material] performance." "This means developing high-performance materials that use cleaner ingredients, contain determined bio-content, and are more durable,"* Rosen points out.

As far as ESG is concerned, the Global Business Director for 3D printing reveals that the company has been focusing on the environmental aspect of this acronym:

"We're reducing our carbon footprint through innovative material design, bio-based materials, and renewable energy sources. This allows us to develop sustainable materials that advance our decarbonization and circularity goals. We choose to invest in 3D printing technology because it allows for on-demand, local production, which cuts down on material waste and minimizes the logistical footprint.

By developing high-efficiency bio-based materials for solvent-free, low-VOC 3D printing technologies, and forming strategic partnerships in additive manufacturing, we're able to push the industry forward toward more sustainable solutions," Rosen said.

Brad Rosen, Global Business Director for 3D Printing, at Arkema

Part produced with a filament. Credit: Arkema

Are there data that can back up these claims?

AM companies have often been criticized for not demonstrating how sustainable their processes and/or products are. Unconsciously, companies that fail to demonstrate data that can back up their words, turn the sustainability topic into greenwashing. For these reasons, we asked Rosen how Arkema's 3D printing division justifies its sustainability arguments; and if the company conducts a full cradle-to-grave assessment. He attempts to answer:

"We have a dedicated team of experts to calculate PCF according to LCA methodology. The tool enables us to quantify the emissions linked to the production of our materials and will enable us to monitor the progress achieved through our climate plan.

Arkema has achieved ISCC+ certification at almost all our global UV manufacturing sites. Using the mass balance approach, we replace fossil feedstocks with renewable ones at the origin of the supply chain, segregating by bookkeeping the quantity of renewable material and attributing it to finished products. This helps in combining performance, circular sourcing, and lower Product Carbon Footprint (PCF).

We also have a few acrylate and methacrylate materials for 3D printing that are USDA Certified Biobased through the USDA's BioPreferred® Program."

Its portfolio of AM solutions and possible applications

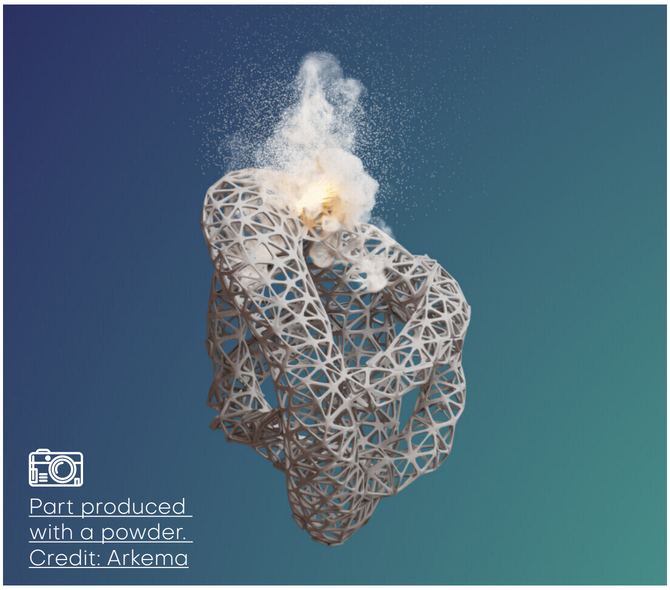
Acknowledged for the development of specialty powders and resins for Additive Manufacturing, Arkema's first investments that appeared on our radar were made for the development of the Rilsan polyamide 11 and Rilsamid polyamide 12 product lines, before shifting the focus to the Orgasol specialty powders portfolio. Interestingly, the Orgasol portfolio was designed for applications that go beyond 3D printing to encompass coatings, and advanced composite materials.

The company's recent product launches support its decarbonization and circularity goals as it includes **new high-performance photopolymer 3D printing formulations with high bio-content.**

Rosen points out: *"This year, we introduced two new oligomers in our Sarbio® product line. Sarbio® 7405 toughening oligomer with 50% bio-content offers an excellent balance between hardness and flexibility, and Sarbio® 7407 is a highly flexible oligomer with 84% bio-content that enables high elastomeric performance.*

We have also developed our first bio-based UV formulation with 53% bio-content. N3xtDimension® N3D-PR184-BIO is an industrial and consumer modeling material that exhibits stiffness, accuracy, resolution and easy processability. This is the first of our 3D formulations to achieve USDA Certified Biobased labeling through the BioPreferred® Program."

These materials can be processed by V**AT printing (SLA, DLP, LCD) and jetting (MJP, BJ) technologies** and can lead to applications in the dental, medical and consumer goods sectors.



Part produced with a powder. Credit: Arkema

"Bio-based materials are becoming more interesting in the consumer goods space due to consumption patterns. We also provide materials and support in industries such as aerospace and electronics, where flame retardancy is becoming critical," Rosen adds.

In the long run, Arkema will continue to explore new cleaner materials, technologies and solutions that advance decarbonization and help it meet its long-term goals. While this cannot be done without exploring strategic partnerships across the value chain, we, at 3D ADEPT, can't wait to see the AM applications that derive from it. In the end, only applications can testify of the capabilities of these materials – sustainable or not.

Moving toward industrialization with 3DCeram's Ceramic 3D printing

*"Better, faster, cheaper." Three words that every manufacturer is looking to use when qualifying their production on an industrial scale – and this, no matter what Additive Manufacturing processes they leverage. The thing is, the quest for industrialization seems obvious when using certain AM technologies while others do not always get the credit they deserve. In the wide array of AM processes that are gaining in popularity, a conversation with **3DCeram** sheds light on the possibilities that **stereolithography (SLA)** offers to achieve production on an industrial scale.*

Acknowledged for the manufacturing of ceramic 3D printers based on **stereolithography** (SLA), 3DCeram's offering has evolved to support customers throughout the entire value chain. While we have covered several applications of the company's technology across the healthcare, aerospace and energy sectors, SLA 3D printing does not benefit from the same reputation as other widely used AM processes. This lack of knowledge regarding this process makes it difficult to consider it for industrialization or series production – let alone the fact that SLA can enable ceramic 3D printing applications.

"Manufacturers who seek production solutions through 3D printing usually do so under the impetus of a specific project," the 3DCeram team explains from the outset. *"This means that manufacturers who consider Additive Manufacturing as a full-fledged production tool are growing in number. But some got a little confused by the diversity of technological offerings. Let's admit that there is a proliferation of technologies (extrusion, FFF, DLP, Binder Jetting, Stereolithography…) emanating from the academic sector, but this often confuses manufacturers. It makes their journey longer."*

According to the 3DCeram team, SLA has a reputation for being a "slow process". In contrast, the technology *"offers the possibility of very large printing areas thanks to top-down printing [and] is most easily automated."*

Key considerations to consider when moving toward industrialization

For those who are not familiar with 3DCeram's technology, it should be noted that in a top-down construction process, the layers are constructed from the bottom up, minimizing the need for numerous supports. Once the printing process is complete, the parts are cleaned, and having fewer supports simplifies and speeds up the process, while also lowering the risk of waste from potential breakage during support removal.

Over time, this process has been enhanced to integrate **automation**, and **artificial intelligence (AI)**. These features along with the **ability to produce large parts** have become key considerations to take into account when moving toward industrialization.

"SLA is a technology that offers significantly large production surfaces, with the possibility to add lasers and to enhance the printing speed," 3DCeram said. Besides this key asset for manufacturers who are looking for mass production, the company's systems are large enough to print either many small parts or a big part.

Moreover, process automation is essential if we want to reach manufacturers, and here 3DCeram already offers partial automation of the process. *"Our 3D Printers have a formulation feed system with a pressurized pot. At the output of the C1000 FLEXMATIC printer, there is a recycling station that allows the recovery of unpolymerized formulation, which then goes back into the production cycle. The printing surfaces of 3DCeram's CERAMAKER printers offer the possibility of printing very large parts. For instance, with the C3601 ULTIMATE whose platform is 600*600*300 mm, there is a considerable space to print large [parts] and in ONE PIECE!"* the company adds.

As far as AI is concerned, 3DCeram has recently developed a solution that can optimize quality and printing time. Named **CERIA**, it can be deployed in several stages.

C1000 FLEXMATIC by 3DCERAM

"First, CERIA Set analyzes the part and the VAT to propose adjustments and generate optimized parameters. This means it will cross-reference incredible amounts of data to make a complete analysis and anticipate all areas of improvement. Once all adjustments are made, CERIA generates ready-to-use printing parameters for CERAMAKER printers. The operator then only has to start the printing.

This new tool is a major asset for a manufacturer as it responds to the need to secure their production process. Indeed, all the knowledge is no longer held by a collaborator who could decide to leave the company. The risk of disruption in the production chain is then eliminated.

Another major contribution of CERIA is the time saved in terms of iterations. We know that, as with any industrial process, there are rejects or failures. The contribution of CERIA here is considerable, as it produces gains in time, raw materials, and machines.

3DCeram will be launching at the end of 2024, a complementary module to its artificial intelligence, ***CERIA Live****. This module is about real-time control during printing. CERIA analyzes the previous 3 layers to anticipate all events that could occur in the next 5 layers to intervene to make necessary adjustments. The idea here is to control all parameters in real-time to optimize printing time."*

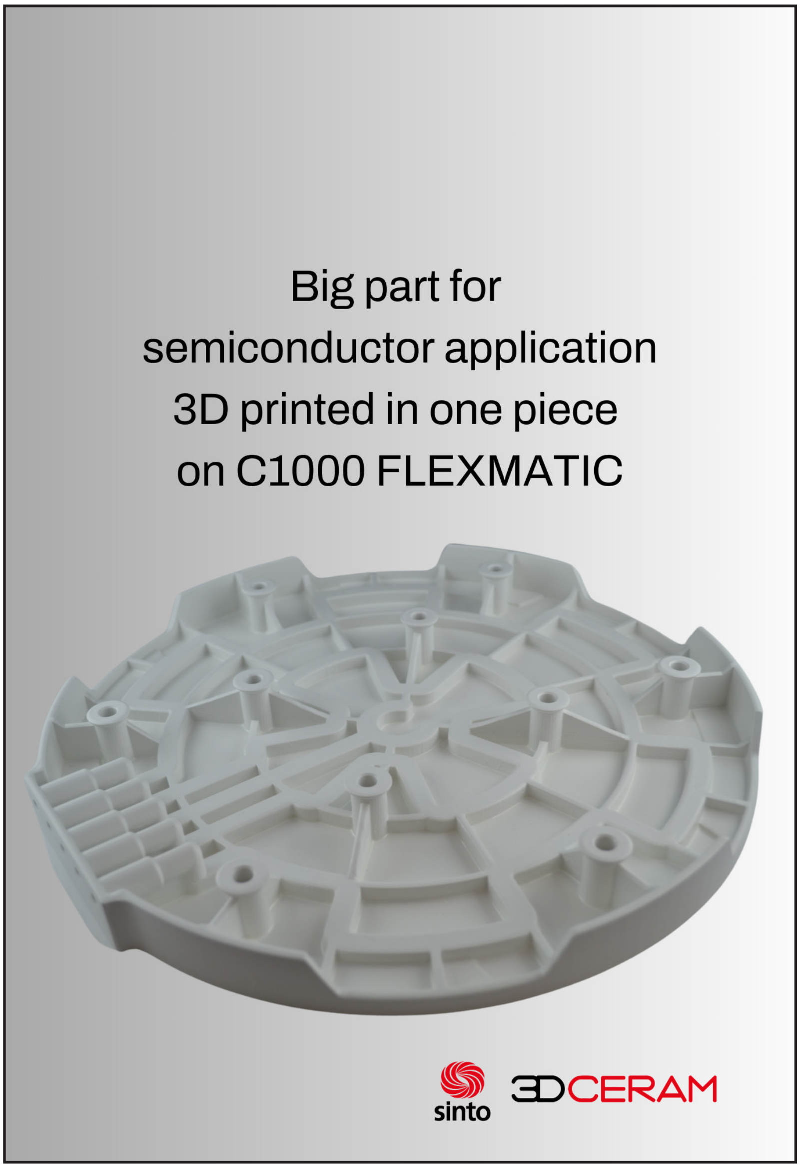
With the growing use of artificial intelligence across all areas of the manufacturing chain, 3DCeram demonstrates that it is examining the current evolution of the market to help vertical industries produce at the best cost – better, faster and cheaper.

Non-technical barriers & applications

While the focus is often made on technical capabilities, the reality on the production floor also reveals that the knowledge gap in large factories, the uncertainty about what to produce with a given technology or even the transition from small-scale to larger-scale AM are also key challenges to the industrialization of AM – challenges that 3DCeram can help address as in two decades of experience in the field, the company has evolved from part manufacturer to 3D printer manufacturer.

As such it is also well-positioned to testify to the capabilities of its solutions – especially with AI offering the possibility to analyze and control the entire AM process.

"All technical ceramics manufacturers will benefit from optimizing AM processes assisted by artificial intelligence and automation. Manufacturers can finally design parts based on the properties they are seeking, rather than being constrained by the traditional processes available in their workshops. The locks are falling and manufacturers are increasingly attentive. At the forefront are all the productions associated with sovereignty and confidentiality issues. We can see that these issues are more and more numerous and more present than ever," 3DCeram outlines.



While the company's solutions can lead to applications in the semiconductor, defense, and aerospace sectors – to name a few, it's crucial to continue contextualizing each application to make the most of the technology.

EDITOR'S NOTES

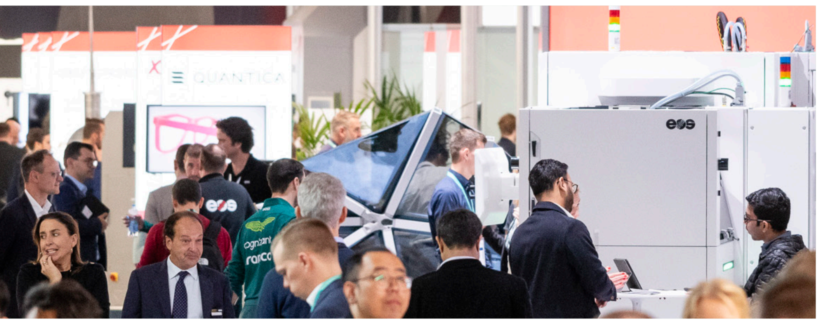
Visitors at **Formnext 2024** could experience CERIA, the artificial intelligence and 3D printing assistant for technical ceramics from **November 19 to 22, 2024** in **Hall 11.1 Stand D21**.

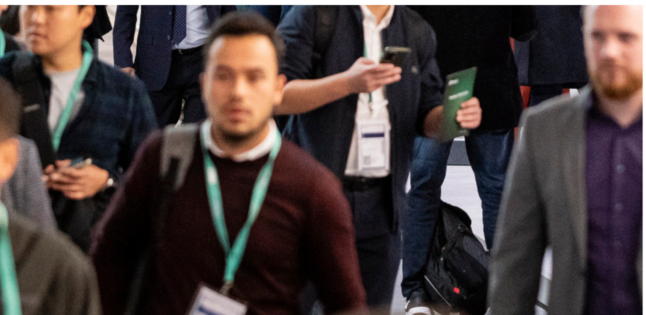
This content has been created in collaboration with 3DCeram. Quotations have been edited to ensure clarity.

SCAN FOR MORE INFO

Innovations, trends, and potentials of Additive Manufacturing

A must-attend event for the modern production world: the global AM elite showcases at Formnext 2024





Even though the Additive Manufacturing (AM) market continues to grow each year, the strained economic situation—particularly in some European countries like Germany—has left its mark on the world of 3D Printing. This makes it all the more crucial for companies and users of AM to continue improving efficiency and unlocking new applications. The latest innovations to achieve this will, as usual, be on display at Formnext in Frankfurt, where from 19 to 22 November 2024 the industry's big players, along with many other exciting companies across the entire process chain, will present their newest developments. Visitors can already purchase tickets in the online ticket shop and take advantage of an attractive early-bird discount available until 22 October.

Despite the challenging economic environment, Formnext, as the world's most important trade fair in this sector, continues its success story. By the end of September, over 820 companies (around 60 percent of them from abroad) had registered for the world-leading trade show for Additive Manufacturing and the next generation of industrial production. Key exhibiting countries include the United States, China, the United Kingdom, France, the Netherlands, Italy, and Spain.

The AM world consistently showcases its most significant innovations each year at Formnext, providing visitors the opportunity to experience the latest developments firsthand and engage directly with exhibitors and experts. In addition to new applications, many exhibitors this year are focusing on how manufacturing companies can integrate AM into their production chains more efficiently and profitably.

Innovations paving the path to success

«The strong registration numbers for Formnext reflect the relevance of Additive Manufacturing for the entire industry,» says **Sascha F. Wenzler**, ***Vice President of Formnext*** at event organizer Mesago Messe Frankfurt GmbH. Ultimately, the AM market continues to grow annually, with many technologies reaching technological maturity or progressing steadily. Increasingly, applications are finding their way into production halls, including in some cases, into serial production. In numerous sectors, particularly automotive, aerospace, and medical/dental, additively manufactured products and components are now indispensable. This is why Formnext is focusing one of its key themes this year on the medical sector.

In challenging times, innovations are ultimately the best way to ensure

Sascha F. Wenzler, Vice President of Formnext

continued economic success or to regain it. *«And AM is a technology that allows us to meet current challenges,»* Wenzler explains. *«At the same time, Formnext reflects the dynamic nature of the global AM industry, which every year prepares the path to the industrial future with numerous innovations and applications.»*

As competition intensifies in the AM space, it becomes increasingly essential for companies and users to stay up-to-date with the latest developments. Only in this way can the full potential of the technology be realized. One of the significant trends this year is the integration of artificial intelligence and digital networking into production processes, which not only improves component quality but also helps reduce costs. Sustainability is also playing an increasingly important role, as will be evident at Formnext 2024. Many exhibitors will showcase relevant concepts and newly developed recyclable components.

New: Formnext Awards

A significant initiative to bring young innovations further into the international spotlight is Formnext's new award concept. The previous Start-up Challenge has evolved into the new Formnext Awards, designed to give extraordinary talents and their ideas even greater recognition. The Formnext Awards will now honor innovations in six categories, including young innovative companies, sustainable business ideas, and groundbreaking technologies. This year, the audience can also participate in the voting process. Exhibits will be available for viewing not only at Formnext but also in advance on the Formnext website starting in mid-October. Voting for one or more categories will be possible until Thursday, 21 November, at 12:00 PM, with the audience vote counting as an additional voice in the jury.

Conference program on three stages

To foster professional exchange, Formnext will continue its extensive and freely accessible conference program. Once again this year, current and future applications, technologies, and overarching trends in the AM and manufacturing industries will be discussed on three stages. Key topics on the Application, Industry, and

Technology stages will include artificial intelligence in Additive Manufacturing as well as medical and dental technology, robotics, and automation.

Diverse supporting program

After its debut last year, the «Service Provider Marketplace» will focus on the fields of medical technology, dental, and packaging in 2024. In the Start-up Area and during the Pitchnext event, young, innovative manufacturing companies will present themselves to potential investors and cooperation partners. On Career Day, job seekers can explore career opportunities in the AM industry. For companies looking to enter the AM industry, the established and daily Discover3Dprinting seminars, conducted in cooperation with ACAM, will offer valuable insights and advice. Four deep-dive seminars, also in collaboration with ACAM, will focus on the topics of AM industrialization, design for AM, surface treatment, and materials.

The Additive Manufacturing Working Group of VDMA (Mechanical Engineering Industry Association) will present a special exhibit featuring valuable AM applications from the world of mechanical engineering. The BE-AM special show will highlight advanced developments in the increasingly important field of 3D Printing in the construction industry through real-world applications. The BE-AM symposium will also present numerous insights and future developments in this field. Additionally, the AM Innovation and Standards Summit will take place the day before Formnext opens.

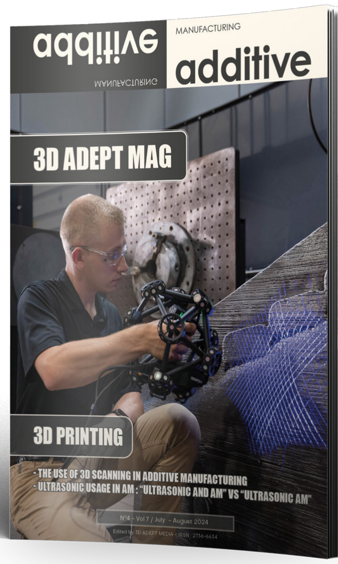
Partner country: Australia

This year's partner country for Formnext is Australia. The versatile continent has impressed for years with a strong AM community, globally successful system manufacturers, service providers, and highly specialized AM companies. This success is driven in part by excellent universities and a unique environment that attracts talent from around the world to Down Under

Find more information about Formnext at formnext.com/visitors.

INDUSTRY EVENTS

2024



Stay up-to-date with the latest additive manufacturing industry events, conferences, exhibitions and seminars.

EUROPE

The 12th Edition RM Forum
September 25–26, Milan, Italy
www.rmforum.it

The Atomising Systems Course on Atomization for Metal Powders
September 26–27, Manchester, UK
www.atomising.co.uk/news

Euro PM2024 Congress & Exhibition
September 29–October 2, Malmö, Sweden
www.europm2024.com

Scotland Manufacturing & Supply Chain Conference & Exhibition
October 23–24, Glasgow, Scotland
www.manufacturingexposcotland.com

AM Summit 2024
October 24, Copenhagen, Denmark
www.amsummit.dk

Advanced Engineering
October 30–31, Birmingham, UK
www.advancedengineeringuk.com

Space Tech Expo Europe 2024
November 19–21, Bremen, Germany
www.spacetechexpo-europe.com

Formnext
November 19–22, Frankfurt, Germany
www.formnext.com

USA

IMTS 2024
September 9–14, Chicago, IL, USA
www.imts.com
Metal Additive Manufacturing Conference

(MAMC 2024)
September 17–19, Aachen, Germany
www.mamc.at

The Advanced Materials Show USA
October 8–9, Pittsburgh, PA, USA
www.advancedmaterialsshowusa.com

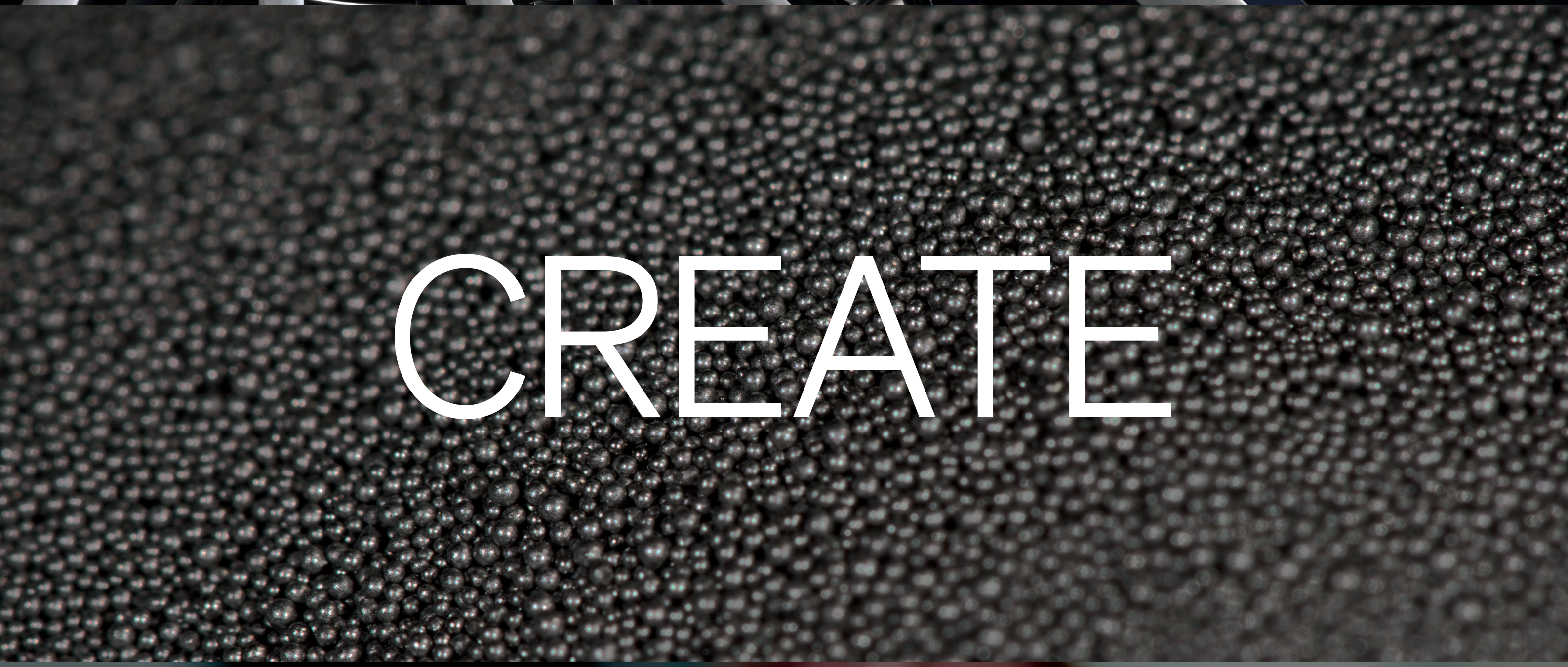
World PM2024
October 13–17, Yokohama, Japan
www.worldpm2024.com

Global AM Summit 2024
October 15–16, Singapore
www.namic.sg/events/gams2024/

International Conference on Advanced Manufacturing (ICAM 2024)
October 28–November 1, Atlanta, GA, USA
www.amcoe.org/event/icam2024/

Aerospace & Defense Manufacturing & R&D Summit
December 5–6, Dallas, TX, USA
www.dec24.aerospacedefensesummit.com

MORE EVENTS WILL BE ADDED LATER !


IMAGINE

CREATE

REPEAT