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3D ADEPT MAG

3D PRINTING

DOSSIER : QUALIFICATION OF 3D PRINTED PARTS
WHAT ? WHY ? WHEN ? AND MOST IMPORTANTLY HOW ?

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All about Additive Manufacturing

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Hello & Welcome

Planning tomorrow, today.

Every year, a range of technologies excites the world and seeks to transform the way one innovates. Our niche industry is no exception to this excitement especially when one considers AM in relation to the bigger picture. The thing is, since AM is already described as "the most overhyped technology", there is a need to lay out the facts and to be transparent about the impact of those non-AM/3DP frontier solutions without enthusing.

In this summer edition of 3D ADEPT Mag, we have identified a couple of topics that are already making strides across the software, materials and applications segments. These topics may not necessarily be "new" as they aim to shed light on complexities one does not necessarily take into account when exploring AM, and lessons that can only result from holistic experiences of the technology.

Beyond these applications and technology solutions that impact the AM industry itself, this edition of 3D ADEPT Mag also brings to the table a timeless and complex topic: part qualification. Chosen by our community, the topic is not a new one at 3D Adept media, but as AM is entering a maturation stage, there is a need to document and characterize qualification efforts, (to attempt) to provide a framework that could really help industries, plan tomorrow, today.

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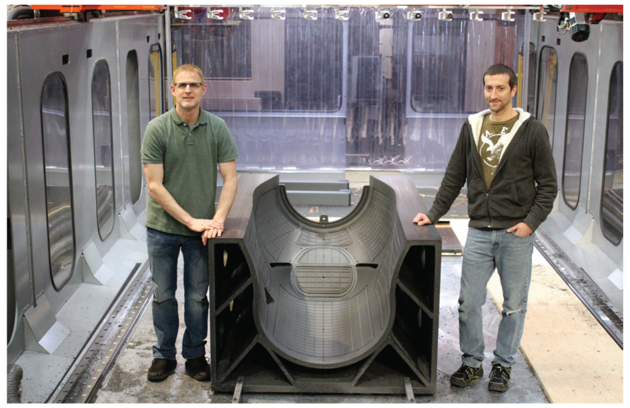
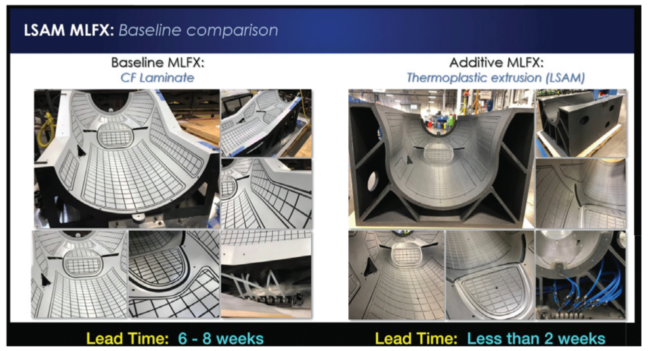
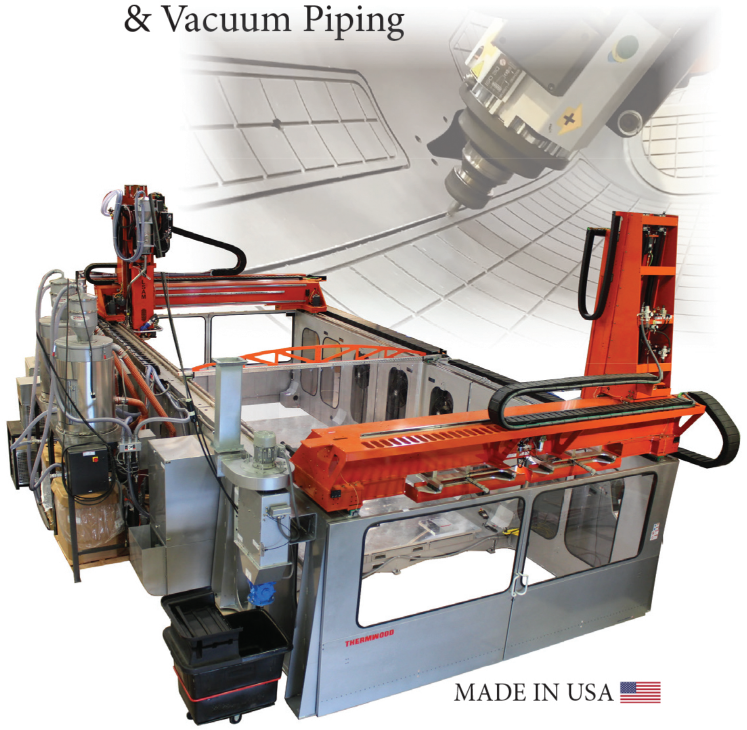
Editorial







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QUALIFICATION OF 3D PRINTED PARTS : WHAT? WHY? WHEN? AND MOST IMPORTANTLY HOW?

Once per year, we sit down to assess some of the key insights we collected from our conversations with OEMs using AM and from (potential) users of the technology at trade shows we visited. Doing that enables us to determine issues or solutions that are common to industries. One thing we learned from last year's insights is that the need to qualify and certify 3D printed parts remains a barrier to more extensive use of AM across platforms. Truth be told, the conversation about "qualification" and certification" is not a new one at 3D Adept media but as this technology is entering a maturation stage, there is a need to document and characterize qualification efforts, (to attempt) to provide a framework that could really help industries.

In this vein, this feature ambitions to help industrials understand/assess:

- Approaches to part qualification
- The tools that can be used in part qualification
- If it is possible to outline specific considerations for qualification across industries such as the military, automotive and aerospace

We do understand it is difficult to discuss qualification without mentioning certification. However, in this article, our key area of focus remains qualification of 3D printed parts.

If I had to choose one way to tell you what part qualification is, I would use **John Barnes**' words: qualification is achieved when "a component meets the design intent." To ensure the integrity of an application, the qualification process involves a set of requirements that are tied to the **parts themselves, machines, materials, processes and personnel.** As **Chuck Nostedt**, Jabil's Quality Engineer for Additive Manufacturing said, the challenge consists in understanding a host of customer or end-user requirements and how they relate to the material and machine combination.

While guidelines are already in place for parts manufactured using conventional manufacturing processes, it should be noted that regulatory and standard organizations such as SAE and ASTM, are regularly working on materials and process specifications that could assist in the qualification and certification of AM parts. Not surprisingly, **this lack of clarity on what constitutes qualification with AM** is what led first to challenges across the manufacturing value chain.

I – Approaches to 3D printed part qualification

I would like to draw your attention to one thing: qualification is a challenge faced by both experienced and beginners in the AM industry. The former group has just been lucky enough to make the mistakes that the latter would want to avoid. That being said, **qualification can be done in several ways.**

For **Nostedt**, the approach to part qualification can follow four steps: **material/equipment selection, equipment qualification, process validation, and part production.**

This means that the AM team should be able to *"choose an optimal material/3D printing platform combination based on customer requirements"* (material/equipment selection) and *"ensure all 3D printers and supporting equipment include test equipment that functions as intended before proceeding to the next step of process validation"* (equipment qualification).

Process validation aims to *"confirm that parts can be produced with desired levels of repeatability and reliably to meet all requirements (mechanical, visual, and dimensional). This includes all process steps of 3D printing and post-3D printing processes (e.g., powder removal, cleaning, support removal, heat treatment, surface finishing, machining parts into dimension, packaging, etc.)"*, **Nostedt** adds before detailing:

· For process validation to begin, the user must understand what the critical parameters are for each process, which sometimes is called **process characterization.** Design of Experiments (DOE) can be used to determine the critical process parameters. It may also include powder recycling studies to understand how often the powder can be recycled as well as how much virgin material can be mixed with reclaimed material.

· The actual process validation uses the critical process parameters established in process characterization to prove parts can be repeatably and reliably manufactured using those established parameters.

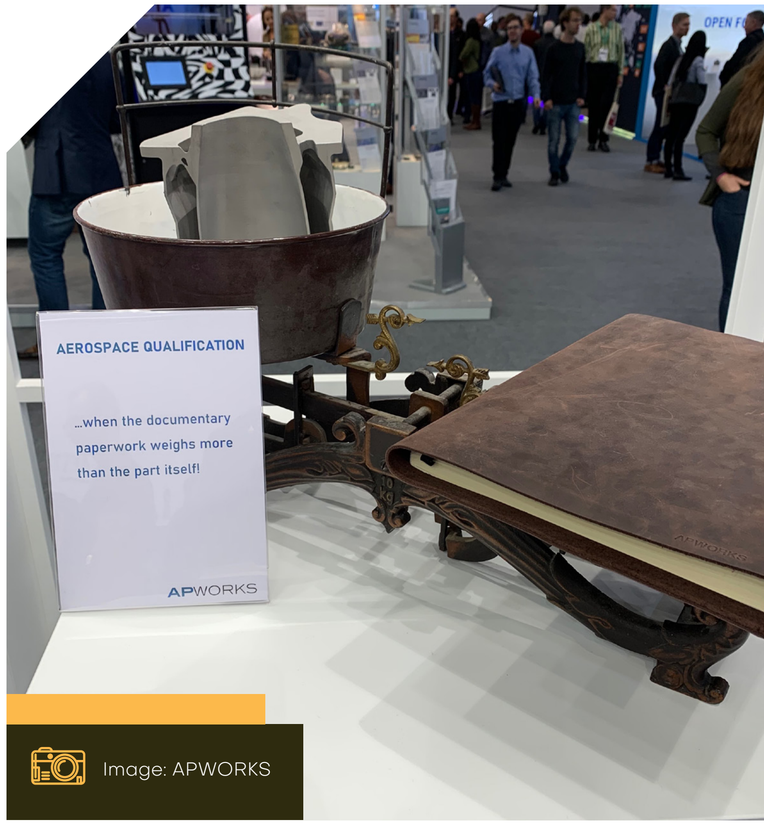


Image: APWORKS

· Proving the parts meet all requirements requires testing, which may include mechanical, visual, and dimensional tests. The user must understand if the test is destructive and will require sacrificing a part or whether a test coupon can be used in place of the part. Part complexity and part volumes will drive the test strategy. For example, dimensional inspection methods, which are part dependent, will determine if the part can be hand measured with calipers, go/no go gauges, Coordinate Measuring Machine (CMM) or Computed Tomography (CT) scanners, etc.

The last step – part production – then occurs after process validation is complete. As per Nostedt's words, it helps *"to ensure the product can be continually manufactured and still meet all requirements. This may include but is not limited to monitoring of process parameters (e.g. laser power, temperature sensors, oxygen sensors, etc.) and product testing (e.g. mechanical, visual, and dimensional). Product testing during production is typically conducted based on the importance of quality requirements as established by the customer."*

This approach includes steps (and probably sub-steps) that many are using or would use, but probably not in the exact same order.

Furthermore, one should not forget that AM is a holistic process by nature. Therefore, there are a couple of questions that one should ask first and whose responses may help define a framework that best meets one's needs.

Aidro received the industry's first certification of qualification from DNV for binder jetting using the Desktop Metal Shop System™ for 3D printing 17-4PH stainless steel parts. The printer is shown here with two valves and coupons printed in 17-4PH. Image: Aidro.

For the President of The Barnes Global Advisors, these questions are: **"Is it a new part or a system concept ? or Is it an existing part and a legacy system?"** For Barnes, the ideal framework for qualification should be common to all engineered parts and encompasses certification and qualification. Remember, I told you at the beginning that it was difficult to discuss qualification without mentioning certification.

So, when one deals with an existing part on a legacy system, *"it's a blessing and a curse"*, Barnes smiles. *"The good news is there are requirements. The bad news is they were satisfied with a different manufacturing process."* With that in mind, Barnes highlights a three-step process to part qualification:

· The first step consists in defining your requirements and the environment in which you operate.

Ideally, everyone's dream is to be in a "new concept stage", where one thinks about AM more holistically so it is not just about one part and a system. You're thinking about how to improve the overall system. In that way, the requirements are a little bit less known, but you're going through the usual processes defined as requirements.

· The second step consists in having a **repeatable, reliable manufacturing process**

Taking examples on how they work, Barnes explains that at this level, they tell you exactly how to make the part. The idea here is to be able to use specifications on standards that exist and demonstrate that you can meet the performance of the part.

· The third step is to prove that you did it. "It's the validation piece", Barnes comments. That's exactly where certification comes in.

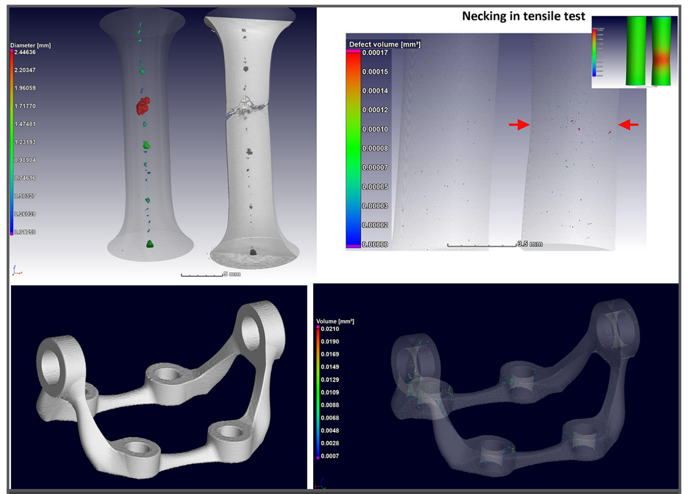
Your goal, regardless of the approach you use should remain the same: mitigate or prevent risks and ensure the same levels of fidelity that are seen in conventional manufacturing processes such as casting, forging, and machining.

II - The tools that can be used in part qualification

There is a non-exhaustive list of tools or devices that can be used to qualify parts. Some of them are often used interchangeably for the certification stage. Jabil's quality engineer explains that **mechanical testing** and **dimensional/visual inspection** often constitute part qualification.

"Mechanical tests include but are not limited to tensile, compression, flexure, fracture, surface roughness, part density, chemical composition, durometer, resistivity, flammability, impact, shear, etc. In addition, visual/dimensional inspections usually look for visible cracks/defects while dimensional inspections are aided by using hand measurement tools, including calipers, height gauges, pin gauges, etc. Dimensional inspections can also be enhanced by using semi-automated equipment, such as CMM or CT scanners", **Nostedt** points out.

CT scanning, for example, is one of the tools that we saw Conflux Technology use to qualify their 3D printed heat exchangers. It helps to detect part cracks and check for porosity to validate part density. It also enables users to verify that their equipment works properly, and their processes are sound and repeatable so that the same metallurgical and mechanical properties can be delivered on the 3D printed parts at any time.



X-ray tomography insights. Image: Science Direct.

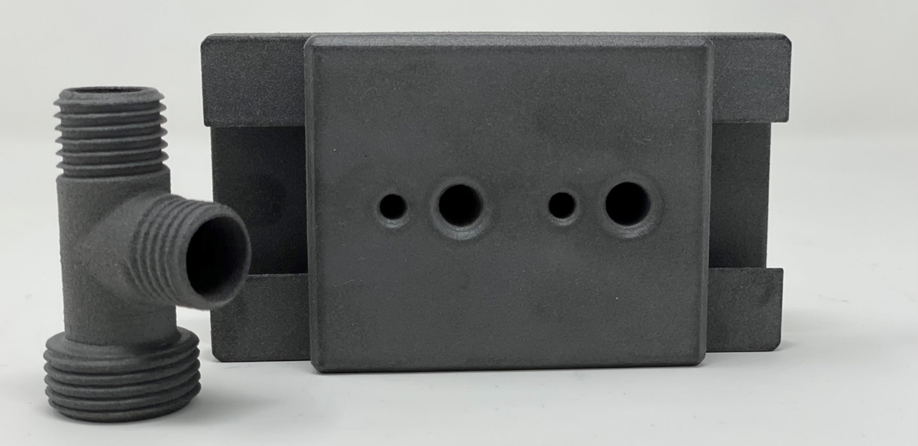
For **Nostedt**, it's important to keep in mind that the tools needed to qualify parts can vary based on the technology, especially since certain technologies require more testing processes than others. Furthermore, device measurement accuracy needs to be determined based on the part specification range. Test method validation (e.g. Gage R&R) is recommended to demonstrate the device is capable and consistent in keeping with application requirements.

No matter how diverse your range of tools is, Barnes warns part manufacturers to be cautious and to **avoid the trap of "fixed processes"**:

Some people are often trying to start with "fixed processes". This means that they try to lock down every parameter that they think they can control and the danger of that is that, it potentially locks out every improvement that comes along, he explains.

He shared the example of a part they once qualified for Airbus. That part was built on a 2-laser system and because that fixed process was written out of a 2-laser system, the part would require re-qualification to use a 4-laser system, for example. It can be the same size, the same manufacturer, the same brand, but it does not make room for improvements. "So, whoever owns the design authority has to be very clear about what the requirements are and the manufacturing team should not try to 'over-constrain' the part", **Barnes** outlines.

Ultimately, *"what you're looking for is a repeatable process to make the part"*, **Barnes** emphasizes. *"AM is a series of processes. So anything you can do, either from the design side through to the inspection side, gives guidance from which you can operate. If we just take the case of a legacy system, the question you will ask yourself is 'How do I show that I am going to have the same or better performance as the prior manufacturing process and will the performance out of the first part, be the same that I get thousands of parts later?'.*



PK 5000 Fluid Connector + Dovetail. Image: Jabil

III – What considerations across industries such as the military, automotive and aerospace?

Different parts may require different sets of parameters. That's a fact. Remember our conversation with Boeing's VP of AM, Melissa Orme, who urged OEMs to seriously take into account the "application vs regulator" consideration to do their homework.

As **Nostedt** explains, *"typically, there are more stringent requirements for validating a part that is designed for use in a regulated industry. The design authority must understand how the part is to be used, as well as the overall impact of a critical application if the part should fail. Typically, there are more requirements for a part with a higher criticality of failure.*

Requirements also can extend beyond the part itself into documentation, like equipment qualifications and training records that would not typically require documentation for a consumer goods product. It is in the part manufacturer's best interest, however, to ensure steps like equipment qualification are performed from a business standpoint to ensure production of the highest quality parts while keeping costs to a minimum."

It is not possible yet to discuss the specifications of part qualification for every highly regulated industry. However, to foster debate, and thus, establishment of qualification frameworks, OEMs in vertical industries should be transparent about the challenges they faced within their respective industry.

Parts produced for the automotive and aerospace industries, for instance, are not subject to the same environment and the industry defines the amount of testing that is necessary for a qualification event.

"The qualification process does not change but the level of data that might be required to meet the requirements of a given industry may change.

To test a spacecraft part, for instance, one will look at very low-temperature environments, low-oxygen environments. For an automotive part, we don't need such testing", **Barnes** points out.

In the same vein, as discussed with Barnes, 3D printed parts built in this industry have to withstand a very austere environment. Traditional parts purchased and used in naval applications for instance, have to undergo destructive tests to ensure their performance satisfies such austere environment demands. The problem with AM is that, despite its potential, there is no standard mechanism yet to assess whether or not 3D printed parts are more or less compliant with established military specifications.

For Barnes, there is plenty of parts that are needed but if they were to fail wouldn't result in loss of the system. Today, a lot of military organizations are struggling with parts traditionally manufactured as castings. And AM comes with a number of questions, the first one being the ability to meet the design requirements. That being said, beyond these manufacturing constraints, the military sector's primary concern right now remains **schedule**.

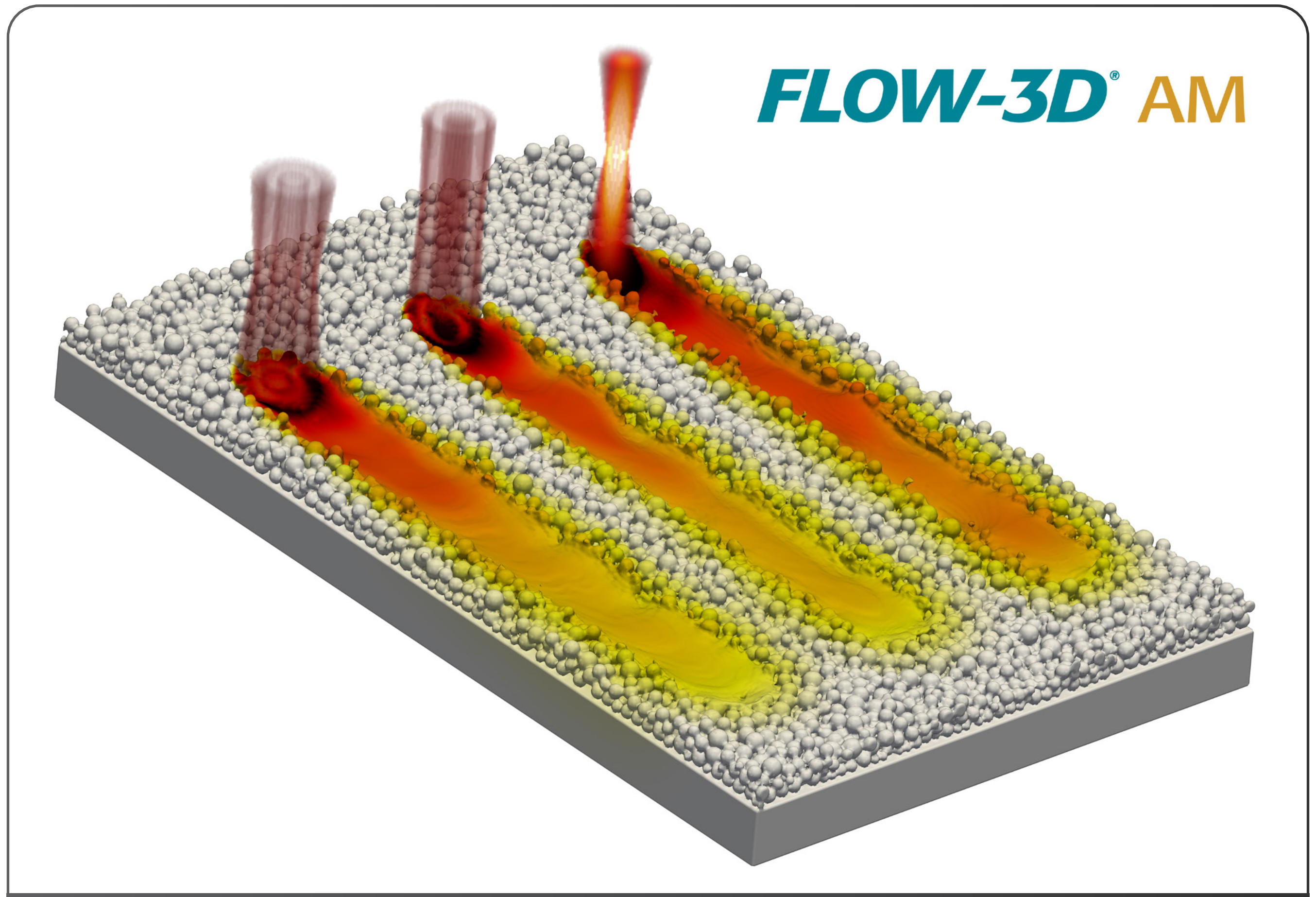
Conclusion

Qualification (and certification) will always remain an everyday topic in the industry whose frameworks will be continuously updated because the properties of the 3D printed part are determined by the material, the processing and the component geometry simultaneously. In the words of Nostedt, as different industries are continually adding part classification guidance documents to aid AM users in how to qualify parts, it's advisable to stay current on part testing processes.

Editor's notes

As a Jabil Quality Engineer for AM, Nostedt oversees the process of ensuring the quality of polymers and metals used in 3D-printed assemblies for the aerospace, medical and consumer goods industries. Additionally, he supports ISO qualifications, creates/updates PFMEA and control plans, and drives data analysis for continual process improvements. As a member of ASTM International, he has contributed to more than 90 documents or document revisions relating to the organization's guidance, specifications and standards relating to AM, including joint ISO/ ASTM documentation.

Barnes' *notable experience prior to founding TBGA in 2017 is his experience as a senior manager at Lockheed Martin's Skunk Works where he helped bring metal 3D printed parts to a number of experimental military aircrafts and where he led several other programs to foster the adoption of AM technologies. Today, with a team of ADDvisors®, TBGA's goal is to get AM qualified and in service across a range of industries.*



How can CFD make a difference in an Additive Manufacturing production ?

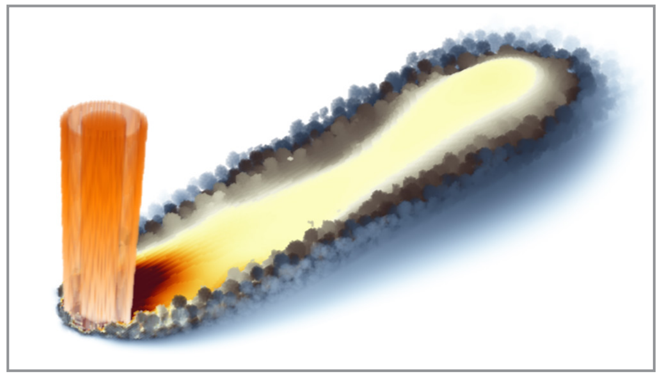
Any engineer designing a product must validate their decisions based on collected evidence, that's a fact. Sometimes, a specific consideration such as the economic, performance or aesthetic reason often weighs heavily in the balance. To ensure that decision is accurate and time efficient, the engineer has to rely on a number of software solutions such as **Computation Fluid Dynamics (CFD)**.

If I had to explain CFD in simple terms, that's exactly what I would have said. The thing is, this explanation can apply to many software solutions. To understand the unicity of CFD and to speak a language that is familiar to engineers, I would like to use **Gabrian Balelang**'s words. The Solutions Engineer at Conflux Technology defines CFD as *"a numerical analysis tool which can be used to analyze fluid flow. [It] enables engineers to visualize, analyze, and optimize fluid flow within their products."*

This means that design efficiency can be calculated at any time, in any condition virtually thanks to CFD. Apart from testing, problems related to fluid flow, heat transfer, turbulence or materials can be addressed using CFD and other hurdles that are slowing down the move from design into production.

Things were not that easy in the past where expensive physical testing was the way to go to address issues. That meant a lot of testing using prototypes with lots of recalls and failures.

An *"alternative strategy to optimize fluid flow within/around a product involves running an*



Gabrian Balelang
Solutions Engineer at Conflux Technology

iterative loop of experimental tests. A physical model of the product must be produced. The product is placed into a wind tunnel/flow rig equipped with a set of sensors to capture flow characteristics within/around the product. At the product development phase, iterations of design evolution are tested as part of design optimization. This process is usually time-consuming and relatively expensive compared to CFD approach.

Complex CFD models also require experimental tests to correlate the model. CFD model correlation involves building a CFD model and testing a physical model at the identical condition to assess the discrepancy between the CFD model and the experimental test. CFD models can then be adjusted to address discrepancies between physical test results and CFD predictions," Balelang outlines.

That being said, these numerical analysis methods may not be new to you if you already produce parts with traditional manufacturing processes. However, if you're using AM, there are a number of differences, challenges and various use cases that are worth highlighting with CFD. That's exactly what this article ambitions to achieve.

Before we discuss this topic, one of the beliefs I got wrong is that CFD was similar to **FEA, short for Finite Element Analysis.** FEA consists in constructing a numerical scheme to solve a problem whereas CFD refers to an application area of computational methods. That's why, as one will learn below, FEA can help solve some of CFD problems.

CFD in AM: The main steps of CFD in AM

In product manufacturing that involves traditional manufacturing processes, engineers have to follow three steps to perform a CFD analysis: **pre-processing, processing and post-processing**. These steps are the same for product development that involves AM.

Pre-processing can help to define the parameters that will be used in simulations. In other terms, it's about defining the model. It includes preparing the geometry, material, and process parameters, as well as numerical settings such as mesh or the number of physical phenomena to be accounted for.

In processing (solving), the meshed geometry is imported into Solver where the required physics model and boundary conditions are applied to the model. This step consists in running the simulation.

During the post-processing stage, results files are imported into the post-processor where the flow can be visualized and data can be extracted from the simulation model. Information such as melt pool size or temperature field, or more complex output such as porosity, surface roughness, temperature gradients, cooling rates, or even spatter potential can be extracted.

CFD in AM: A few examples of applications where CFD has made a difference

So far, we've seen CFD made a difference in **thermal management, cavitation, turbomachinery and structure interactions.** Cavitation applications for example include pumps, valves, compressors and fuel injectors are subject to vapour bubbles which lead to noise and vibration. To prevent this issue, a range of CFD analyses and simulations can be performed to make sure the design doesn't produce a model which is prone to cavitation in any of the relevant components.

Known for reinventing high-performance heat exchangers with AM, Conflux Technology uses CFD in design development. *"Conflux can iterate through design at fast-paced to achieve optimal solutions. Several design iterations can be analyzed without the need to produce multiple physical models and perform multiple experimental tests. Flow within Conflux heat exchangers can be visualized and analyzed with the use of CFD. Unique flow characteristics around complex core geometry and manifolds can be better understood and optimized to maximize performance. Heat transfer, internal flow, external flow, and combustion models can be built using CFD software packages,"* Balelang told us.

Another example that is worth mentioning is the one of **Domin**. The hydraulic solutions company has been using CFD as a cost-saving tool. It has created various Computational Fluid Dynamics models for the dynamic simulation of pumps to observe cavitation risks, as well as static simulations of valves highlighting areas of inefficiency in fluid flow.

The image above shows fluid streamlines in a static Computational Fluid Dynamics model of a valve body. Credit: Domin.

The iteration of designs can now be rapidly validated digitally, saving time and cost compared to when this had to be done with physical bench tests. The image above describes one such example. It is part of a study of a miniature rotary actuated valve developed at Domin. Computational Fluid Dynamics modeling led to a 40% reduction in torque from flow-force optimization around the spool whilst maintaining flow capabilities. It is with the extensive use of modeling techniques, such as those shown here, that Domin Fluid Power designs and develops high-performance products with the flexibility and complexity of AM, the company says.

On another note, for **Marcin Serdeczny**, CFD Engineer at Flow Science, the companies that use CFD, or more specifically their software ***FLOW-3D AM***, are more often research and development focused and work in applications, such as aerospace or defence, that have less tolerance for defects or failure.

"In short, those who are using CFD are usually of scientific disciplines and are looking into alloy development or mission-critical applications, whereas those who are using FEA tend to be more consumer-level shops that are running high volume production. On the R&D side, there are simply less people working in this domain, and they tend not to share their research tools as freely," Serdeczny comments.

Marcin Serdeczny
CFD Engineer at Flow Science

CFD in AM: What AM process and what challenges?

Among the wide range of AM processes that are used on the market, CFD is mainly harnessed with metal 3D printing processes such as **Selective Laser Melting/Laser powder-bed fusion and DED processes.** While we haven't seen any applications yet – mostly due to confidentiality reasons surrounding commercial contracts, Serdeczny explains that the solver of their software solution can be used for material extrusion and binder jetting – in addition to powder-bed fusion and DED.

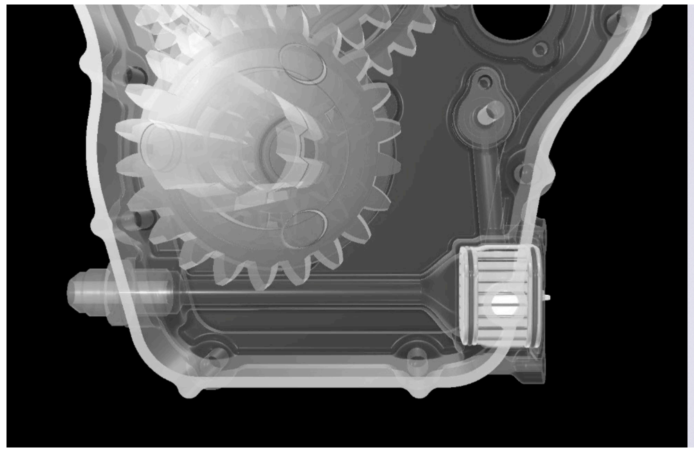
The main concern with AM and SLM in particular, is to be able to achieve a fully dense part out of the interconnected tracks – hence the right choice of process parameters to get a porosity-free component.

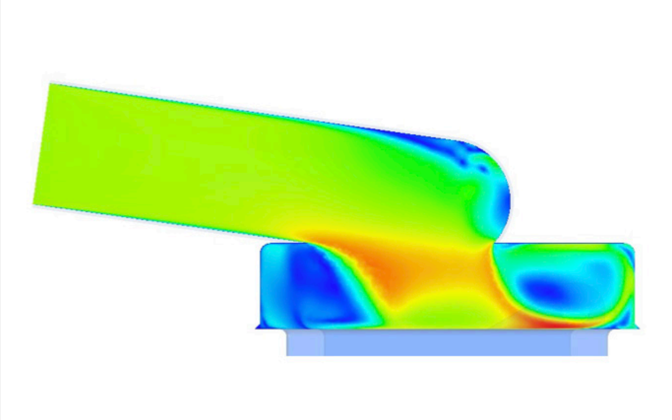
"Broadly speaking, [it's about ensuring] that the combination of process parameters, geometry, and material is right for the manufacturing of a product. For example, in high-pressure die casting, we may want to change the design of the runner system that delivers the molten metal to ensure uniform and defect-less filling of the mold. In laser welding, the choice of laser power, welding speed, and material thickness is important to obtain a strong joint with minimal heat-affected

zone and no pores. Additive Manufacturing has a large number of settings that can be varied, so the choice of parameters to ensure a defect-free print is not easy. The metal 3D printer user needs to think about laser parameters, such as power, scanning speed, path, spot size, or even a beam shape, as well as powder type, layer thickness, part orientation, etc. Finding a correct combination via experimental trial and error is tedious and costly. These efforts can be replaced or at least greatly reduced by using computational fluid dynamics (CFD) simulation," **Marcin Serdeczny**, CFD Engineer at Flow Science explains.

While Serdeczny is right, the first challenge to address these issues with CFD is that these numerical analysis methods – no matter how user-friendly they are –, cannot be used as a plug-and-play device. Not only every CFD solution available on the market comes with its share of complexities but it is known that historically, **modeling AM processes has been largely focused on part-scale simulations from a production standpoint** where finite element (FE) codes are usually employed. According to **Serdeczny**, this gives users the ability to make part-scale design decisions (support structures, topology optimization), without the need to consider physical phenomena at the individual layer where there are computational assumptions made about the track geometry, thermal cycling, etc.

*"CFD is looking at the problem from a **meso-scale perspective** where the focus is on a few tracks and layers and there are no assumptions made about the geometry or heat cycling. However, by incorporating so many additional physical phenomena, and not making assumptions, simulation runtimes become higher than in FE constructs. From our experience, most AM companies are doing on the fly design changes which do not require such rigorous and accurate simulations, so the FE solution is sufficient,"* Serdeczny completes.





First image shows a compact cartridge heat exchanger produced by Conflux Technology. Second image shows the compact cartridge heat exchanger in automotive gearbox application. Third image shows a manifold simulation. No flow optimisation of the manifold was carried out as part of this case study, hence the less than optimal flow distribution into the cartridge. With proper CFD effort, better flow distributions can be obtained. Credit: Conflux Technology.

Although efficiency, flexibility and practical feedback are the main benefits of CFD we have learned so far, it's important to mention a couple of challenges AM users might face during the use of CFD per se. These challenges include for instance, **meshing and computational resources issues** for complex 3D printed parts as well as **inherent surface roughness of 3D printed parts and CFD correlation.** For Balelang:

"Building CFD model requires the geometry model to be discretized into elements. During CFD solving process, mathematical equations are solved, and information is passed between each of these elements. The process of discretizing a geometry into elements is called Meshing. For a very complex and intricate component, which usually is characteristic of AM component, meshing can be challenging. The mesh needs to capture all surfaces and volume of the component and still adhere to 'acceptable' mesh quality. Capturing appropriate inflation layers for intricate geometry can also be difficult. Usually, complex geometry will require a fine element volume which results in a high number of meshing elements leading to computationally expensive process."

On another note, it is no secret that AM parts come with inherent surface roughness which results from process parameters and build strategy of the part selected.

"For components produced by SLM, the energy density/melt pool produces roughness on the surfaces of the component. Downward-facing surfaces tends to have higher roughness.

Geometry produced by CAD software for CFD model generally does not capture the inherent surface roughness produced during the build of the component. This inherent surface roughness can affect the performance of the component. For example, surface roughness can result in turbulence and higher pressure drop. The effect of surface roughness is not captured by CFD simulation which usually leads to discrepancies between CFD prediction and experiment results. This highlights the importance of CFD correlation for AM component," Conflux Technology's expert adds.

One thing is certain, CFD is best suited for applications where material flow is an important aspect of the process. We see this in most additive processes where raw powder or wire is melted down to a liquid state and deposited to form a 3D part, Flow Science's expert completes.

Conclusion

If CFD was already an essential tool to the design engineer, its importance has proven to be more impactful with AM, as it enables a high rate of both complex design iterations, and validation in meeting performance targets. However, the fact that most applications only highlight the use of LPBF may give the impression that CFD's potential may be limited to certain technologies. Part manufacturers and AM users now need to go the extra mile to demonstrate how CFD can be applied in product manufacturing involving other AM technologies. That's in any case, the next area we hope to see developed.

Last but not least, even though CFD does reduce the number of experiments needed in prototyping and testing (and this includes the overall cost and risks associated), one should never forget that CFD does not replace real-world testing.

A few words on the contributing companies

Conflux Technogy is an AM company that specializes in the development of thermal and fluid applications. The team utilizes CFD in the product development phase of heat exchangers. The company explains that a heat exchanger design involves maximizing heat transfer with the minimum pressure drop possible. Even flow distribution into the heat exchanger core is also key to achieving maximum performance. CFD is used by Conflux engineers to optimize heat exchanger core performance and assess flow distribution from the end tank/manifold into the heat exchanger core.

Flow Science develops ***FLOW-3D AM***, a CFD simulation solution that AM manufacturers can use to develop data sets of process parameters that yield good prints without needing to spend hours of human time in the lab. Accurate predictions of the melt pool shape allow manufacturers to avoid lack-of-fusion porosity that can occur between the layers and hatches and reduce density. By comparing the simulated temperatures inside the melt pool, resulting from different sets of process conditions, a user can judge which recipe may lead to higher thermal stress during the print. Predictions of the thermal gradient and cooling rate at solidification supplemented by experimental tests allow our users to target specific microstructure. ***FLOW-3D AM*** can also be used to tune low-fidelity models that are less accurate but faster and operate on a part scale level to, for example, predict thermal warpage. Importantly, not only AM users and material developers benefit from ***FLOW-3D AM***. R&D departments at OEMs also use ***FLOW-3D AM*** to improve their equipment. For example, laser producers look at the influence of beam shaping on the melt pool behavior during the process, so they can suggest to their users' predefined intensity profiles that minimize spatter. Laser scanning path and velocity control can be improved by simulating small sections of the print such as corners or overhangs and analyzing the best combinations of parameters. Finally, ***FLOW-3D AM*** can contribute to new technologies being developed, including multi-laser AM machines or blue and green laser powder bed fusion.

Post-processing

KEY CONSIDERATIONS TO TAKE INTO ACCOUNT FOR DEPOWDERING OF PLASTIC 3D PRINTED PARTS.

Among the post-processing tasks that have often been considered modest priorities by OEMs, there is ***depowdering****. The thing is, a lot of consideration© has always been given to depowdering of metal 3D printed parts, letting vertical industries adopting Additive Manufacturing (AM) with little information on how to properly handle this process with plastic 3D printed parts. The article below ambitions to change that by discussing 4 key considerations to take into account for this specific post-processing task. To do so, we have given the floor to* **Andreas Hartman**, founder and CEO/CTO of Solukon and **Philipp Kramer**, CTO & Co-founder of DyeMansion.

It is no secret that 3D printed parts that are coming straight away from the 3D printer can already be utilized. However, for those parts to deliver value and achieve the desired performance, other post-processing steps need to be undertaken. For **Andreas Hartman**, founder and CEO/CTO of Solukon, these post-processing steps can *"be divided into four categories: unpacking, cleaning (= depowdering / removing residual powder sticking (sintered) on the part surface), surface finishing (chemical or mechanical smoothing, polishing, blasting, infiltrating or milling, [coating and spray painting]) and coloring/dyeing."*

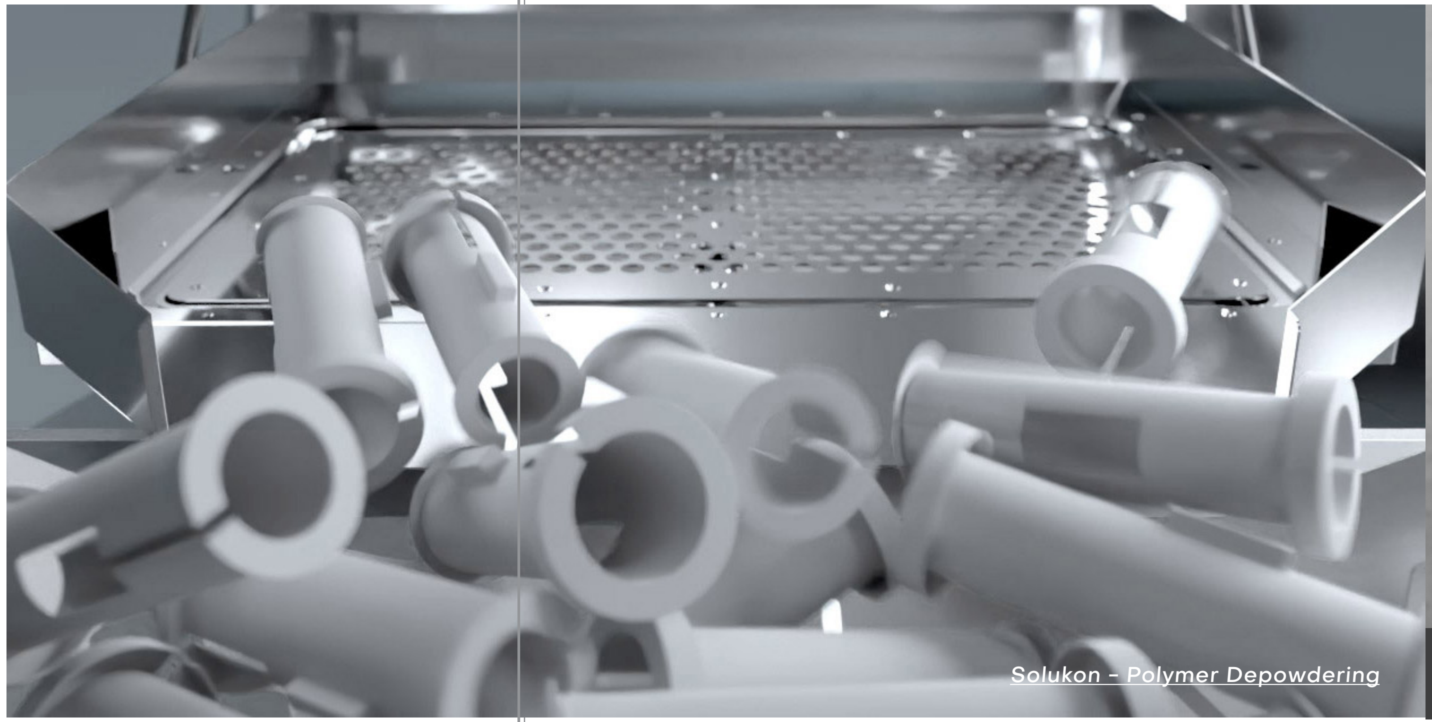
"Compared to Metal AM, there are even more processes for surface treatment and finishing in the post-processing of polymer components. This is because often the main goal of post-processing for polymer parts is a perfect resolution, look and color (automotive interior, glasses etc.) in addition to optimal functionality," Hartmann adds.

When it comes to depowdering of parts, the concept is often interchangeably used with **unpacking** and **cleaning** – which is not entirely correct. This terminology may vary from one machine manufacturer to another depending on what their machine can do. For most manufacturers, depowdering which is the removal of powder from 3D printed parts is directly followed by cleaning, and can be done within the same machine. However, cleaning can also be done manually after the depowdering phase using brushes or in an automated way, using glass bead blasting. Unpacking the part on the other hand, means freeing the part from the powder cake; it often involves vacuuming and clearing away powder. This step occurs right before the depowdering and cleaning processes.

Interestingly, the depowdering of plastic 3D printed parts can easily be understood by comparing the same process performed with metal 3D printed parts. That's why, we have identified 4 key considerations that may help part manufacturers to better understand this process.

1- The AM processes that work with depowdering

This is quite obvious, right? What AM process may require a depowdering of a plastic 3D printed part? For **Philipp Kramer**, CTO & Co-founder of DyeMansion, plastic parts manufactured in powder-bed technologies like Multi-Jet Fusion, Selective Laser Sintering (SLS), Selective Absorption Fusion [SAF™] and High Speed Sintering (HSS) are best suited for cleaning and surface finishing. *"With those technologies the post-processing consists in removing excess powder in a cleaning step, delivering the right surface finish through blasting or vapor smoothing and coloring the parts in the desired color,"* he adds.


Solukon - Polymer Depowdering


Philipp Kramer,
CTO & Co-founder of DyeMansion

2- The depowdering technique

Here again, the depowdering technique is quite different from what one uses to see with metals. Two differentiating factors shared by Hartmann and Kramer are **quantity** and **weight**:

3D printed plastic parts need to be depowdered in quantity whereas in metal depowdering only one or a few parts are mounted on one build plate. A plastic build box (e.g. of an EOS P7) often contains many different components of various shapes, structures and sizes that need to be unpacked and depowdered simultaneously.

The **main challenge in post-processing of polymer parts is** not getting complex inner structures powder-free (like in metal) but carefully and automatically **loosening the parts from the powder cake and targeted blasting with glass beads without damaging the fragile and filigree parts.** Especially because the plastic parts are not firmly attached to a build plate like in metal, but jumbled up in the build box and later in the rotation basked they need to be handled very carefully to avoid part damage.

In other terms, metal parts that are usually fixed on a large built plate, are depowdered before being removed. Therefore, either the built platform is rotated, or manual blasting is used. Plastic parts are lighter, more flexible and produced without support structures or a built plate. So, automated batch blasting processes in a basket or continuous belt are very well suited.

Another challenge may come with the use of glass beads. Solukon's spokesperson warns that during the depowdering process, the glass beads get statically charged and adhere to the component. These adhesions must be released again with ionized air. Furthermore, during the process, more and more powder gets into the blasting material which can result in an undesirable discoloration of the parts due to thermal processes (the surface gets hot when plastic particles hit the surface). Therefore, when depowdering polymers, special care must be taken to ensure that the glass bead quality remains high (as little powder residue as possible in the blasting material). To keep glass beads quality high and refreshing rates low, some systems like the Solukon system use ultrasonic screening.


Andreas Hartman, founder
and CEO/CTO of Solukon

In any cases, one should keep in mind that *"depowdering in the polymer sector is normally the final cleaning process in postprocessing, whereas in metal processes the part may be contaminated again during support removal, for example, and must be fine-cleaned again at the end,"* Hartmann outlines.

3- The ideal machine

This is probably the most difficult consideration as there are a lot of options on the market and this article does not aim to study the unique features that set them apart. If each solution comes with its share of strengths and limitations, it's important to keep in mind that applications, volume production, and costs are the key factors that may drive your choice for one solution or another.

"Some basic manual blasters might be suitable for both metal and plastic parts. Once you use automated solutions, there are major differences in the machine setup and the process as well. So, it is recommended for users to [rely on] systems that have been designed and dedicated to either metal or plastic. Handling metal or plastic powder requires quite different technological setups," DyeMansion CTO outlines.

4- The safety measures

Eliminating all risks related to health and safety has often been one of the major goals of machine manufacturers developing automated solutions. This goal has become a top priority given the fact powder handling of metal 3D printed parts could be explosive, and simply toxic for the operator.

Such hazardous dust can also be a risk for the operator's health during the unpacking of plastic 3D printed parts due to the fact that they often manually uncover the parts from the powder cake.

“The creation of clouds of powder that could be inhaled is unavoidable [hence the need of] respiratory protections or dust-extraction units. Since the dimensions of the build job can be very large, manual unpacking in protected gloveboxes is difficult or impossible due to the limited accessibility.

Since a high throughput of components is required in large production facilities, a lot of powder is also processed. Reducing human contact with hazardous powder is an even more pressing concern in the polymer field than in the metal field. The dust-free production must be the goal with regard to occupational safety and health protection. This calls for automated, sealed and consistent postprocessing of polymers without any manual intervention,” Hartmann alerts.

In the same vein, sustained inert material handling is often required for metals to avoid contamination with oxygen. Since polymer powders are not as reactive as certain metal powders, protective gas inertization is not usually used.

“Gentle cleaning processes with a low risk of dust formation and charging of the powder, a system design free of ignition sources and suitable dust extraction can sufficiently reduce the explosion hazard of polymer powders. Unpacking and depowdering only take place when the polymer parts have cooled down and therefore no inert gas is required. Oxidative processes only play a role in the build process and cooling, not in unpacking or depowdering,” Hartmann concludes.

A few words on the contributing companies

DyeMansion GmbH provides connected & fully integrated end-to-end solutions for all finishing steps for 3D-printed polymer parts. They specifically offer two different systems for the depowdering step. The classic Powershot C, which is an automated solution for handling small to medium batches, and the Powershot Performance C/Dual, which is dedicated to larger batches, digitally and physically integrated production setups. The latter comes with all digital interfaces and process control that is required for a full traceable manufacturing and can combine the cleaning and surfacing in one system. Both systems can also work with the PolyShot Cleaning process, which offers several advantages over traditional depowdering with glass and has been developed specifically for 3D printed plastic parts. The company believes that the right gentle depowdering plays a vital role in achieving reproducible results in surface smoothing and coloring.

Solukon Maschinenbau GmbH provides automated depowdering solutions for Additive Manufacturing. The company believes that what differentiates polymer depowdering from metal depowdering systems is the need for a particularly gentle part handling. For the depowdering of polymer parts, they offer the SFP770 for parts printed on an EOS P 7, P1 and P5. Globally, the SFP770 is a one-of-a-kind post-processing system. It is the only one on the market to include both an automated unpacking station and a cleaning station for SLS components in just one system. What makes the system unique is not only the combination of the two process steps unpacking and cleaning but also the fact that the system is able to accommodate the whole build box of a polymer printer. The SFP770's process includes the loading, unpacking, transferring and cleaning (depowdering). To ensure optimum cleaning results, the powder material is not separated from the blasting material by gravity separation in a cyclone, as is usual in standard blasting systems. Instead, Solukon uses a very compact ultrasonic sieve to clean the powder precisely from the blasting material (glass beads). Thus, practically no blasting material is lost and only very clean glass beads are used for cleaning.

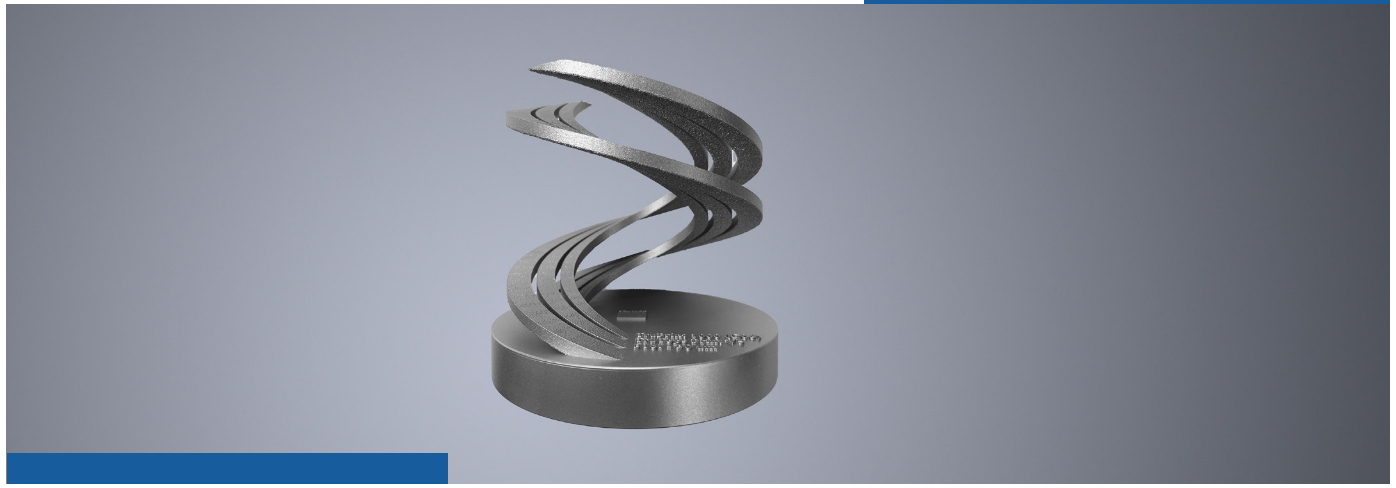
Solukon thus enables a closed cleaning process and for the first time gets significantly closer to the idea of a dust-free shopfloor. In addition to economic efficiency, occupational health and safety is significantly improved and the acceptance of 3D printing in the industry is once again increased.

Solukon - Polymer Depowdering

Applications

TRUMPF

THE QUEST TO AVOID OR MINIMIZE SUPPORT STRUCTURES IN ADDITIVE MANUFACTURING



There are two types of people working with 3D printed parts: those who know how to deal with support structures and those who don't. Last year at Formnext, while walking across the aisles, I saw a couple of parts that were built without support structures and a couple of them where they seem to be necessary. It got me thinking: should the operator build a "support structures" strategy?

Strategy might be a strong word but in Additive Manufacturing, I came to realize that despite this advocated "out of the box" philosophy, everything has to be thought twice including the things you least expect.

In this case, the words "support structures" themselves are quite explicit. Described by many in the industry as a "necessary evil", there are structures that support (pun intended) your component during the AM process. The goal? Ensuring that the **part comes out of the 3D printer without any deformation** caused by sagging. Nevertheless, the upfront thinking process is worth having once you realize that they might actually affect the price of your part.

The article below aims to discuss:

- What AM processes may lead to the formation of support structures (SS) – in case you're new to AM – and most importantly, why do we need them?
- What is that cost consideration?
- And how should we approach a "support structures" strategy?

What AM processes may lead to the formation of support structures (SS) & why do we need them ?

First and foremost, *"support structures are needed to connect the parts to the build plate. Without any connection, the recoater would push the molten material to another position. In addition, supports are needed to absorb material tensions that occur during solidification of the molten material. Furthermore, support structures dissipate heat from the part to the baseplate and thus prevent overheating,* **Dominik Maurer**, TRUMPF Additive Manufacturing, Application and Process Development, states from the outset.

Anyone with a slight experience in **FDM 3D printing** may have already come across an occasion where they have made use of SS. Since the technology process works by depositing layer over layer of filament, each new layer must be supported by the layer beneath it. It's physics!

That "fixation" reason also applies to SLA and other resin-based technologies such as **DLP** and **LCD**.

Surprisingly, while SS are not required for SLS technology, they are required for **DMLS (Direct Metal Laser Sintering)**. Furthermore, given the high temperatures in the build volume, they also ensure heat is evenly dissipated.

Needless to say, the formation of SS implies certain specifications that are peculiar to each technology:

"Support structures are needed for different reasons depending on the technology, and in some instances are not needed at all. For example in Selective Laser Sintering (SLS) there are no support structures, parts float free in adjacent build powder allowing you to build complex parts with little geometric compromise.

In the case of Stereolithography (SLA), i.e. real vat-based top-down no-membrane, very minimal supports are needed as the build process is largely buoyant, and the supports you do use are very fine point, material efficient, and easy to remove. Generally, they are required to initiate, stabilize and then precisely fixture emergent cross-sections. With SLA you can get away with very shallow surfaces and large self-supporting spans.

When a membrane is introduced as we see in the case of DLP, LCD, and some laser-based systems the supports become more rugged and robust, depending on the type of membrane as well as the nature of the geometry.

With FDM and/or general plastic extrusion systems, supports are pretty extensive as you are building in air and the effects of gravity as well as process tension from the cooling shapes drive the need for extensive anchors. That being said, there are tricks deployed here ranging from design modification to special process settings to interact with the interfaces to reduce the density as well as improve the removal process.

In the case of Direct Metal Printing (DMP), supports are actually multi-functional. Not only are they generally needed to initiate down-hanging geometry, they actually serve two functions both as fixtures to hold down cross-sections from the stress accumulation during the build process to transferring heat out of the geometry during building.

Recently, as engineers better understand the complex physics involved in melting and re-solidifying powdered metals we have seen remarkable step changes in support reduction, to the point now where it's often possible to get rid of the bulk of them. This has a huge impact on material consumption, build times, and downstream labor. But the biggest impact is on design. ***"The best support is no support" philosophy*** *– enabled by advanced process development and vector level control – is expanding the design space. Design is a fundamental value proposition of AM,"* **Patrick Dunne**, Vice President, Application Innovation Group, 3D Systems, states.

What is that cost consideration?

We are often told that post-processing is the manufacturing step that increases the final cost of the 3D printed part. By saying that, it might be easy to overlook the other (minor considerations) that keep increasing the cost in the end.

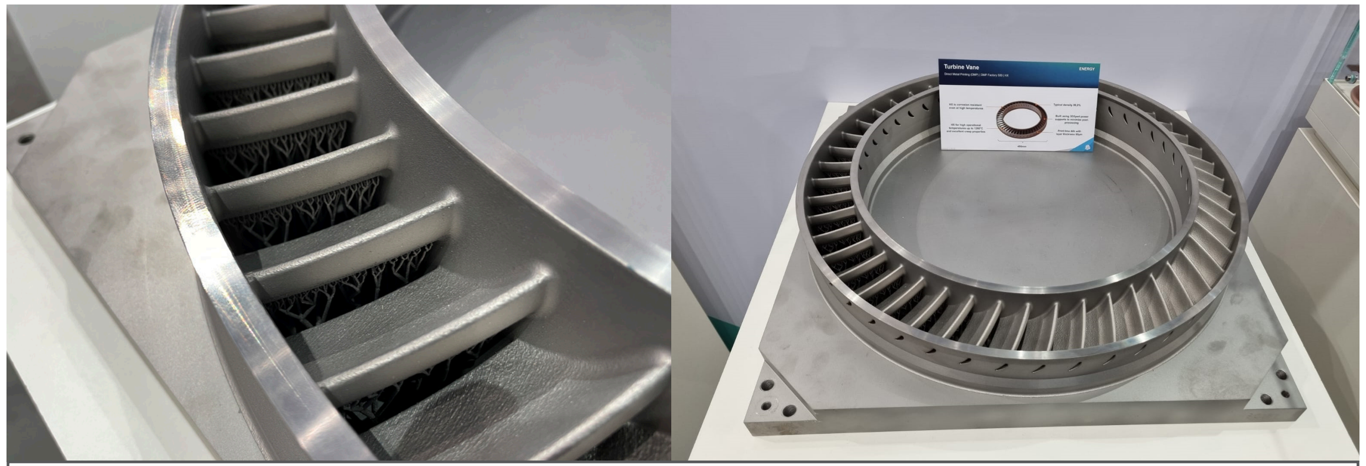
Take FDM for instance, since SS require additional printing material, this somehow increases the production cost within this process. Not to mention that whoever says SS means some additional work at the post-processing level, and this – regardless of the AM process used, which means more cost in the end.

On another note, as we advocate more and more the need for "greener" manufacturing processes, let us remind that SS also somehow means more *"material waste"*. *"Some materials require more support than other materials due to differences in the internal stresses of the material when solidifying. For example, many aluminum alloys require rather few supports compared to stress-intense materials like titanium alloys,"* **Maurer** says.

The problem is, since the manufacturing process is the primary driver of SS, engineers are left with one main option to avoid or minimize their formation: **improve their part design.** An idea that Dunne confirms: *"[the] presence [of SS] is driven by the combination of hardware and manufacturing process, materials, part design, and of course, build orientation. Combining DfAM with optimal orientation and fine process control capabilities can reduce them massively – in some instances to zero!"*

The "support structures" strategy

Since it all begins in software, adopting an SS strategy through DfAM means that the engineer should integrate the SS into the design in a way that fulfils



Turbine vane produced using breakaway supports. Credit: 3D Adept. Images taken on 3D Systems' booth at Formnext 2022.

multiple functions.

“Ideally, that is done by designing the parts without any critical overhanging surfaces that have to be supported. Conventionally, all surfaces with an overhanging angle of lower than 45 ° to the baseplate had to be supported. Due to intelligent process parameters for the overhanging areas (the so-called “downskin parameters”) it is now possible to print overhanging angles to around 25 ° without any support structures. With special adjustments of the downskin parameters it is sometimes even possible to print angles down to 10 ° without any support structures. As the surface quality of these low angle surfaces is comparably bad and the special downskin parameters often go in line with additional print time, surfaces of lower than 25 ° are still to be avoided in the part design if possible,” **Maurer** explains.

By taking the specific example of LPBF where the need for support structures depends in particular on the geometry of the part and the print material, he specifically adds:

“Generally speaking, the design of the parts should be suitable for the LPBF Process. There are a lot of guidelines like minimal wall thicknesses, maximum hole diameters or the lowest support-free angle. At TRUMPF, we offer design for LPBF trainings to internal and external design engineers to enable them screening potential LPBF parts and often redesigning the parts suitable for the LPBF Process.

In most cases, part design is done with conventional CAD Software. There are many useful features for the designers to optimize their parts for LPBF and to reduce support structures. But these features do not replace the general understanding of the design guidelines for LPBF of the design engineer.”

This seems to be a lot of constraints for a technology that should allow “design freedom”. If sometimes, holistic experience teaches the best lessons, here are a couple of ideas that we would like you to consider:

- Use a software solution that allows for the control of supports in your 3D printed parts

- Ensure control over build parameters in the area of the part’s overhang feature

- According to 3D Systems’ expert, simple tricks like self-propagating features that don’t need supports or even embracing them and making supports permanent and integrated can help a lot. By making the supports part of the design and left in place you remove that labor required downstream

- Otherwise, in-situ monitoring could be another option. By using a contactless recoating system for instance, the engineer can remove the need for supports

- Something interesting we saw at Formnext 2022 was a solution brought by machine manufacturer Duplex. By 3D printing from above the part and below at the same time, the lower 3D printing head becomes an answer to support since it essentially is the SS. As you may see in the video, the nozzle itself supports overhanging features as they are being fabricated.

- Lastly, another recent example that popped up on the market focuses on the thermal management of the melt pool. With their Free Float solution, for example, SLM Solutions gives options to users to choose between profiles depending on the part quality and support elimination desired.

Concluding thoughts

SS are definitely an interesting area of development for AM as new solutions are being developed to achieve “no support” manufacturing. While they may affect the design, the material and even the post-processing decisions in AM, they reinforce the idea that there is no “one size fits all” solution in AM.

IS THERE A SERIOUS FUTURE FOR WOOD 3D PRINTING ?

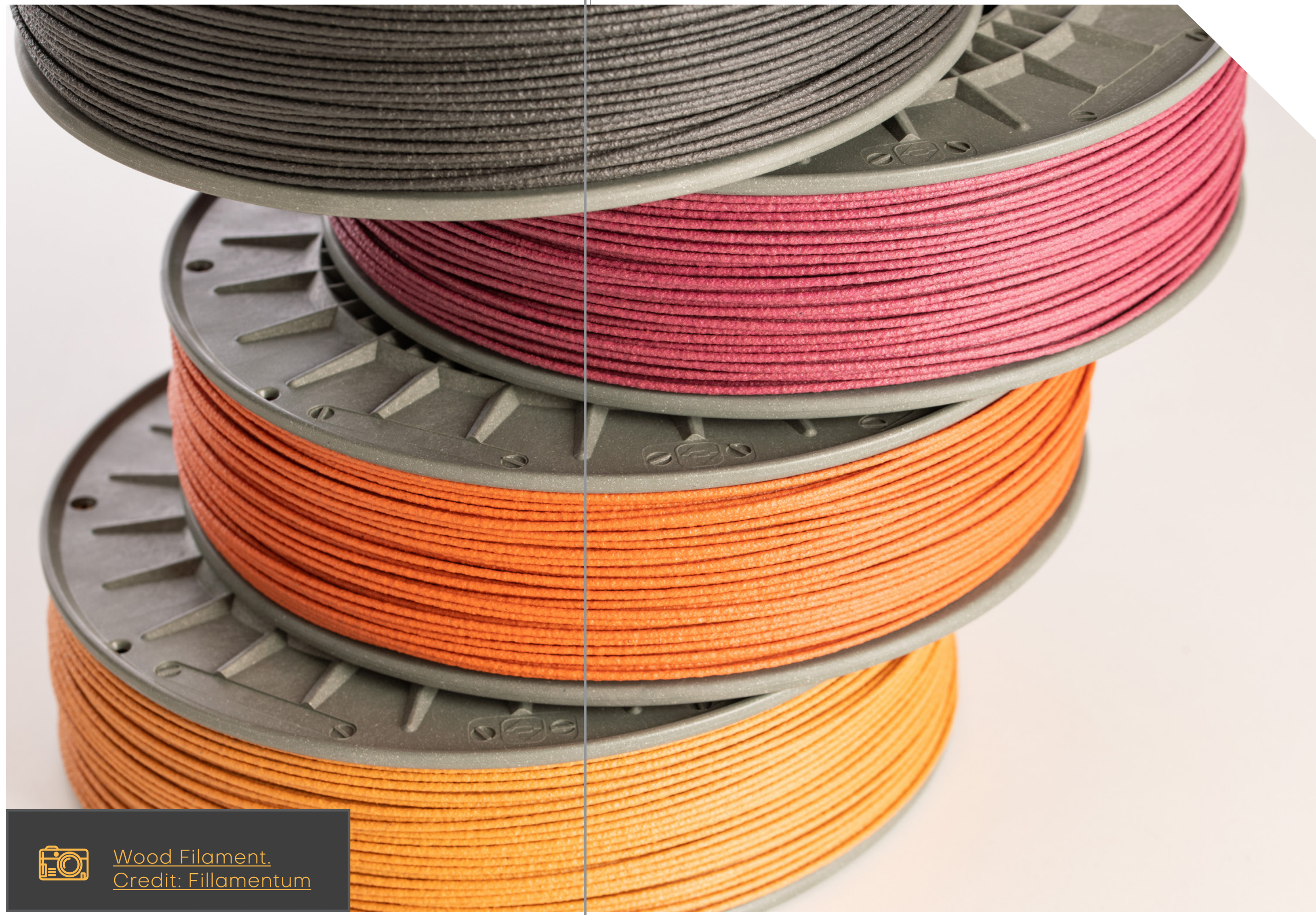
It's been a decade that wood 3D printing has been around. Yet, it takes the launch of Forust™, Desktop Metal's subsidiary dedicated to end-use wood parts, to question the future of this material in this industry. ForustTM claims that their binder-jetting technology can achieve high-volume of end-use wood parts. Is that what industrialization of wood 3D printing will look like ?

Ten years ago, wood 3D printing was assimilated to the use of wood filaments with an FDM 3D printer. Simply put, new or waste wood was milled to a fine powder, and thereafter mixed with binders such as sodium silicate, cement, cellulose, gypsum, plastics, and adhesives to create a filament. Over the years, researchers with an interest in this material came up with new material solutions that could be used with other technologies – and sometimes, that would allow for production in an environmental-friendly way, without cutting trees.

Type of wood materials

As said above, apart from FDM 3D printing that processes **wood filament**, wood can also be processed with **binder jetting**. In Forust™' case for instance, the process is based on a patented single-pass binder jetting AM technology which upcycles waste byproducts from wood manufacturing (cellulose dust) and the paper industry (lignin) and re-materializes functional wood parts through high-speed 3D printing including digital grain throughout the part. The material is then processed by the 3D printer in the form of a **powder**.

In addition to powder, wood can also be available in the form of **pellets**. Industry SE, a machine manufacturer based in Sweden is utilizing this type of material for their 3D printers. **Jonas Carlsson**, the company's CEO explains that this process is interesting both in terms of "material costs and print efficiency". *"We work mainly with Stora Enso, one of the largest forest- and wood companies in Sweden. They have developed a material called* ***Durasens 50 and 30****. The Durasense 50 contains 50% of sawmill dust, and the Durasense 30 contains 30%. Stora Enso has a MAGNUM 3D printer installed at their facilities in Hyltebruk, Sweden. They have used our machine for developing the material, and also do production within their OneLoop concept. [A bar chair can be printed in less than 2.5 hours for example]. It is possible to reuse this material up till 20 times. After the 3D printed product has reached its end-of-life, you simply shred it into pellets again and print it in the MAGNUM again,"* he adds.



Wood Filament.
Credit: Fillamentum

Furthermore, in Israel, another team of scientists is developing wood in its **liquid form** for 3D printing. **Shany Barath**, Disrupt.Design Lab (D.DLab) told 3D ADEPT that *"certain materials have been developed within the Disrupt. Design Lab (D.DLab) at the Technion Israel Institute of Technology. This development process involves design-led iterative exploration aimed at creating a printable wood paste. Additionally, collaborative efforts extend to industry partners like Daika Wood, involving experimentation with their waste-based materials. The material arrives as a powder, and through experiments with different formulation ratios, we define the suitable paste for our printing requirements. Utilizing natural binders, sawdust derived from industrial waste can be efficiently repurposed for applications in 3D printing. The employed printing technique hinges on the principles of Liquid Deposition Material (LDM), a choice substantiated by the inherent material properties, akin to the procedures utilized in printing clay-based materials."*

Another approach to wood 3D printing that is worth mentioning is the one of **Ashley Beckwith,** an ex-MIT student who founded **FORAY bioscience** to further develop new methods for growing wood without cutting trees. Their technique requires the use of **tissue engineering for producing plant matter** in a lab. So far, scientists have only used this method for animal cell culture.

"Analogous concepts have not been translated to the plant culture space, particularly with respect to the production of materials. This work thus represents a first look at a cellular agriculture approach to plant material generation," the researchers note in their study. With the goal to drastically reduce deforestation, the next step for this team is to 3D print timber in a lab from cells of trees like pine.

Applications: Is industrialization possible?

While most of these wood 3D printing solutions have already produced viable prototypes, it should be noted they do not always target the same vertical industry.

With FDM 3D printing and binder jetting, some of the interesting applications that have already been publicly shared, have been made for the **consumer goods industry**.

FDM 3D Printing

Material producer Fillamentum for instance offers **Timberfill**, a material made up of wood fibers, specifically spruce fibers. *"The composite material Timberfill is specifically designed for 3D printing needs, specifically for FDM/FFF technology, so the length of the fibers had to be taken into account. Timberfill was developed by mixing PLA-dominated biopolyesters and wood fibers obtained from spruce trees. The development process involves mixing biopolyesters and wood fibers in the desired ratio, typically 15% wood fibers and 85% PLA. The printed objects have an authentic look and a temporary smell of wood. We currently offer 8 color shades and are preparing more. Thanks to the bio-sourced origin of the material, it is 100% biodegradable by industrial composting"* **Barbora Jurčová, head of Research & Development** explains.

As far as applications are concerned, the material can be used to develop 3D-printed speakers like the one developed as part of the Spirula project in cooperation with Akemake.

At the manufacturing level, utilizing Timberfill in the 3D printing process requires specific considerations to achieve optimal results. According to **Jurčová**, as the material contains wood fibers, it can influence printability and cause increased nozzle wear. To mitigate this, users are advised to employ a specially designed hardened nozzle suitable for composite fibers. Additionally, using a nozzle with a minimum diameter of 0.5 mm is recommended. Properly drying the material before printing is essential to prevent material degradation, stringing, and poor layer adhesion. Just like with any filament, fine-tuning print settings, including temperature, layer height, and print speed, plays a critical role in obtaining high-quality prints.

Other applications involve all kinds of decorative objects, artistic sculptures, furniture models, personalized gifts and even functional parts with the appearance of wood. The versatility of wood fiber filament 3D printing opens up opportunities in a variety of industries, especially design, art and prototyping.

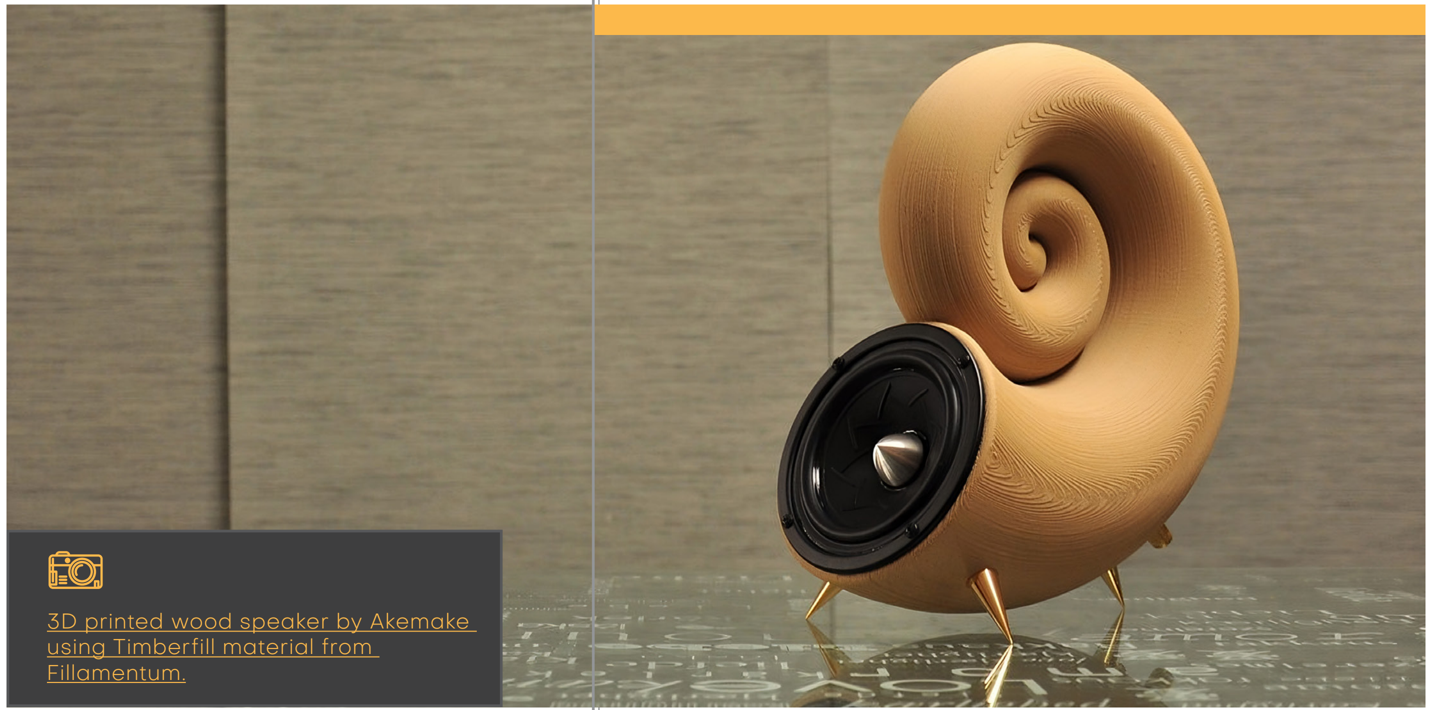
As far as industrialization is concerned, it should be noted that several factors **can limit the development of filaments with wood fibers**. *"There are limited mechanical properties (mainly fragility) compared to traditional materials such as metals or plastics. Furthermore, it is the low-temperature resistance of the material, which is due to the polymer used. For some users, the need to dry the filament before using it, as well as the use of a nozzle with a larger diameter, can be limiting. And last but not least, it is a higher price compared to standard PLA or ABS filaments,"* **Jurčová** outlines.

Timberfill is available today in 8 colors, which can deliver "an authentic-looking wooden surface". According to the company, the potential for robotic 3D printing opens up possibilities for manufacturing large-scale objects, bolstering the case for industrial adoption.

Pellet 3D printing

While the consumer segment has a great potential, the combination of wood pellets and 3D printing has already delivered interesting applications in architecture.

The current use of the technology for one-time applications such as decorative objects or artistic sculptures makes it hard to envision an industrialization project.



3D printed wood speaker by Akemake using Timberfill material from Fillamentum.

3D printed wood speaker by Akemake Image: Clarius – 3D printed plant pot produced with wood pellets

Wood 3D printing with Liquid Deposition Material

The **WoodenWood** project of D.DLab is the only one we've seen so far, that explores the use of wood as a paste. With the goal of developing circular solutions for wood products and processes, **Barath** explains that they incorporate traditional modular woodworking expressions with robotic printing of wood paste for the **prototyping of seating elements.**

The printing toolpath creates a new 'wood-textile' resembling a rattan texture while using an inferior material, sawdust. The raw wood structure serves as the mold for the printing process, avoiding additional waste through by-products. Together, traditional and digital designs present a circular expression for wood waste towards a new end of life. Our primary objective was to prototype a case study that could be expanded to a wide range of applications using natural waste and degradable materials in the fabrication process. The WoodenWood project serves as a demonstrator of this platform, with potential applications spanning from construction and architecture to fashion and various product designs, **Barath** adds.

WoodenWood Chair Photo credit: Disrupt Design Lab

At the manufacturing level, the material formulation is suited for LDM printers (such as clay printers) that are based on air pressure. However, the developed design to manufacturing workflow requires knowledge in computational design and robotic tool pathing techniques. The truth is, the use of natural materials within LDM printing requires establishing specific protocols to handle the inherent shrinkage and subsequent drying processes effectively.

What might slow down the adoption of this technology is **the disruption in the fabrication processes.** Considerations such as overhangs, bridging, slamp, drying, etc. become more exaggerated as the print grows in scale. Therefore, adjustments to the formula and print toolpath are needed, and this requires further research and experimentation. In addition, apart from its design-oriented nature, mechanical testing is essential for evaluating the performance of the process at different scales, **Barath** outlines.

While it is too soon to speak about industrialization, it should be noted that in the long run, they seek to achieve applications tailored to the **construction industry.**

Conclusion

Wood 3D printing is definitely appealing, regardless of the AM process used. However, the current types of applications that can be achieved with these methods make it hard to envision an industrialization-based business model for companies exploring these techniques. Hopefully, with the improvement of these techniques, users will be more confident to make the shift from prototypes and small series to actual series production.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Education

Guest Column

SAM PROJECT : THE TEAM REFLECTS ON THEIR INITIATIVES AFTER 5 YEARS OF ACTIVITY AND THEIR LEGACY FOR THE AM INDUSTRY

The Sector Skills Strategy for Additive Manufacturing project aka SAM funded by Erasmus+, is coming to an end after five years of activity. The project aimed to implement an actionable plan to train and drive more people to experience a career within the additive manufacturing industry. 3D ADEPT Media took part in this project as a SAM Associated Partner. In the article below, the team reflects on their initiatives and their legacy for the AM industry.

With an updated **Skills Strategic Roadmap to 2030**, the team behind SAM aims to work on seven key impacts, present 30 strategic recommendations to overcome challenges in the AM industrial implementation process, and introduce **the International Additive Manufacturing Qualifications System (IAMQS).** The IAMQS comprises a collection of professional profiles, qualifications and courses, and a European Observatory Platform that displays updated data on AM trends, skills shortages and mismatches, together with captivating content such as articles, reports, enriching events, and information about AM education and training courses.

Over the course of four and a half years, SAM has spearheaded diverse initiatives that have engaged students, trainees, trainers, and European citizens of all ages, unlocking a world of opportunities for career growth. Within this context, the recently updated **Skills Strategy Roadmap 2023** emerges as a visionary framework, meticulously bridging industry gaps by identifying strategic initiatives and corresponding activities.

Operating in harmony, the «Roadmap» structure and accredited training providers enable the implementation of each strategic initiative through the **AM Observatory** and the deployment of the (**IAMQS**).

Some of the existing qualifications in AM, already contemplated in the IAMQS such as the **Metal AM Coordinator** and the Metal **AM Engineer for PBF-LB** were revised during SAM while new qualifications and/or competence units were designed according to the needs of the labour market. As an outcome, an Online Qualifications Catalogue was developed to compile the AM training offers. The IAMQS education and training activities were regularly conducted from 2020 to 2023, through 34 courses (most of them remotely) focused on advanced and specialized subjects in the field of AM processes, materials, design, standardization, and even business development and sustainability, reaching more than 900 participants.

As part of SAM activities, the implementation of the IAMQS and delivery of AM training was ensured through a consolidated network of training centers complying with the EWF Quality Assurance System. The implementation process followed a top-down approach, meaning a transnational curriculum for AM was defined, addressed by harmonized training guidelines, and then uptaken at the national level by each training center, under the supervision of the representative organization in the AM field.

A total of **17 training organizations** are now authorized for the IAMQS implementation in Italy, Spain, Germany, Portugal, Turkey, Ireland, England and France.

Additionally, SAM has organized eight highly successful National and Regional Roll-out events for the IAMQS, expanding AM expertise across diverse geographical locations.

The resounding success of the SAM project is exemplified by tangible accomplishments. A good example of cooperation was reached between Vocational Education and Training (VET) and Higher Education (HE) institutions, which through a joined effort, delivered the 1st European Course for Metal AM Coordinators, thus mobilizing their expertise and resources to qualify the first group of AM Coordinators for Industry. Notably, the project's impact is demonstrated by the completion of the inaugural **«International Metal Additive Manufacturing Coordinator»** course in May 2023 with 58 registered students and the awarding of 38 Diplomas.

The SAM project's website has also evolved into a captivating platform, offering an array of engaging tools tailored for children, students, AM professionals, and teachers. Through dynamic resources such as flyers, quizzes, interactive sessions, thought-provoking podcasts, a captivating comic series, and informative presentations **(3D Printing)**, the website captures the attention of learners, immersing them in the world of 3D printing. Among SAM's engaging activities, TECH4KIDS hosts interactive hands-on sessions, fostering curiosity and knowledge among children, leaving an indelible mark on the project's impressive legacy. To ensure that no significant insights are missed, the project has compiled a **Booklet** featuring all 13 articles developed by the consortium, covering various aspects of AM.

As the SAM project triumphantly concludes, its unwavering commitment to sustainability and leaving a remarkable legacy is evident. With around 3500 participants enrolled in Open-day events and 4315 children/youngers involved in dedicated Tech4kids events, approximately 500 quizzes, and thousands of people reached, the project has significantly increased its social media following. Embrace the chance to join our dynamic community of ambitious **Students, Trainees & Jobseekers in Additive Manufacturing** gaining exclusive access to upcoming insights that will fuel your success.

Interview of the Month

The use of Fluid Management Systems in Additive Manufacturing

In a recent Additive Talks session, one learned the importance of thermal/fluid system designs to enhance speed, and performance in electrification. A few weeks later, Megnajet, a fluid management system expert, appeared on our radar with a new fluid management system designed for AM. This raised so many questions on the use of fluid management systems in Additive Manufacturing that we have decided to ask ***Mike Seal****, Megnajet General Manager.*

Megnajet (a subsidiary of Xaar) may have appeared on our radar lately, but the company was founded in 2010 to meet the growing demand for inkjet print systems in various industries. The more inkjet technology advanced, the more industrial sectors were looking for customizable solutions to create any image in any quantity at any time. As the potential of this 'industrial inkjet revolution' was gaining momentum in the ceramics industry, the subsidiary of Xaar decided to explore this potential for inkjet 3D printing, thus providing fluid management systems to several players in the AM realm.

Simply put, fluid management systems are a set of devices, and procedures that help to control, measure, and maintain the flow of fluids in various industrial applications. This set of tools has proven to be critical in a number of industries such as pharmaceuticals, manufacturing, food & beverage processing, and wastewater treatment, to name a few. This management system, therefore, consists of several components that can often be produced using AM. They include for instance valves, flow meters, tanks, pumps, filters, and sensors.

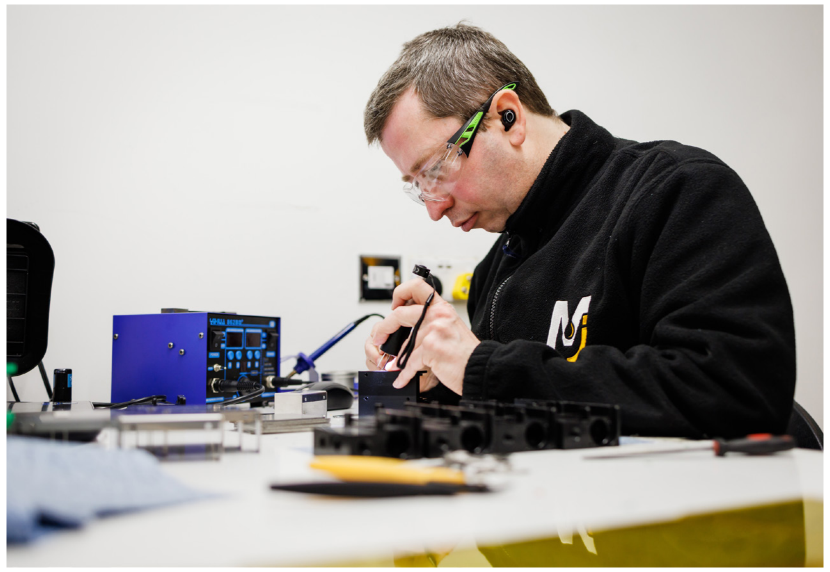
Nevertheless, in AM and inkjet printing in particular, fluid management systems help to provide precise control and conditioning of the fluid, to ensure the printhead can jet effectively.

According to **Mike Seal**, *"All printheads require a reliable input to deliver a consistent and accurate output. Fluid management systems are responsible for this reliability by conditioning the fluid, ensuring it is at the correct temperature, pressure, particle uniformity, and that the particles are maintained in suspension – all of which are critical for effective jetting.*

Inkjet 3D printing applications demand a high level of fluid control due to the multilayered nature of the printing process. Any faults or failures of the system to deliver each layer reliably could result in a range of errors from cosmetic to part failure – which is exacerbated the larger the part is, or the more parts are produced. In addition, developments in printhead capability to jet higher viscosity fluids mean a fluid management system must maintain precise temperature control to ensure an ink's viscosity remains within the optimal range for seamless jetting.

High-viscosity inkjet typically utilizes recirculating architecture within the printhead which when matched with an effective fluid management system fully realizes this capability and provides increased reliability. These technologies are significant for inkjet 3D printing as they enable the use of more advanced materials and ultimately improve the functionality of parts and ensure part failure is avoided."

AM processes that require the use of fluid management systems



While fluid management systems can be used with AM processes that involve fluid control and conditioning, Megnajet decided to focus on **polymer jetting, binder jetting and inkjet-based powder-bed fusion** technologies.

Among these technologies, the focus on inkjet 3D printing makes sense when we know the company already has deep expertise in 2D printing, when we know there was a shift from single-pass digitalized printing of ceramic tiles to a wide range of applications with diverse printing requirements.

The development of the **JetSource** in particular, the fluid management system Magnajet recently unveiled, has been driven by a demand from clients in inkjet 3D printing and Label printing who wanted to achieve higher flow rates, faster speeds, higher productivity, and a wider array of printheads.

"Our latest fluid management system recirculates fluid at up to four liters per minute across up to five independent ports for printheads for use in various applications such as inkjet 3D printing, labeling and packaging embellishments, special varnish effects and braille. This system allows for increased productivity and improved scalability in 3D printing processes", the General Manager outlines.

Speaking of the key specifications related to the use of fluid management systems with the aforementioned AM technologies, he adds:

"In inkjet 3D printing, reliability is paramount. A small defect in one layer can lead to a costly and timely functional or structural failure in the final printed product. Therefore, fluid management systems are indispensable in additive manufacturing to achieve consistent and reliable printing results.

In binder jetting, fluid management systems are responsible for accurately delivering binders to the printheads for depositing onto powder beds to create 3D-printed parts. Precise control over the fluid parameters is essential to achieve accurate and repeatable results.

Similarly, in inkjet powder bed fusion, our systems are crucial for maintaining the right fluid characteristics, such as temperature, pressure, particle uniformity and dispersion to ensure proper fusion of each layer to itself and subsequent layers during the printing process. Thermal regulation of the fluid over a high-temperature powder bed is also an important role of the fluid management system in inkjet-based powder-bed fusion.

In polymer jetting, fluid management systems are crucial because they must be able to handle heated fluids, often at higher viscosities than typical inkjet applications. Megnajet's systems excel in both traditional and high-viscosity fluids, surpassing the capabilities of most conventional inkjet systems. This capability enables the use of a broader range of materials in 3D inkjet printing applications, including advanced polymers and functional fluids."

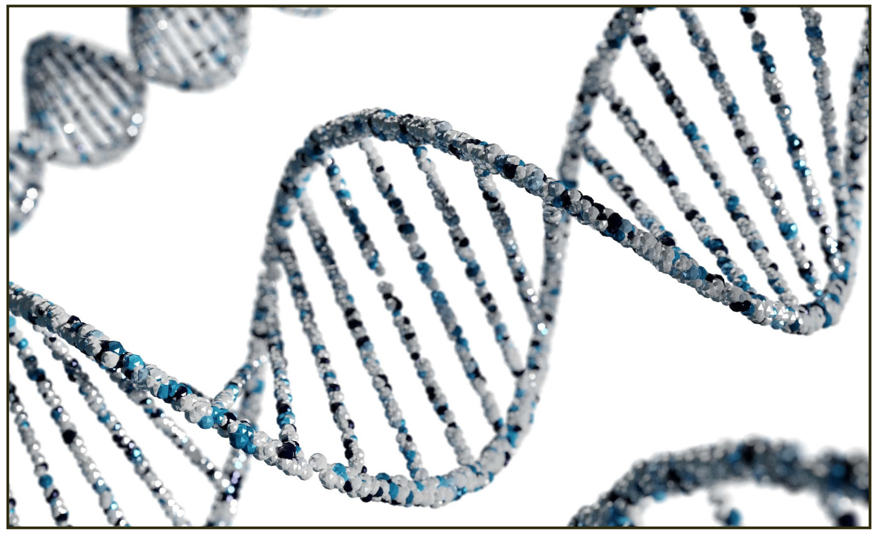
So, how does one select the fluid management systems that work best for an AM process/ an AM application ?

Just like there are different types of AM processes, we also have different types of fluid management systems, each designed to meet the requirements of specific printhead technologies and the number of printheads required for the application.

As little information is available on how to select the ideal fluid management system in an AM application, AM experts should have a conversation with experts in the field to have a clear understanding of what might meet their needs. Not to mention that testing can often be offered by companies to help industrials make up their mind.

That being said, by creating fluid management systems that are based on industry sector requirements and specific customer needs, Seam ensures that Megnajet can supply off-the-shelf, customized and bespoke solutions for a wide range of printhead technologies and applications.

How do nanotechnology & Additive Manufacturing intertwine and what opportunities lie ahead ?



Among the wide range of technologies that can bolster an Additive Manufacturing (AM) application, nanotechnology is often the least mentioned. Yet the synergy between both technologies can lead to versatile and multifunctional applications that go beyond the healthcare industry. One reason that may explain this lack of exposure is a blurred understanding of nanotechnology and how both AM and nanotechnology can intertwine.

For some reason, nanotechnology often raises confusion with "tiny robots" or "micro-3D printing" technology. This field of activity actually refers to material science at the nanoscale. It reaches into a variety of sciences such as physics, chemistry, biology, and numerous branches of engineering.

The nanoscale is 1000x smaller than the microscale and a million times smaller than a millimeter – here one deals with individual or small groups of atoms, the latter of which are called **nanoparticles**. In addition to size, an interesting phenomenon is utilized when working in the nanoscale: in many instances, the increase in the ratio of *[surface area]:[volume]* by having more atoms exposed drastically changes the expected material properties of a device or object.

How do both AM and nanotechnology intertwine ?

Simply put, AM can be applied to nanotechnology on the one hand, and nanotechnology can be applied to AM on the other hand.

In the former case, the complexity and design flexibility of nanoscale structures can be enhanced using 3D printing this means that AM becomes a tool used to create nanoscale structures and geometry. In the public's eye, this would be a gigantic step forward as most additive technologies that are commercially available have as low as 25-50-micron resolution (SLA and DLP mostly). Several nanotechnology techniques that are additive in nature are already commonly used in the nanotech industry: **2 Photon Lithography, Dip-Pen Nanolithography, Electron Beam Melting,** and **Atomic Layer Deposition** to name a few. Do not be mistaken, however, because these techniques are inherently quite fragile and require a great deal of precision as-is, so bringing them to an industrial market is a challenge.

In the latter case, the characteristics of 3D printed parts can be enhanced using nanomaterials' advanced and tailorable properties. In some ways we are already seeing this – there are several companies such as **Tethon3D, Covestro, and Mechnano that are adding nanocomposites to their photopolymer resin chemistries to enhance material properties** significantly.

This means that nanoparticles (NPs) can be incorporated into a 3D printing host material like polymer or a ceramic matrice to form a nanocomposite. The new material can then be used as a feedstock material in AM processes such as FDM, SLS or SLA. Such incorporation can fill the gap that could help deliver macroscale geometries with exceptional properties, addressing this way the most prevalent issues of AM: the limited feedstock materials that are compatible with a given AM process.

In most instances, these nanocomposites are **nanoscale ceramic particles or even carbon nanotubes,** but these materials are becoming more advanced and unique every day. As such, the more there is a focus on materials development, the more one will see the critical role of nanotechnology.

What challenges may arise in combining both technologies ?

One of the main problems in adding nanotechnology to existing additive manufacturing techniques is **the concern for environmental and personal safety.** To this day, we are still exploring the negative impact of microplastics and finding traces of them on our beaches and in our bloodstream. Much like how previous generations struggled with exposure to mercury, lead, and asbestos, the last thing the world needs is to struggle with undesired exposure to nanotechnology. In many instances nanotechnology is safe – for example, your sunscreen is white largely because of the titanium dioxide nanoparticles found within it to reflect UV radiation from the sun, or the silver nanoparticles in your laundry detergent which have an amazing antimicrobial effect. The sheets of hexagonal boron-nitride found in your makeup provide an effective lubricant that requires no liquid or gas molecules, not to mention one of the most famous pieces of nanotechnology – graphite in pencils!

However, **it is important to understand that for every nanoscale material or device that has overwhelmingly positive effects in our everyday lives, there is another that could cause severe health problems.** A great amount of testing and regulation is used in the research phases of R&D to prevent these environmental and personal health risks from becoming 'the next microplastic' so to speak and this topic of responsibility is heavily discussed within the nanotechnology community.

Engineered clean energy storage solutions

What applications?

On another note, the main industries that could benefit from 3D printing nanocomposites are the **biomedical** and **electronic** sectors. An increase in organizing the atoms of any structure comes with greater material properties and thus better-engineered devices/structures. The photopolymer resins with nanocomposite fillers have already shown a huge leap in material properties: strength, thermal conductivity, electrical resistance, impact resistance, and more. For example, by integrating carbon-nanotubes and hydroxyapatite (HAp) NPs into the acrylic polymer polymethylmethacrylate (PMMA) for instance, it is possible to improve the flaws that may occur in the surgical fixation of artificial joints.

Photopolymer resins for SLA, DLP, and some material jetting techniques will foster the use of nanotech as these are the easiest materials to enhance, followed by thermoplastics for FDM. It will likely take longer for metal additive manufacturing to implement it due to the harsh processing conditions of techniques like powder bed fusion and directed energy deposition.

Creating structures with perfect surfaces, microscale features, and unparalleled consistency linked with the automation of AM definitely promises to be a powerful combination.

About the authors

This feature has been co-written by **Andrew Miller & 3D ADEPT Media**. Mechanical Engineer by training, Miller has decided to devote his career to AM and nanotechnology. By co-authoring 2 publications on metal additively manufactured heat exchangers, he learned of the fracture mechanics of rocket engine parts when working as an aerospace engineer for Blue Origin. It was there that it became clear to him that expanding his horizons into the realm of material science would expand his knowledge of additive manufacturing, and specializing in the field of nanotechnology would futureproof that education.

He is part of the Johns Hopkins Engineering for Professionals graduate program and with lessons learned from Professor John Slotwinski, Chair of the ASTM Executive Committee on AM technologies, he dreams of contributing to the AM community by implementing nanotechnology in new, unforeseen ways during the remainder of his career.

OPINION

THE POWER OF HYPE: MARKETING LESSONS FROM 3D PRINTING

Last year, Forbes Technology Council listed 3D printing as the first in 12 "revolutionary" technology solutions that are not living up to the hype. According to the journal's expert panel, 3D printing is probably the most overhyped technology ever. Lots of advocates sold it as a technology that would enable personalization in scale manufacturing while it's certainly not the core of manufacturing at scale.

I obviously disagreed with this statement – not because I work for a trade press that specializes in the field, but simply because Forbes included in that expert panel professionals who do not work in the AM field. To me, their opinion was not legitimate when it comes to manufacturing at scale. They were right about something though: 3D printing continuously undergoes a lot of media hype and among all the vertical industries that can leverage AM, there is one sector that is, in my opinion perfectly aligned with this wave of popularity: **marketing**, in particular **advertising**.

Advertising may not be the first sector that comes to one's mind when it comes to leveraging AM. One should note that there are a few similarities with the technology. This culture of **thinking out of the box** as well as **product customization** are for instance the most striking ones.

Could 3D printing be a hidden marketing strategy?

It might seem obvious, but it's not. Marketing is the process of identifying customer needs and determining how best to meet those needs whereas, advertising is the exercise of promoting a company and its products or services through paid channels. In other words, advertising is a component of marketing. Since marketers are continuously required to think out of the box, to develop ideas that could help sell products, one observes an increasing use of 3D printing as a resource in creative campaigns.


Credit: C3D

Visual merchandizing

This practice consists in optimizing the presentation of products and services to better highlight their features and benefits in the retail industry. Such actions are very dependent on the brands themselves and the reaction they expect from their customers for certain product launches. For the launch of a new product in Dubai, **C3D**, a 3D printing service bureau 3D printed a gigantic PUMA NITRO Shoe of 1.5 meter. Consumers could take pictures in front of them and share them on their social media, creating this way a viral campaign.

Interestingly, a wide range of disciplines fall under the umbrella of ***"retail"***, which means 3D printing can be applied to a wide range of applications in this sector. They include for instance **packaging, shop fittings, lighting, exhibition spaces, and the products themselves.**

Among the other iconic brands that have already harnessed the technology for their creative campaigns, one notes Coca-Cola, Dior, McDonald's, Louis Vuitton or Volkswagen. In our very own industry, remember how post-processing company 3D printed 6,000 3D printed parts to build its Formnext booth in 2019.

The company's booth spanned 84 square meters and 4 meters in height, and was described by AMT as a modular, fully customizable, and, importantly, reusable construction. The one-of-a-kind exhibition stand was designed and produced in collaboration with Steel Roots Design, a Sheffield-based shopfitter that specializes in the design and construction of commercial furniture and interiors. Each of the 6,061 pieces that kept the stand together was 3D printed by Materialise on a selective laser sintering (SLS) system by EOS. All the parts were printed using a Nylon PA 2200 material and were post-processed using AMT's PostPro3D system.

"The whole point of exhibiting at a show like Formnext is to demonstrate your technologies and capabilities," commented **Joseph Crabtree**, CEO of AMT at the time. *"At AMT we don't have to just tell people how good our technologies are, we want to really show them."*

Street marketing

This form of guerrilla marketing uses non-traditional or unconventional methods to promote a product or service.

To generate excitement for the release of "Elemental," an original feature film of Disney Pixars, Gentle Giant Studios, a creative agency, embarked on the ambitious project of creating life-size versions of the film's characters for photo opportunities at various events worldwide and in public areas. The team of Gentle Giant Studios provides creative services to the Consumer Products, Fine Art, Gaming, Visual Effects, and Experiential Entertainment industries and has produced intricate prototypes for this movie using Nexa3D's polymer 3D printing technology.

With the proliferation of platforms and leisure activities fighting for our attention, creatives and marketers have to work extra hard to get their audience's attention. So far, it is fair to say that the use of 3D printing as a key strategy helps to cut through the noise and reach more than their intended audience.

To those marketers that are always looking for accurate results in their campaign, it's important they keep in mind, they can only get an estimation of the audience they would reach, just like they get with advertising in a print magazine.

For me, this estimation is already enough to consider exploring the AM route as a marketing strategy, because at the end of the day, it's an effort that is part of an ecosystem; an ecosystem whose individual tactics should aim to target the right people with the right message at the right place.

Events

Danish AM Hub on the Danish AM market, their key area of interest and the upcoming AM Summit

With the “back-to-school” season, we start reflecting on the AM trade shows that could be interesting to visit. AM Summit, the largest AM conference in Scandinavia is in our list. To have an overview of the AM market in the host country known for the world’s most valuable toy brand, we caught up with Danish AM Hub’s CEO **Frank Rosengreen Lorenzen**.

Initiated by The Danish Industry Foundation, **Danish AM Hub** is the focal point for Additive Manufacturing in Denmark. With the goal to strengthen Danish business competitiveness through AM, the organization focuses on small and medium-sized businesses while exploring new business models that induce growth, innovation and sustainable solutions.

“Denmark has a fair amount of both AM users and providers. There is a clear trend in the last few years, with new AM providers challenging the few big and established service bureaus that have been around since the early days of AM (1990-2000’s). AM equipment which is capable of producing parts with the required quality has dropped drastically in price the last 5 years, turning AM service concepts upside down. This is changing the AM provider landscape in Denmark. The share of AM users is expanding in a moderate pace, as they now have to become aware that 3D printing now has a competitive price to traditional Manufacturing – when they view all the benefits of [this technology],” Lorenzen states.

Frank Rosengreen Lorenzen

With “the Nordic region” announced as partner country of Formnext 2023, one learns that **sustainability** is a key area of strength for these European neighbours. For Danish AM Hub, since AM provides an opportunity local on-demand production – hence less transport and less C02, there is a reason to help companies see the advantages of the technology for their business. To do so, they recommend **4 steps companies** can take to go digital:

- Manufacture only when it is necessary
- Mind the materials and use recycled materials whenever possible
- Rethink design entails abandoning the linear take-make-waste system
- And adopt a holistic perspective that incorporates the whole value chain and life cycle of your products

If this sounds easy to say, Danish AM Hub also helps companies implement an actionable plan through several innovation programs and projects. *“From actual making the technology available to them by providing them with a 3D printer and advice on how to use it – and for what – to programmes helping them redesign and optimize design for Additive Manufacturing, or using AM for more distributed manufacturing,”* Lorenzen explains.

More specifically, in 2023, *“we are making 3D metalprint available with our AM Metal Bridge-initiative, we are supporting strong Danish actors on their work of using Additive Manufacturing to rebuild Ukraine – and we are especially proud together with our partners to have build a CO2e-calculator of AM processes,”* he adds.

What about the AM Summit?

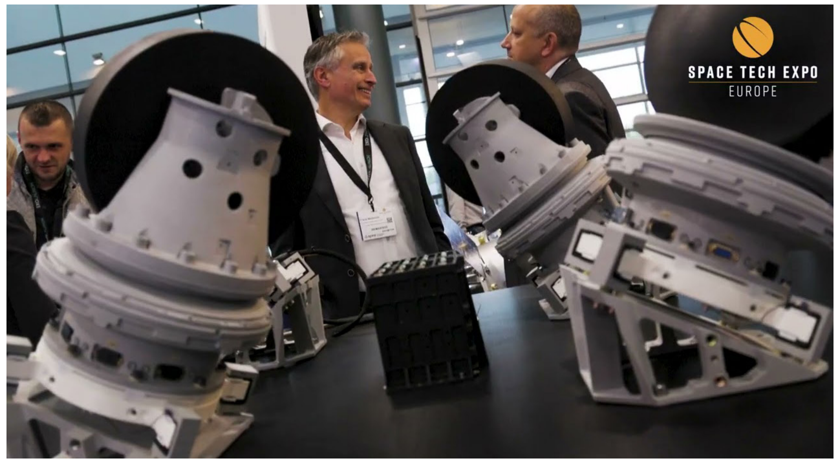
The 2023 edition of the event will be the fifth conference organized by the association. The conference has evolved from 150 participants in its first year to an attendance record of almost 450 visitors in 2022. This can be explained by the fact that, over the years, the organizer has made significant efforts to attract an international audience and international speakers that are willing to discover what the region can bring to the international table of AM.

*“The theme for this year’s conference is **‘Additive Impact – Additive Manufacturing and 3D printing as a driver for sustainable manufacturing’**. Under this theme, 50+ speakers will take the stage with concrete solutions and inspiration on how new technology like 3D printing can help us produce more sustainable with stronger and more circular business models and more robust supply and value chains,”* Lorenzen notes.

For this year’s edition that will be held on September 21st, the host expect to welcome around 600+ participants. With a strong lineup of speakers like Skylar Tibbits from MIT Self-Assembly Lab and Paul Gradl from NASA, we might expect to learn insights that go beyond Danish competencies in the industry.

Will you join them?

Space Tech Expo confirms dates and location



The 6th edition of Space Tech Expo Europe is scheduled for 14 – 16 November 2023, returning to its home in the city of space, Bremen, Germany. It’s set to attract 6200+ professionals from the space sector with 94% of 2022 visitors saying they can’t wait to return for 2023, and many new industry representatives signed up to join them.

From budding start-ups to big industry players, over 550 exhibitors will showcase their latest space solutions on the exhibition floor. From Spaceflight Inc, Spire, Berlin Space Technologies and D-ORBIT to Rocket Factory Augsburg, Polaris Raumflugzeuge and Reflex Aerospace, all of them aim to inspire and advance the space industry in their own way, while addressing its critical challenges.

Gordy McHattie, Event Director at Space Tech Expo Europe says: *“The 2023 event has grown dramatically yet again, maintaining its status of hosting more exhibiting companies than any global space B2B event. This increase signals further growth and collaboration opportunities in the European space industry. We’re extremely excited to see the progression and increased traction for genuine business project discussions as we return to Bremen this year!”.*

This year, the event has expanded into Hall 4.1, located upstairs, to bring attendees even more of the latest products and technologies. The additional hall has also presented the opportunity to introduce the Exhibitor Technology Forum. Here you’ll find exhibitors showcasing their products and services, offering you the chance to experience their tech up close and in person, and ask the experts your burning questions there and then.

Alongside the exhibition, the event will host three free-to-attend conference stages, bringing over 150 expert speakers together from across the continent, to discuss the latest trends, challenges and opportunities in the European space industry.

The Industry Conference, Smallsats Conference and Mobility Connectivity Conference will address a variety of topics including sustainability (in-space, supply chain, system development), space traffic management, European sovereignty in space, funding and investment, space for Earth (climate change, agriculture applications), satcom for decarbonisation, improving passenger and crew welfare and safety and digitalisation.

This year, speaking companies include ESA, Airbus Defence & Space, Totótheo Maritime, SpaceX, European Innovation Council and SMEs Executive Agency (EISMEA), Kongsberg NanoAvionics, Skyrora and OHB.

An opportunity for both Additive Manufacturing companies and space professionals

There are at least a dozen ways AM can contribute to space travel, research and habitation — and in some cases, it already is. With the increasing number of space companies relying mainly on AM to build their rockets, one observes a gap that still needs to be filled at the materials level and at the hardware level, particularly when it comes to the use of AM in space.

Space Tech Expo provides a room for both parties (space companies and AM companies) to discuss and exchange new ideas that may lead to this much needed collaboration.

Enhance your event experience and take advantage of the B2B matchmaking platform. Pre-book one-to-one meetings on the show floor with new prospective clients, partners and industry suppliers. You can also enjoy complimentary drinks and canapés at the networking evening, taking place on **Tuesday 14th November, from 16:30 - 18:00** in the exhibition hall. Both opportunities are completely free to all attendees with one all-access event pass.

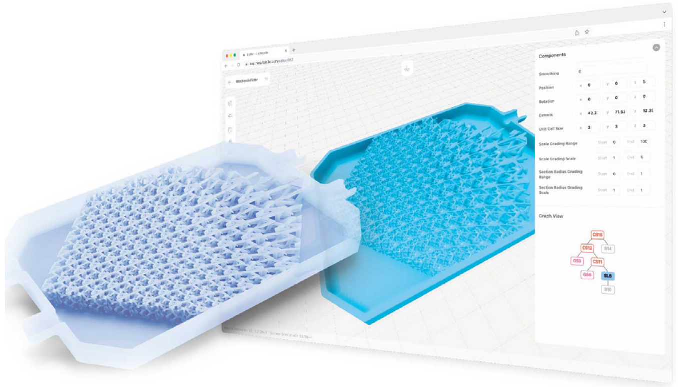
Summer News RoundUp

During summer, it is hard to always stay abreast of what's happening in the industry. If you have had some time off during the months of July and August, then don't worry. We've got your back. This news-round provides a summary of the announcements you shouldn't have missed this summer.

Funding, Mergers & Acquisitions

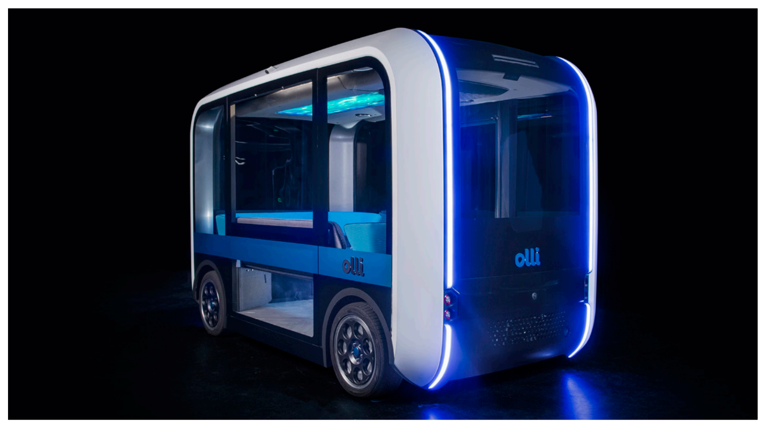
Metafold, a newcomer in Design for Additive Manufacturing, just secured $1.78M to get into the market

The company has developed an "ultra-precise, lightning-speed geometry computation engine for outputting accurate designs for 3D printing complex parts".



RapidFlight acquires Local Motors' IP portfolio, underscoring its commitment to harness Additive Manufacturing

Somehow, I have always believed they will rise from their own ashes. RapidFlight, an unmanned aircraft manufacturing company headquartered in Virginia, makes me believe today this idea is probably not the worst.



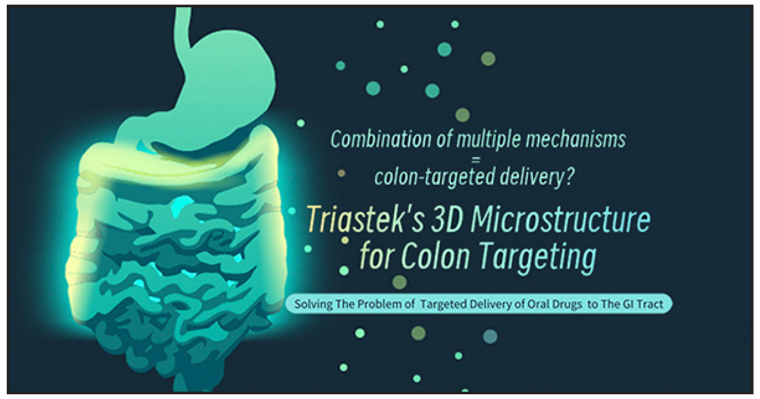
Product launches & Projects in progress

Photocentric discusses the reasons behind the growing demand of plant-based 3D printing resins

Oil-derived resins have often been the number one choice of 3D printing resins' users. However, with the current fight against climate change, manufacturers are exploring if bio-based resins can deliver the same or better performance than their traditional counterparts.

Triastek completes First In-Human study of its 3D Printed drug

Developed using Triastek, Inc.'s 3D Microstructure for Colon Targeting (3DμS-CT), T21 is designed to deliver the drug directly to the colon. This is the first time the colon targeting platform has been verified in human trials.



Additive Manufacturing Solutions Ltd. explores the feasibility of using recycled aerospace materials

Additive Manufacturing Solutions Ltd (AMS), a UK-based startup, embarks on a new project that aims to explore the feasibility and practical possibilities of using recycled metallic materials in additive manufacturing (AM).

Applications

How a 3D printed bandage helps deliver treatment for diabetic foot ulcers

As a strategy to manage DFUs, skin alternatives and wound dressings are successful treatments as they keep the wound environment "under control", whilst providing bioactive compounds that help to manage infection and inflammation and promote tissue repair.

2023

EVENTS

STAY UP-TO-DATE WITH THE LATEST ADDITIVE MANUFACTURING INDUSTRY EVENTS, CONFERENCES, EXHIBITIONS AND SEMINARS.

GERMANY	SPAIN	DENMARK
EMO HANNOVER 18-23 SEPTEMBER, 2023	METAL MADRID 15-16 NOVEMBER, 2023	AM SUMMIT 2023 COPENHAGEN 21 SEPTEMBER, 2023
FORMNEXT 2023 7-10 NOVEMBER 2023	**PORTUGAL**	**JAPAN**
SPACE TECH EXPO EUROPE 14 – 16 NOVEMBER, BREMEN	EURO PM2023 1- 4 OCTOBER, 2023	FORMNEXT FORUM TOKYO 2023 SEPTEMBER 28–29, TOKYO
INTERNATIONAL SYMPOSIUM ADDITIVE MANUFACTURING (ISAM) DRESDEN NOVEMBER 29 – DECEMBER 1	**AUSTRIA**	**USA**
UAE	AM CERAMICS 27-28 SEPTEMBER, 2023	FORMNEXT FORUM AUSTIN AUGUST 28–30, AUSTIN, TX
MIDDLE EAST REAM SEPTEMBER 25–27, DUBAI	MAMC 2023, VIENNA OCTOBER 17–19	IMPLEMENTAM SEPTEMBER 21, AUSTIN

MORE EVENTS WILL BE ADDED LATER!

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