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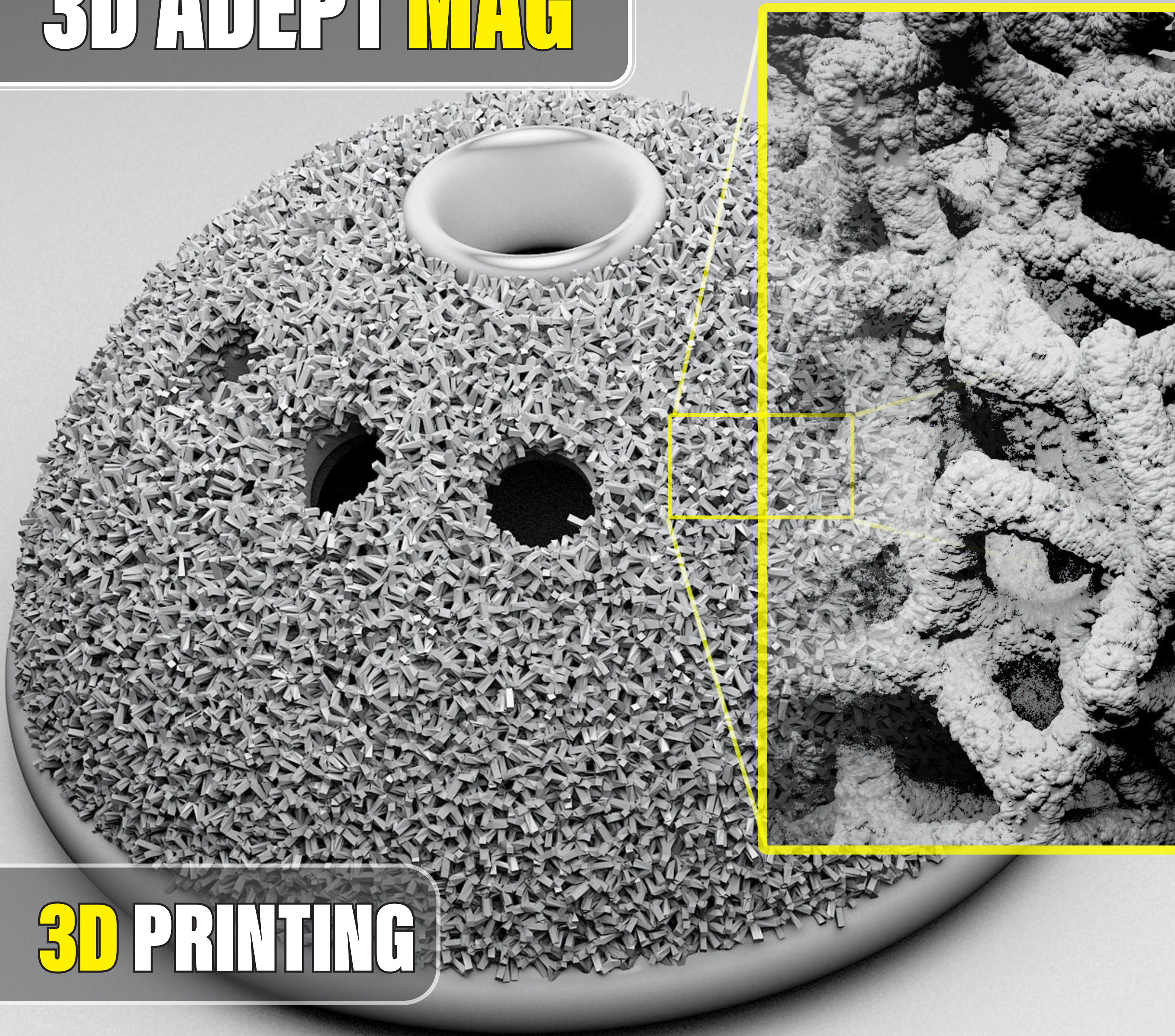

3D PRINTING

FOCUS - ADDITIVE MANUFACTURING IN THE AEROSPACE INDUSTRY

DOSSIER - MULTI-MATERIAL 3D PRINTING : WHERE DOES THE DRAWBACK LIE ?

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Hello & Welcome

Looking into space, perspectives and more...

In January 2021, when we started a new volume of 3D ADEPT Mag for the year 2021, things were quite uncertain. The previous year had been a tough one, especially for the aerospace industry that saw commercial airline fleets and air traffic down around the world. Interestingly, the manufacturing side of this vertical confirmed something though: innovation has always been first and foremost a return to the basics. Which is interesting when we know that AM and aerospace have been linked from day one.

Aerospace companies were among the first to capture the essence of AM and its potential to create efficient and enhanced components. Over the years, the synergy between academia, SMEs and final users has been leveraging "basic science" to evolve and qualify AM processes, and to further enhance the efficiency of aircraft and manufacturing workflows.

Did we need that fresh reminder? YES. Will this help move forward? DEFINITELY. How? There are several roads, but they all lead to Rome.

To kick off this new volume of 3D ADEPT Mag – which also signals a new year, we decided to explore the current routes of additive manufacturing in aerospace, interesting applications in this vertical, «new» additive manufacturing processes that can be integrated within existing technologies and the hybridization of software solutions.

This is an issue that reminds and shows that the additive manufacturing industry is «competing» with manufacturing techniques that have been around for at least a century and there is reason for optimism when you see how far it has come.

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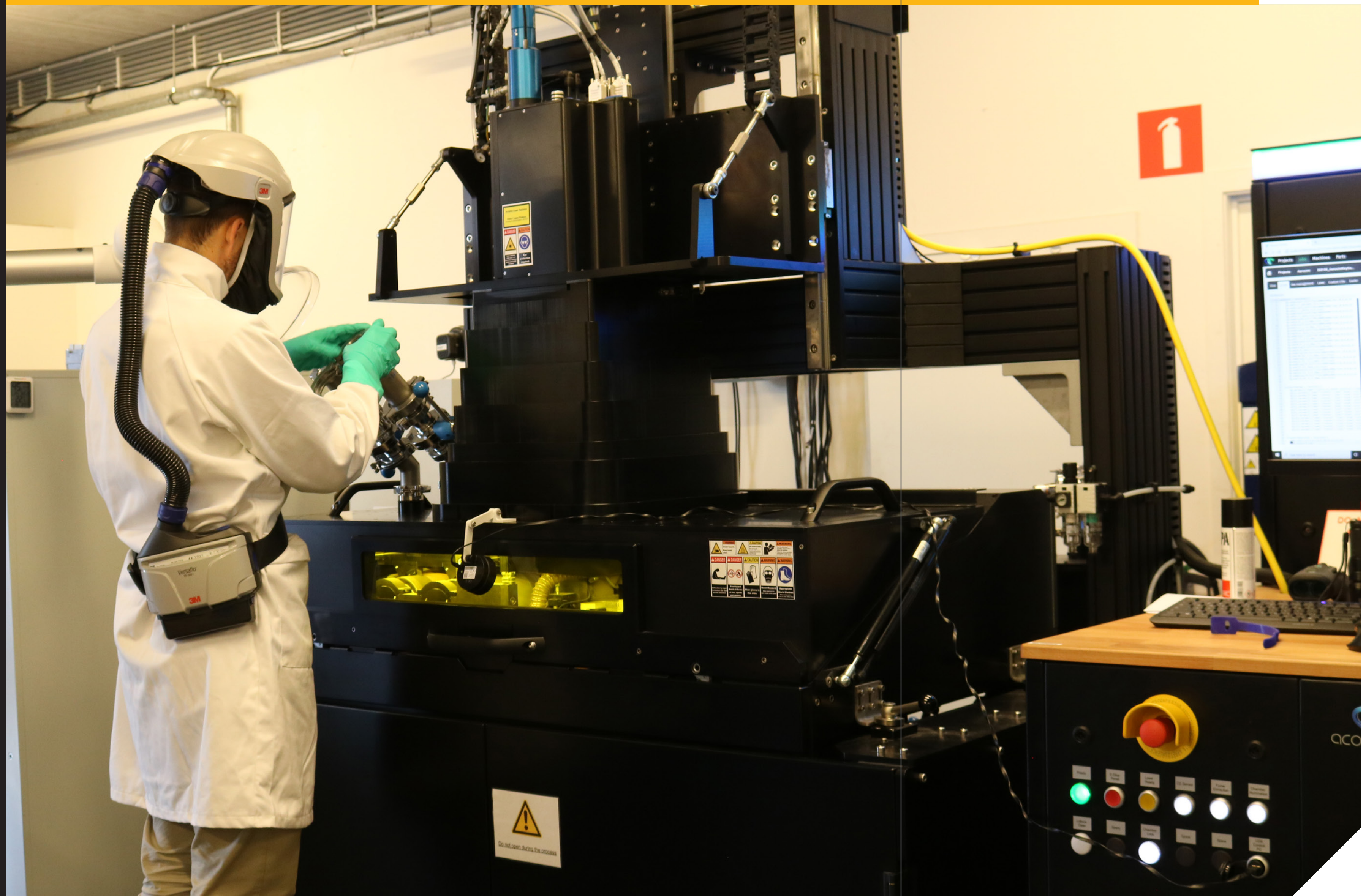
Editorial

Multi-Material 3D printing

DOSSIER



MULTI-MATERIAL 3D PRINTING:
WHERE DOES THE DRAWBACK LIE?

Multi-material 3D printing is hot. Who wouldn't want to receive a part that meets the 'best value for money' criterion? That's the most important unique selling proposition (USP) of multi-material 3D printing. Like most AM technologies you would tell me, but multi-material 3D printing has a more appealing argument when one understands the manufacturing process: using multiple materials at the same time to fabricate an object. This means that from product development, prototyping, and internal tooling, to low volume production parts, this manufacturing method can bring a significant return on investment – if well performed. So, where does the drawback lie?

Multi-material 3D printing (MM3DP) raises confusion in the way industries should define. Is it a type of AM process? Is it a form or a procedure added to an existing manufacturing process? Both industry and academics fail to found common ground yet.

At 3D ADEPT, to avoid further confusion in the way we will discuss this topic, we have considered multi-material 3D printing as a "specific procedure" that defines the type of AM process you leverage; a procedure that can be applied to several types of AM processes.

So far, we have identified six different types of AM technologies that can use this procedure: Fuse Filament Fabrication (FFF – with single nozzle or multi-nozzle), Stereolithography (SLA), Material Jetting, Binder Jetting, Directed Energy Deposition (DED) and Powder-Bed/SLS.

Interestingly, the Aerosint team splits the difference and considers MM3DP as both a procedure and a new type of manufacturing process:

"The new multi-material aspect can be seen as adding a degree of freedom (and complexity) to existing techniques. However, being able to use 2 materials in a single bed also offers other, perhaps somewhat unexpected, possibilities.

For instance, using the multi-material deposition to deposit virgin powder alongside recycled powder. This can make it possible to only use the virgin powder to build the parts, fill the rest of the bed, and build support, with recycled used material. Perhaps this angle is more ready for industrial adoption.

Likewise, as in FDM, perhaps a second material can be used for printing just supports.

Finally, our focus is on the material deposition. While it is indeed useful for powder bed-based AM, powdered materials are used in other production techniques as well. I already mentioned traditional powder metallurgy (PM) for one. Technically nothing stops an end-user from trying to control which powder is located where in a die using selective powder deposition to make multi-material parts in this manner. If you will, this falls somewhat between AM and PM."

Regardless of the type of technology with which it is associated, multi-material 3D printing's adoption remains relatively slow across industries. To understand the reasons behind this slow uptake, this feature will look at:

- The manufacturing process itself
- The materials' standpoint
- The software perspective.
- The market reality

Several technologies enabling multi-material 3D printing will be cited as examples. Moreover, to address this topic, two organizations joined us: the Aerosint team (Bram Neirinck, Maxime Schoenmakers, Edouard Moens de Hase) that brings the manufacturer's point of view and the KU Leuven AM team (Prof. Brecht Van Hooreweder, Dr. Louca Goossens & Dr. Jitka Metelkova) that brings the academic and user perspective.

The manufacturing standpoint

Amid the list of advantages that are often mentioned when talking about multi-material 3D printing, the most highlighted are often speed and precision.

"From an end-user perspective, the total lead-time can be further reduced by using multi-material printing. Especially when it comes to assemblies, which typically require joining operations such as welding, bolting, gluing, etc.", the KU Leuven team comments.

However, the arguments of speed and precision can easily be highlighted in other AM processes. In the case of multi-material 3D printing, comparison is usually done with a single material manufacturing process – which in our opinion, can be a double-edged sword.

Machine manufacturers should pay attention to the way they qualify their multi-material 3D printing processes, especially when targeting industrial prospects, because not only can the latter have different benchmarks in mind, but if these requirements are not met, they could easily disqualify their systems.

For these reasons, we understand the nuances the Aerosint team establishes here when they state, it is difficult to say that the manufacturing process with a multi-material approach is automatically faster:

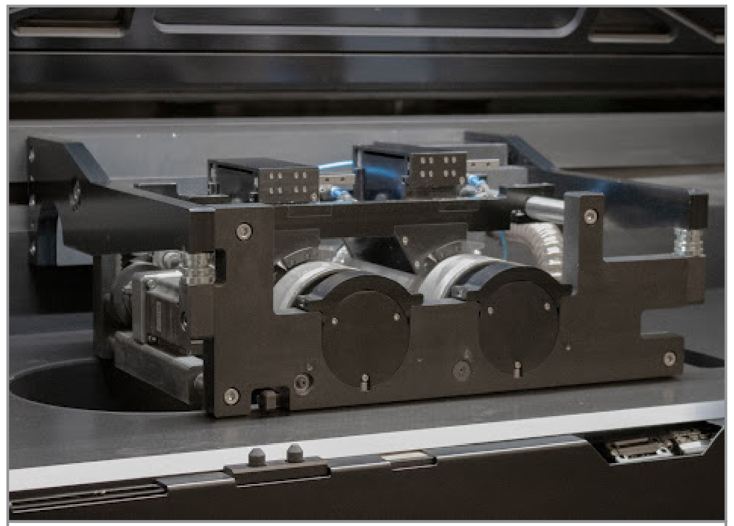
"This depends on what shapes and applications you compare, and which manufacturing methods you want to compare.

Much like with single material AM, it is hard to compare with traditionally machined parts and methods. As we have more design freedom / other design rules, often the focus will be more on optimizing the design and functionality of the parts. As a result, parts made for the same application might look completely different.

In our case specifically, our benchmark is the layering of powder with a standard scraper. Currently our recoater is still slower, but we are working hard on getting the deposition speed with our multi-material recoater in the same speed range, and even potentially going beyond this.

As we don't push a heap of powder forward over the already printed parts and powder bed, we don't experience the same kind of friction effects resulting in rippling, undulations or defects caused by a coater hitting parts. So there is a potential for going faster if we can optimize the patterning."

On a different note, we looked at other benchmarks that enable other multi-material approaches to stand out from the crowd. Two years ago for example, a team of engineers at Columbia University in New York modified the selective laser sintering (SLS) process by inverting the laser so that it points upwards. This change meant multi-materials printing could use the process.

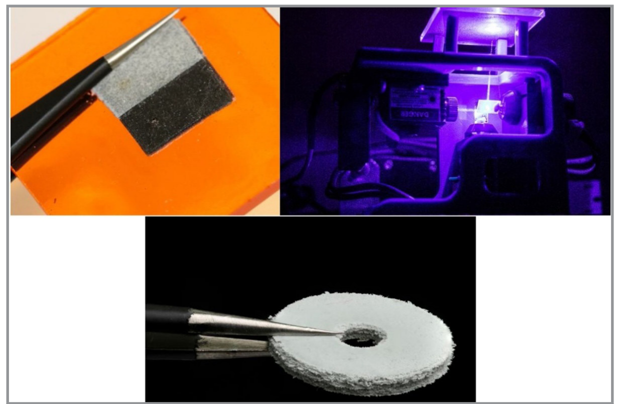


Legend: Since its foundation in 2016, Aerosint has been developing a technology that is called «Selective Powder Deposition». This technology is an alternative powder re-recoating system that, instead of uniformly spreading just one single powder material, selectively deposits two (or more) powders to form a single layer containing two materials. This powder recoater can be integrated into any powder bed Additive Manufacturing process (LPBF, Binder Jetting, SLS …) and give those multi-material capabilities. Image: Courtesy of Aerosint.

Selective laser sintering traditionally consists in fusing together material particles using a laser pointing downward into a heated print bed. A solid object is built from the bottom up, with the printer placing down a uniform layer of powder and using the laser to selectively fuse some material in the layer. The printer then deposits a second layer of powder onto the first layer, the laser fuses new material to the material in the previous layer, and the process is repeated over and over until the part is completed. This process works well if there is just one material used in the printing process.

To eliminate the need for a powder bed entirely, the engineers from Columbia set up multiple transparent glass plates, each coated with a thin layer of a different plastic powder. They lowered a print platform onto the upper surface of one of the powders, and directed a laser beam up from below the plate and through the plate's bottom. This process selectively sinters some powder onto the print platform in a pre-programmed pattern according to a virtual blueprint. The platform is then raised with the fused material, and moved to another plate, coated with a different powder, where the process is repeated. **This allows multiple materials to either be incorporated into a single layer, or stacked. Meanwhile, the old, used-up plate is replenished.**

Another interesting multi-material approach that is worth mentioning is the one from Inkbit, a US-based start-up that develops an inkjet 3D printer. Unlike other industrial 3D printers that are based on material jetting, this one comes with "eyes and a brain". The company calls it a "vision system"; it is integrated inside their 3D printer and makes the machine intelligent. During the manufacturing process, each layer is scanned at micron resolution immediately after deposition. If there are any deviations from the expected geometry, they are immediately corrected in real time by remapping the next layer.



Legend: Image on the left (in orange) shows a dual thermoplastic SLS print sample. Picture on the right shows a laser beam transmitting upwards through glass. Image in the middle shows a multi-layer, single material print sample. Credit: Columbia Engineering.

Intended for production, Inkbit develops a machine that can produce parts that contain, for instance, both a soft and a rigid area, in the same build.

These capabilities make us question the functionalities of these parts. **Can we legitimately say a multi-material approach leads to multi-functional 3D printed parts?** "*Besides for its multi-functionality, multi-material can also be used for single material components with the extra benefit of adding support structures in another material (e.g. water soluble support), or of manufacturing micro channels filled with an easy to remove filler material*", the KU Leuven team draws attention on.

What about the mechanical performances of the part?

Whether it is a multi-material approach based on material jetting like the one of Inkbit or dp polar or based on powder-bed fusion like the one of Aerosint, the response is often the same: This field is driven by specific material demands so, there is very little data on mechanical performance.

Taking example on their technology, Bram Neirinck, Manager Sintered Applications at Aerosint, states:

"I consider multi-metal AM in this aspect to be at the stage where L-PBF was when the first fibre lasers capable of yielding dense parts became available. Though the potential is there to yield parts of which the properties can compare to billet materials welded together, the work developing this process is just getting started. One advantage we have is that L-PBF is already much better understood, therefore, we expect developments to be carried out with an accelerated rate compared to the first metal AM efforts."

Legend: the image shows an Aerosint machine alongside an Aconity3D system. Aconity MIDI+: Today the multi-material printing approach was validated within a Laser Powder Bed Fusion process. The Aconity MIDI+ printer equipped with Aerosint's recoater is the first commercially available multi-material Laser Powder Bed Fusion printer in the world. Image: Courtesy of Aerosint.

The materials standpoint

In general, the additive manufacturing industry already suffers from a lack of materials. This gap seems to be exacerbated for manufacturing processes that aim to provide multi-material 3D printing at the heart of their process.

For the two teams that contribute to this dossier, **material compatibility** is the major issue for main processes.

Furthermore, to address the material compatibility issue, the entire process chain has to be developed and secured from scratch: "*this includes the basics like lasing strategies to post-processing such as heat treatments, and this for every single material combination*", the Aerosint team explains.

Specific considerations should be taken into account when defining the material compatibility with a multi-material 3D printing system. For metals, the KU Leuven Team notes the importance of the following items: "melting points, coefficient of thermal expansion, electrochemical compatibility, solubility and the final application. E.g.: heat cycling of a component. This can then significantly influence the stress level in the component, leading in the extreme case to crack initiation and fatigue failure."

"*Because we are combining materials, it will rely a lot more on fundamental metallurgy. We are directly involved in a project which is just looking on the effect of miscibility and chemical reactivity on the potential to process materials*", the Aerosint team adds, speaking of their technology.

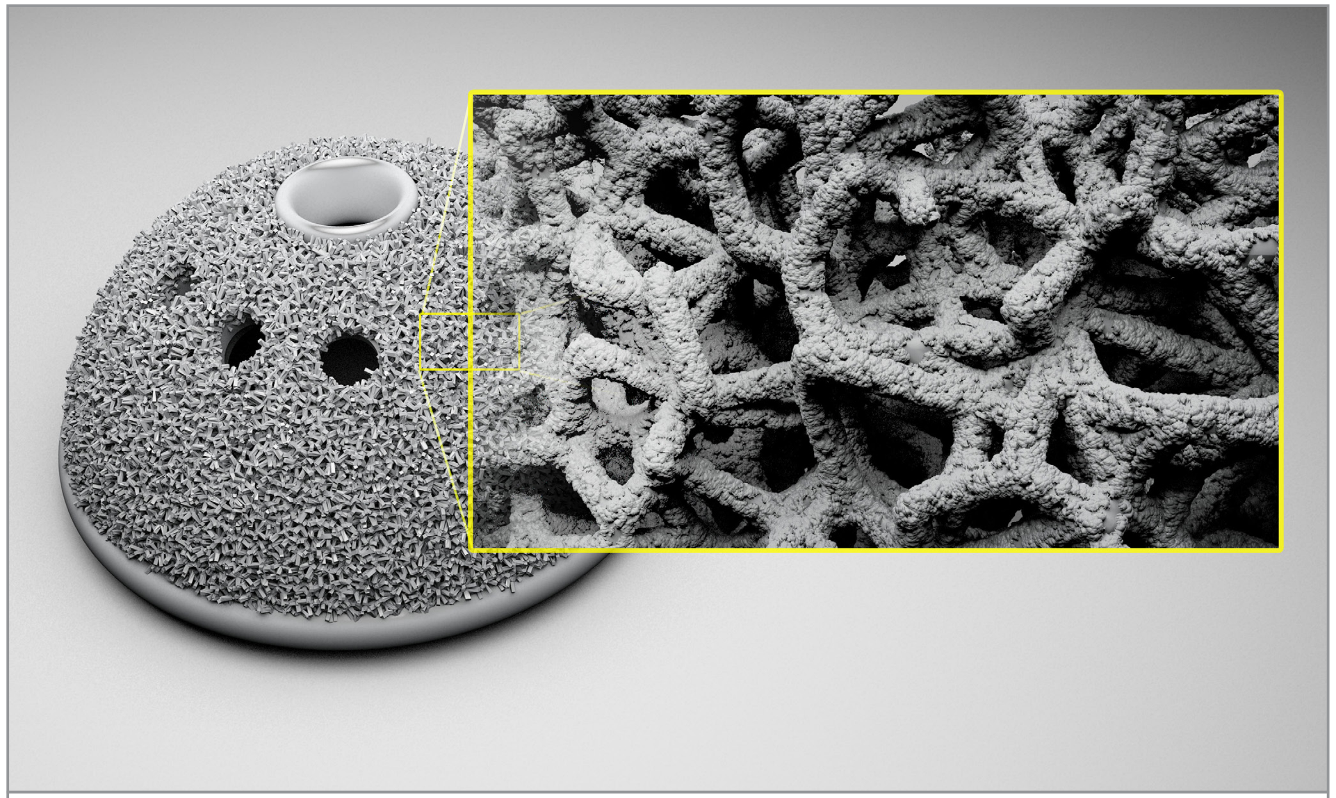
Other challenges related to the use of multiple materials at the same time include the case where the component is in contact with an electrolyte. This leads to galvanic corrosion that strongly affects the component's lifetime. "*There is also a risk of materials mixing, especially for powder bed-based technologies, rendering the unconsolidated leftover powder useless. An approach to solve this is to add an extra filler material and only deposit the material needed for fabrication. The filler material can then be recycled for reuse*", the KU Leuven completes.

As seen across other segments, one of the key solutions to address these materials issues is by fostering collaborations between material producers and machine manufacturers.

The software perspective

As you may know, multiple file formats are suitable for AM. Nevertheless, not all of them support the definition of different materials in the same file as the geometry. STL, OBJ, and PLY for instance, cannot directly achieve "multi-material support". To use the STL file format, the engineer needs to save one STL mesh per material, which results in multiple files for the same 3D objects. The OBJ file format for instance, needs to be accompanied by the MTL file format.

File formats that easily support multi-material printing include 3MF (the new standard file format for 3D printing backed by the 3MF Consortium) as well as VRML/ X3D (which features capabilities for including animations.)



Legend: The 3MF Beam Lattice Extension enables for lattice-type geometric information to be used during additive manufacturing at all scales. Image courtesy of Autodesk.

However, certain machine vendors or parts producers may require to use other file formats with specific technical information. For instance, when printing in Polyjet, engineers would need to separate their solid bodies, specify which body should be printed with which material and save as a STEP. This can easily be done in most parametric CAD programs – although SolidWorks makes it easier.

The Aerosint multi-material process on the other hand, requires sliced scanning files as used for normal single material AM. "*Only these are now split up in zones for the different materials with different parameters. We are working with the Autodesk NetFabb team on slicing specifically for this, but technically any OEM slices should work if you can load the different sections and slice them individually. The deposition if handled by a separate sliced filed indicating the required material zones. But we are using an open file format for this, and even stacked image files could be used*", they outline.

Beyond the file formats, Aerosint deplores the fact that "*software tools, both for the design and modelling of parts, are often overlooked heroes of additive manufacturing. Such tools are a tremendous aid in getting the most out of the design freedom offered by AM, while circumventing limitations of different techniques. Adding an extra design parameter, like a second or third material, only fuels the imagination of the people developing these tools. In that light we've already printed demonstrators for Gen3D, Hyperganic and Additive Flow, and every one of these approached the potential of multi-metal parts from a different angle, truly demonstrating their creativity.*"

The market reality

If you are a regular reader of 3D ADEPT Media, you certainly know we focus on applications. We believe that's one of the most tangible ways to approach a manufacturing solution. Multi-material 3D printing can be used through various processes, and as such, this approach makes room for a myriad of possibilities.

"*To get a grasp of this, you only need to consider the number of applications where people have optimized material properties in parts to increase their properties. It's like hardening the teeth on steel gears, applying chrome plating to make something rust or scratch resistant, over-moulding TPU rubber onto tool handles to make them more comfortable, … Even in AM Scaffold sections have been used to control the E-modulus locally in medical implants to avoid stress shielding. And that is without changing the material itself. A lot of these can be driven to the next step if the actual material composition can be controlled locally*", Neirinck enthuses.

The KU Leuven team also mentions several examples which involve tools with ductile impact absorbing core and hard & wear resistant outer layer; heat exchangers with conductive but non-structural zones combined with strong and stiff regions for load absorption as well as structural parts with local gradient in stiffness, conductivity, magnetic properties.

That being said, we came to realize that most industrial 3D printers that propose a multi-material approach are often based on FFF or DED. Although they present a big potential for the market, there is still a wide range of multi-material 3D printing processes that are not leveraged at the production level. Certain inventors are still enhancing their technology while machine vendors who already operate as standalone companies, first target research institutes.

On the other hand, as **Boeing's Melissa Orme** told 3D ADEPT Media in an interview (PP 32-34), if companies continue to invest in R&D to enhance AM technologies, that's only because they see the immense value of the technology. This argument applies to MM3DP. However, let us not forget that, the more investments are made, the more the technology will be expensive for the buyer. This will inevitably raise the need to justify the cost, and in an industrial setting, this can only be done if we deal with "*high end use cases with often stringent requirements*", as per the words of Neirinck.

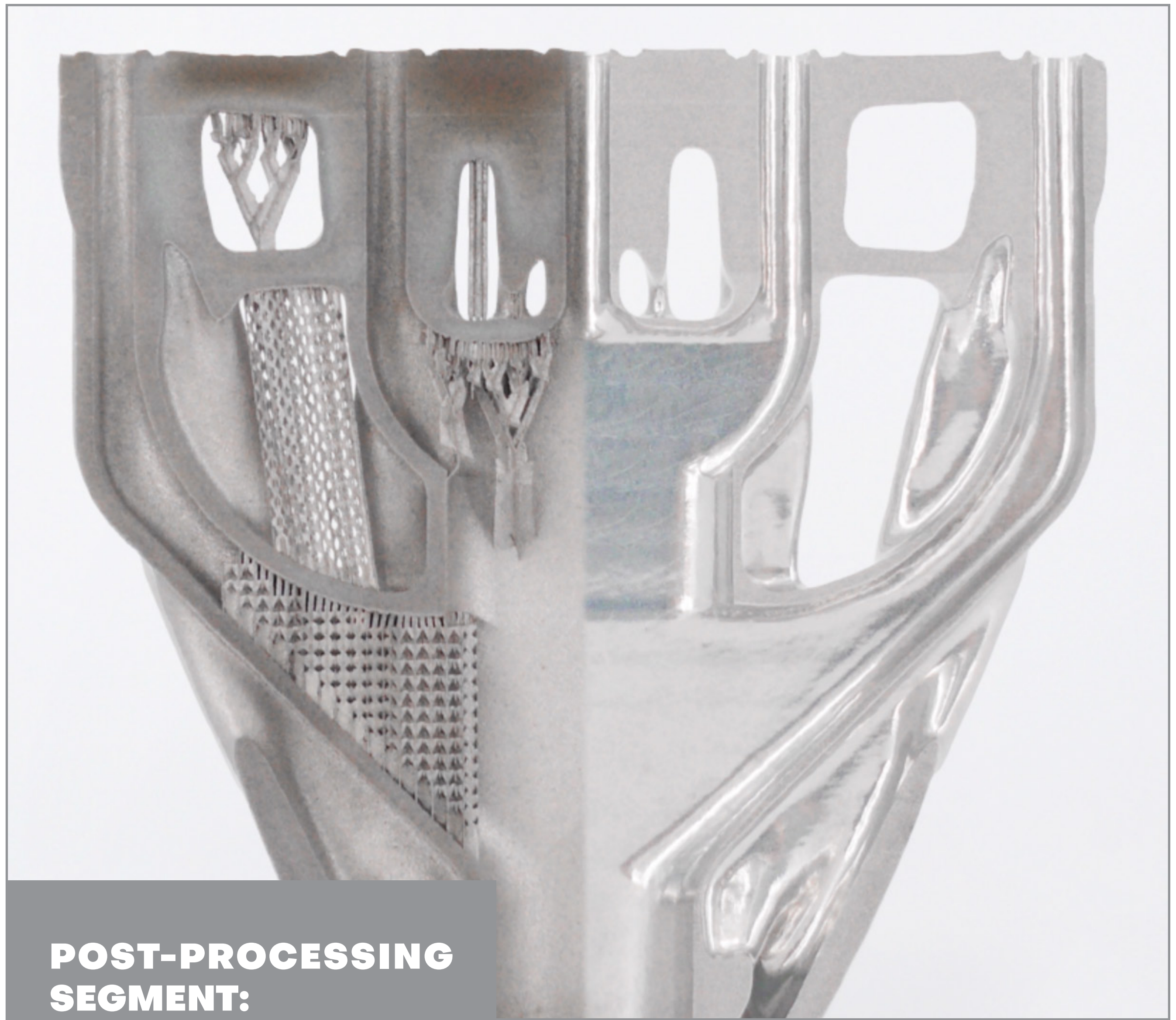
As Neirinck recalls: "*We must remember that we are, with additive manufacturing, competing with manufacturing techniques that have been around for at least the better part of a century*". So, there is reason for optimism when we look at how far the AM community has come.

Notes to the readers

In addition to all external resources leveraged, this dossier would not have been made possible without the great contributions from the Aerosint team and the KU Leuven AM team.

Headquartered in Belgium, Aerosint was founded in 2016 and became a **Desktop Metal** company in July 2021. The company develops a technology called selective powder deposition that enables full three-dimensional control over material placement in powder bed 3D printing processes. This patented technology unlocks a number of use cases in additive manufacturing, powder metallurgy, and beyond, including the printing of multi-functional parts. While the company's multi-material recoating systems for AM start to be used by research centres, the team currently focuses on the development of steel and copper material combinations. A choice that is driven by the need to explore what's possible to achieve in the grey world of metals and the huge number of applications that could benefit from combining high thermal conductivity with chemical resistance and or high strength. The company salutes and celebrates any progress made in multi-material AM as it believes all development in multi-material AM contributes to deepening the knowledge base, fuel applications and inspires developers.

Under the supervision of their team leader **Prof. Brecht Van Hooreweder**, the team at KU Leuven AM group focuses on research for AM and carries out most of their projects with the industry. With the goal of spreading knowledge about AM and supporting industries through collaboration and development of joint research projects, KU Leuven AM unit also acts as a hub between different companies which would not have achieved pivotal collaboration for dedicated research projects on their own.



POST-PROCESSING SEGMENT:

A closer look at surface treatments in metal 3D Printing

Remember when we told you that post-processing is an umbrella term that covers a variety of stages that 3D printed parts have to undergo before being used for the final purpose? With the goal of providing a thorough understanding of each post-processing task, we have started sharing key insights into issues raised by metal powder removal, the use of furnaces in Additive Manufacturing, or even the Automated Dyeing Process For 3D Printed Parts. In this article, we will have a look at the best practices and tips to know when conducting a surface treatment method in metal 3D printing.

The theory is that, in AM, engineers can benefit from freedom of design to create complex shapes but practice reveals design constraints which show that the geometry you print will not be the same as your 3D model.

Several causes may explain that :

- During the export of your print file for instance, 3D model's edges, contours, curved surfaces and more are approximated by triangles in a process called tessellation. When this happens, the forms of the circles are no longer perfect. They become approximations formed by a series of straight lines;

- Despite the optimization of the build direction, the layer-by-layer fabrication mode of AM can still be tricky for slanted surfaces, curved shapes, or holes; and provide a "staircase" effect;

- Other manufacturing and design challenges can be related to the geometry of the 3D model, the quality of the metal powder or the build orientation. They may affect the dimensions and tolerances of your final 3D printed part.

These issues may be some of the reasons why operators decide to conduct a surface treatment process; so that in the end, they could improve the appearance of their component, enhance their durability or the ability of the part to better withstand wear, corrosion, heat or other elements, smooth out uneven surfaces or improve its electrical conductivity.

This feature will provide a closer look at surface treatment methods operators can conduct for metal 3D printed parts. To discuss this topic, we have invited key contributors from two companies: **Jan Panhuis**, Senior technical commercial advisor at Lering Hengelo (Normfinish) as well as **Paul Gagorik**, Solution Architect and **Behrang Poorganji**, VP Material Technology from Morf3D.

In case you are not familiar with these companies, please note that, Normfinish (known as Leering Hengelo in the Benelux region), has been operating in the world of blasting and surface technology since 1980. The company provides a wide range of products and services for operations related to fine blasting, polishing, matting, finishing, deburring, surface roughing, cleaning of surfaces such as rust (oxides) and coating, as well as shot peening.

Morf3D on the other hand, brings a user experience around this "table". The company leverages an unmatched experience to deliver AM serial production to aerospace companies. As a parts producer, Morf3D leverages its in-house post-processing capabilities to achieve fully optimized functional structures and build processes for top-tier aerospace clients. Once a build is removed from the build chamber, the Morf3D team can conduct a wide range of post-processing steps. They include for instance, depowdering, NDI (X-RAY, CT Scan), Heat Treatment (Stress Relieve, HIP, Solution, Age, Quench), removal of substrate (build plate), support removal, CNC Machining, surface treatment (Media Blast, Ultrasonic Cleaning, Electropolish, Pickling, Passivation, Coatings, Paint), Assembly/Installation as well as Digital Data Package/ Certification. **Gagorik** and **Poorganji** will focus here on surface treatment methods.

We also thank machine manufacturer 3DEO, online manufacturing platform Factorem and SPC – Surface Treatment Experts for the resources shared.

Justifying the importance of surface treatment methods

Categories of surface treatment methods are not standardized. Therefore, their listing often varies from one organization to another; or it depends on the type of "aesthetic, feel or part properties" they deliver to parts. Soo far, we have identified:

- The finishing methods that include hand polishing, sandblasting or numerical control grinding. The "Mechanical finishes" category that includes sanding, ultrasonic polishing, rumbling and tumbling, magnetic polishing, lapping, filing or vapour smoothing.

- Coatings, which can include anodization, powder coating, painting or plating.

- The "undefined cutting edge finish" category that includes abrasive blasting, and vibratory finishing

- The "electric power finish" category which involves electropolishing;

- Solidification by plastic deformation: Shot peening

According to Panhuis, no matter what surface treatment option you choose, the most important issues to address concern the "dimensions of the part, the desired roughness, the optical requirements, the type of treatment (is it a manual or an automatic treatment?)". Needless to say,

HIP – Heat Image. Image: courtesy of Morf3D

the type of parts you process can also play a key role in the surface treatment option you will choose. A medical 3D printed part made in Titanium will not be post-processed as another one made in steel. A medical 3D printed part may only be blasted while a steel part, depending on its mechanical characteristics and the final purpose, can be painted, plated, or filed. "For some parts again, we need to check the allowed amount of contamination with blasting media", Panhuis adds.

Gagorik and Poorganji go further as they take into account the complexity of the part, its performance but also all the steps that may influence its final cost. They draw attention on the fact that “the ability to correctly/thoroughly apply a treatment to all intended surfaces, can be impeded by increasing the complexity of part design”. Key contributors in this case, include cleanliness, surface topology, and accessibility. “One important concern is how surface requirements in 3D printed part relates to materials property (For example HCF, LCF, Corrosion) and overall part performance. This is critical as dictates what surface finish treatment and metrics need to be achieved for each part CTQs*. This will eventually drive the cost and viability of AM process”, the experts explain.

*CTQ = Critical to Quality specifications

A closer look at surface treatment methods

While many of the same reasons for conducting a surface finish option apply to both 3D-printed parts and parts fabricated via conventional manufacturing processes, the first features to consider when choosing a surface finish method are the part’s ones.

“It should be driven greatly by the intended operating environment (assembly/installation, operation/performance, maintenance, decommission) of the part. It should not be driven solely by existing standards, specifications, «best-practices», etc.. – as all these approaches were created with specific assumptions/conditions that may not apply in all cases. Significant savings (in downstream lead-time and cost) can be realized when taking necessary time to interrogate your application before you design/define. The surface treatment is typically determined by the part CTQs, dimensional requirements, and heavily depends on the AM process (Modality)”, the Morf3D experts lay emphasis on.

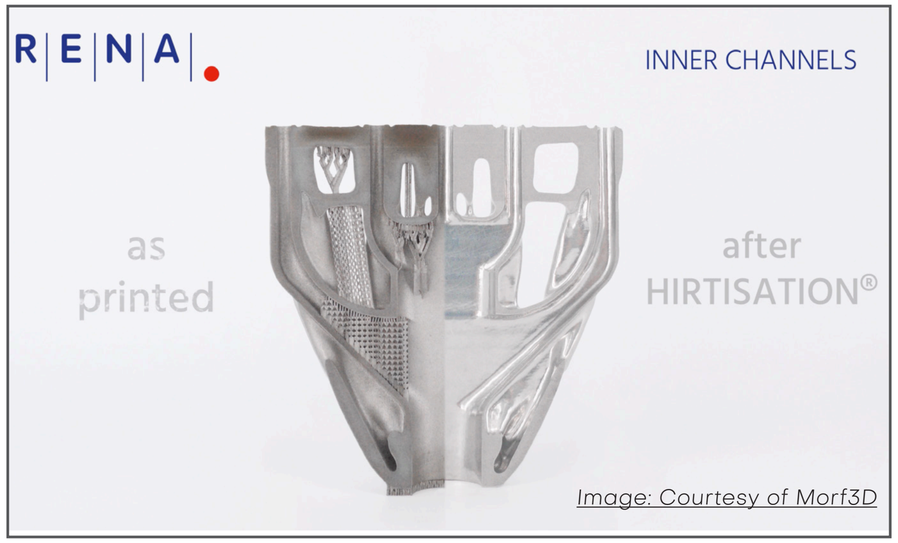


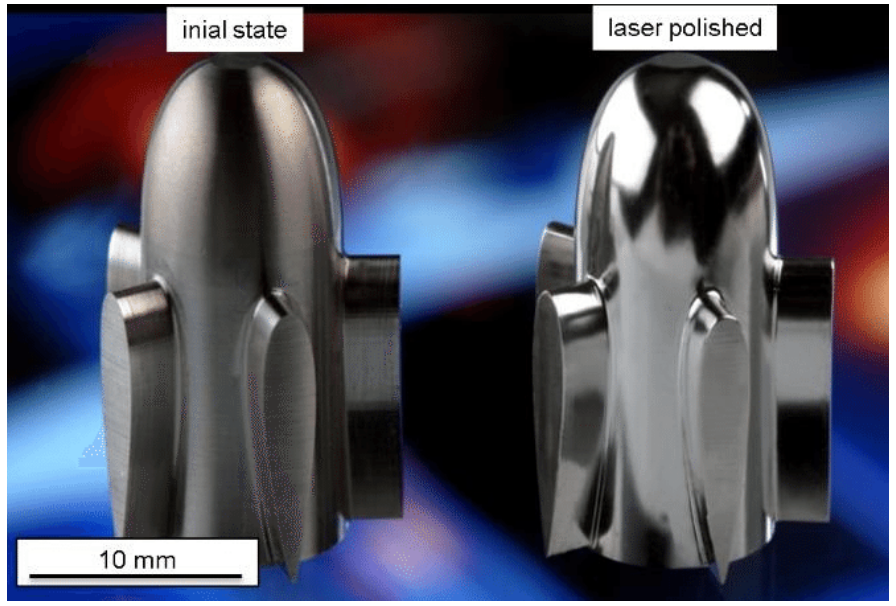
Image: Courtesy of Morf3D

That being said, let’s have a look at some of these methods – irrespective of their main category:

- **Sanding** is one of the most widely known surface treatment methods. It consists in rubbing abrasive particles on the surface of a work-piece creating random, non-linear surface texture. In other terms, a rough material such as sandpaper can be used to smooth out and remove small imperfections from a surface. Sanding is most useful when applied to curved or contoured surfaces. However, experts doubt its efficiency when it comes to tight corners.

- **Ultrasonic Polishing** on the other hand is ideal for internal finishing of tight corners, holes or pockets that can be quite difficult to access. In this method, a soft, fine tipped tool mounted onto an ultrasonic spindle vibrates at 30 kHz which, in combination with an abrasive slurry, induces a pressure wave that safely works away at the surface to create a fine polish. What’s interesting about this process is that the tip of the tool is not in contact with the work face. It works well on hardened steel, and there is little chance to cause damage to the part.

- The polishing options also include **laser polishing** where a high-energy laser beam melts the surface material of parts again to reduce the surface roughness. In theory, this method can deliver a surface roughness of 2~3µm (Ra). In practice, the high cost of laser polishing equipment slows down the adoption of this technique in AM post-treatment processes.



Ventricular assist device (VAD), left: initial state, right: laser polished

- **Chemical polishing** can also reduce the surface roughness of a given part to 0.2~1µm.

- **Rumbling and tumbling** are similar to sanding to the extent that abrasive particles are used to modify the surface roughness of the 3D printed part. According to SPC, tumbling is similar to vibration, but it rotates the components and the polishing medium around in a drum rather than vibrating them. This is a gentler movement, which makes tumbling better for more delicate parts and those with fine details. The unit used is often called a centrifugal barrel system.

- Intended for increasing the strength and durability of a part, **shot peening** consists in the use of pressurized air shoots tiny metal or plastic beads at a surface at high speeds.

- The shot peening process is very similar to bead blasting. This process makes it easy to reach the insides of channels and other tricky spots. The operator uses here a spray gun to shoot finely reground thermoplastics at the surface, removing therefore imperfections and smoothing out the surface.

- In the method of **sandblasting**, the operator blasts the part’s surface with abrasive particles under high pressure. Those abrasive particles can be used in combination with air and water, and cover a large surface area fairly quickly. Different levels of surface finish can be achieved by using varying types of abrasive media. Depending on the use case, the operator can enhance the mechanical properties of metal by increasing its fatigue strength and improving corrosion resistance through shot-peening.

- **Vibratory Finish** is a machining process with an undefined cutting edge. The goal is to improve surface quality of small parts. This is done by rounding edges, smoothing processes, and grinding.

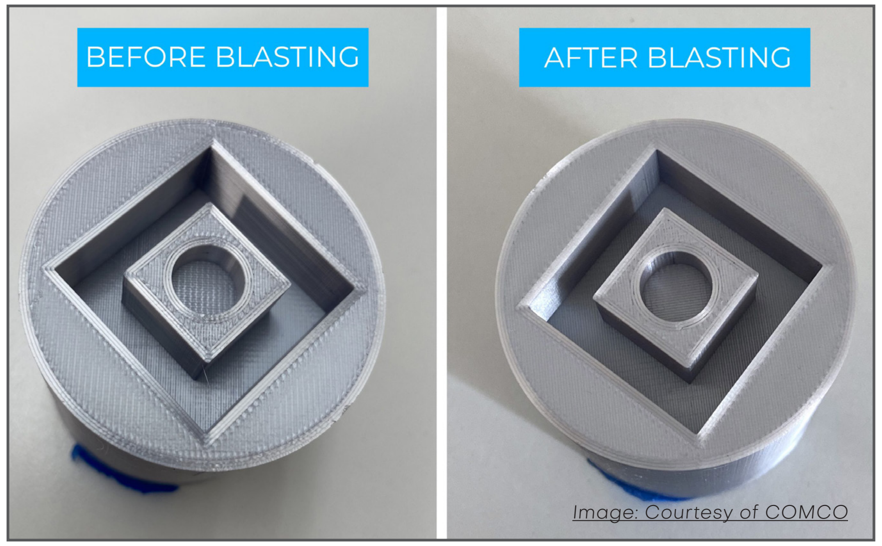


Image: Courtesy of COMCO

- **Plating** consists in coating steel with a small layer of an inert material. It enables protection from corrosion and oxidation of the base part. Despite these advantages, it should be noted that the part can be damaged by impact, wear and other external factors.

A surface treatment method can be conducted after the part has cooled down and is free from powder. However, as you may guess, the advantages of a surface treatment method can compensate for the disadvantages that another many cause to the part. That’s why, Gagorik and Poorganji said the appropriate order of the post-processing steps depends on the requirements of the final configuration of a given part.

“Surface Preparation processes (including Ultrasonic Cleaning, Abrasive Flow, Electro-polishing, Chemical Milling) typically happen prior to any surface Coatings (including Anodize, Metallic/Ceramic, Paint), and can sometimes be required (as cleaning operations) prior to Heat Treatments and Assembly processes as well. Usually, the surface finishing is coming at the later / final stages of the post processing. However, the sequences of the process is designed in a way to maximize the performance and minimize the cost”, the experts point out.

One key consideration at the heart of surface treatment methods: surface roughness

Experts have made it clear that all aspects of the 3D printed part, such as the material, shape, thickness, and weight, its planned use, and the environment in which it will be used, count when it comes to choosing a surface finish option. However, beyond all these aspects, a key emphasis has been made on *“the surface roughness problem”* of additive manufactured parts.

“Surface roughness is a measure of the variance in a part’s surface topology. Roughness can affect part aesthetics (e.g. shiny or maNe) and mechanical behaviour like crack initiation, wear resistance, fatigue life, marine, sealing, bearing, and fluid dynamics. The rougher the surfaces in an integrated dynamic machine, the less quietly, efficiently, and safely it will operate. Reducing roughness, or friction, is critical in mechanical parts like pistons, bearings, and seal surfaces where too much contact between moving surfaces can lead to rapid wear and tear. Specifications may differ by case, but the smoothness required of an end-use part can be an important factor in costing it. Surface roughness analysis includes the use of parameters to inspect and determine whether the part manufactured meets quality control standards. This helps

manufacturers and designers quantify the roughness of the surface finish they select" **Matt Sand**, Founder & CEO at **3DEO**, comments.

This explanation implies another one: surface condition can vary significantly by 3D printing process [even within the same process, but with different process parameters]. Therefore, we can't legitimately say certain surface treatment options work well with certain metal 3D printing processes.

For **Morf3D**, it is essential to understand the starting conditions for acceptable application of the surface treatment needed for the given material and part application, and then determine what manufacturing processes are necessary to get you there. Taking the example of their in-house capabilities, Gagorik and Poorganji note that the surface treatments they are using today, are the

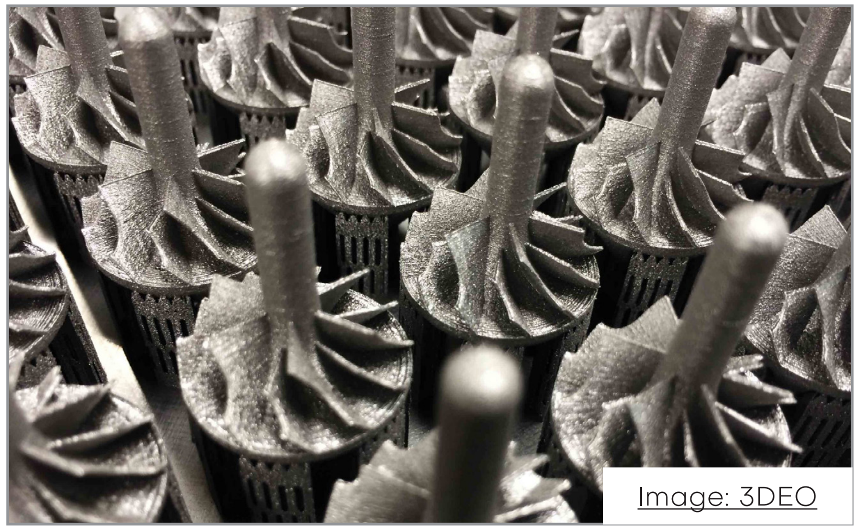


Image: 3DEO

advanced/developed version of the existing processes for conventional processes which are modified or geared towards the needs of 3D printed parts. For example, access to internal channels which are rougher than a machined channel, or chemical-mechanical polishing of a rotating component surface.

Lastly, the reasons for using a surface finish apply both to 3D printed parts and parts manufactured with traditional processes. Since different finishing options come with different costs, responsibility, as per the words of Morf3D's experts, lies not on the technology used to manufacture, but on informed design and manufacturing teams in collaborating to make the best decisions on what to use.

INTERVIEW

Brian Neff, Founder & CEO, Sintavia

THE AM STRATEGIES SINTAVIA TAKES TO EMBRACE THE VARIOUS DIRECTIONS THE COMMERCIAL AEROSPACE MARKET IS EMBRACING

3D ADEPT MEDIA   Brian Neff

The aerospace industry has always been mentioned as one of the early adopters of Additive Manufacturing. At the time (in the 2010s), being able to leverage plastic 3D printed parts for testing and simulation was already a huge achievement for aerospace companies. However, rising production needs around the world continuously impact the way the business of aerospace and defense is transacted globally. Furthermore, they lead to trade considerations that require new means of manufacturing to meet new demands of players in this sector.

Aerospace players such as Lockheed Martin, Airbus, Boeing, Northrop Grumman, and others who are at the forefront of commercial operations, may spearhead these demands, but the real heroes behind the scenes are often those who need to explore these new means of manufacturing in order to create aerospace components.

A conversation with Sintavia's CEO Brian Neff highlights these various directions the commercial aerospace market is embracing as well as the new manufacturing strategies they require.

One of the mistakes we often make in this industry is that we consider any parts producer as a 3D printing service bureau. A 3D printing service bureau delivers its services to a wide range of industries adopting AM technologies. Yet, given its primary focus on aerospace and defense, I see Sintavia as a technology and producer partner to aerospace and defense companies.

With the founder & CEO's roots in the aerospace industry, roots that include an extensive experience in the MRO and OEM manufacturing fields, it's easy to understand that Sintavia seized the opportunity to build an offering that is vertically integrated with various demands within the aviation industry. Indeed, AM might be the most highlighted manufacturing process in Sintavia's production, but to be good at this game, it's crucial to have a solid understanding of metrology, metallurgy, machining, heat treatments, testing, etc.; in a nutshell, all sub-processes that may help you define a real manufacturing strategy around AM.

Manufacturing strategy

The Florida-based company was founded in 2015, an era that coincides with the first recognitions of AM's potential within the aerospace industry. The thing is, despite these recognitions, the learning curve of AM was quite slow – and with good reason: companies needed to understand the ins-and-outs of the technology and this requires investment, a lot of investment.

With about 30 industrial printers in-house today, including multiple from GE Additive, TRUMPF and, obviously, EOS, including eight M400-4 quad laser printers, Sintavia decided very early to focus on *"the very best way to leverage AM"*.

This might seem crazy when we know that at the beginning, the aerospace AM market was not that advanced. The ROI for specific use cases of AM was not that clear.

"It can be frustrating, but to get there you have to invest in the void. It can be hard to do for some organizations because it requires a lot of money, time and dedication to see value and that's a risk many do not want to take. When we first started, we acquired a number of different machines from various OEMs. It is essential to any company diving into this business to understand the technology and that's what we were trying to do: understand the technology and gain a lot of hands-on experience. As time has developed, we have been able to identify which areas for which machines are the best. These 3D printers are tools we have to leverage for specific purposes and each of the various 3D printers we acquired brings a unique strength for specific areas. These areas involve for instance, the alloys that we use, the size and dimension of the parts we manufacture, the use cases of the component for manufacturing…for instance, we can meet the needs of those who want tall parts with the AMCM M4K-4 systems, we produce very good Titanium small parts on Arcam machines. In a nutshell, we try to make sure that we can meet all the different needs of our customers. Once we saw the benefits of printing very complex systems via DfAM, we said we wanted to focus on the hardest geometries possible, and it was a very smart choice. Achieving and focusing on the most complex applications is what enables us to leverage the best of these technologies", Neff explains.

That being said, Powder-Bed Fusion (PBF-LB) remains the most widely used process in Sintavia's portfolio.

Part of the production environment. Image: Courtesy of Sintavia

Powder-Bed Fusion yes, but an eye on other AM processes

From a **regulations standpoint**, the increasing use of this manufacturing process makes sense when we know that due to the conservative nature of the aerospace industry, it might now be easy to qualify parts manufactured with this technology. Remember, in January 2021, the ISO TC261 and the ASTM International committee F42 introduced a new standard which provides AM companies with qualification requirements for laser beam powder bed fusion (PBF-LB) in the aerospace industry. This standard aims to improve the ability for additively manufactured metal components to qualify for commercial, military, and civil aircrafts, as well as space flight and space propulsion.

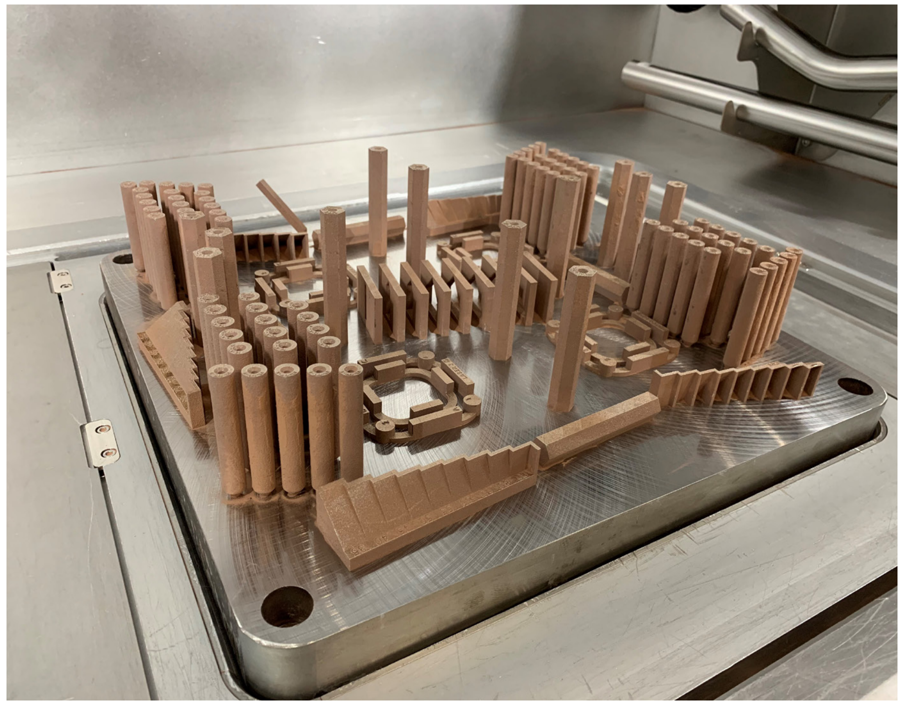
From a **manufacturing standpoint**, PBF-LB would provide greater benefits for aerospace parts than other metal 3D printing processes. *"The reason comes down to* ***materials properties****. In every type of manufacturing, you have to show a level of quality, and this requirement is even more stringent in aerospace manufacturing. On the other hand, it should be noted that the rigours of flying and landing can be hard in this industry because many errors could occur. Powder-bed fusion is a very sturdy type of technology that can deliver strong and durable components. The robustness of the process is demonstrated through lab analysis, microstructures, and mechanical testing. [PBF-LB] enhances a specific part, and we can demonstrate that this 3D printed part is stronger than its counterpart made via traditional manufacturing"*, the expert outlines.

As AM processes use to be compared to traditional manufacturing processes, Neff draws attention to the fact that engineers should not compare PBF-LB to freeform welding. *"This is not freeform welding. Freeform welding presents some weaknesses that aerospace manufacturing cannot withstand—similar to investment casting which has production variations that aerospace manufacturing does not like. At Sintavia, we use digital molds instead of physical ones and they deliver a totally repeatable process"*, he adds.

Apart from the potential of PBF-LB, Sintavia's team will keep an open mind regarding other AM processes that may deliver a significant difference in the manufacturing of aerospace parts. These manufacturing processes include for example, **DED** for its versatility of use and ability to deliver multi-material parts and **WAAM**, *"which is still very underestimated, yet is interesting for some rocket applications and large structural applications"*.

Investing efforts to develop the right materials parameters for the right processes

On the other hand, the *"materials properties"* argument goes even further as the development rate of AM depends a lot on **materials**. The reality is, aerospace parts producers acquired more experience on polymers (plastics) than metals because AM was first developed for polymers. However, the original structure of the aircraft makes it possible to maximize gains with metal AM, if well leveraged. These arguments lead all stakeholders involved in the aerospace industry, including parts producers to invest significant efforts to develop powders that best meet the parameters of the 3D printers they use.



Sintavia was no exception to this rule as the company made a real splash last year with the development of a **proprietary printing technology for GRCop-42**, a material described as the preferred copper alloy used by NASA and private space flight companies for **rocket thrust chamber assemblies**.

As a reminder, the new technology is a combination of a proprietary parameter set and post-processing heat treatment. It was developed on an EOS GmbH M400-4 printer, and results in GRCop-42 components with minimum density of 99.94%, minimum tensile strength of 28.3 ksi, minimum ultimate yield strength of 52.7 ksi, and minimum elongation of 32.4%. More importantly, the technology avoids the use of a hot isostatic press in post-processing steps, thereby reducing the time, complexity, and cost of production.

The proprietary printing technology for this material is just one of many examples of properties Sintavia has developed over the years. While Neff clarifies that, they have no intention to become a powders' producer, the ability to address the **reflectivity and high thermal conductivity challenges** raised by copper is a milestone the entire team was very proud to achieve.

"You have to develop your own printing parameters if you want to have the best chance to succeed. We have already developed nearly 30 proprietary material parameters. We usually don't announce each set of parameters we develop for specific powders but copper being a unique material, we were very proud of what we achieved with this material. Other developments (with refractory powders) are in progress and will be announced soon", the CEO comments.

Current routes the commercial aerospace market is embracing

You've certainly heard me say this a lot, and I will reiterate it: investing in materials and processes is good, but these investments might be ineffective if they are not supported by current demands in the market you target. Surprisingly, for an industry that is described as very conservative, the aerospace market is opening up to more ambitious sub-segments that are perhaps worthy of AM's potential.

"My expertise has always kept me to more traditional aerospace applications. There has been a lot of mini-markets that have been developing lately. Three of them currently stand out from the crowd: private space launches, hypersonic flight and electric commercial flights. When I started the company in 2015, I couldn't imagine it would explore the path to private launches", Neff shares.

Marten Jurg's rocket engine design, 3D printed with a cooling mesh wall on an EOS M280. Photo via Betatype

For Sintavia's representative, the common thread to these routes is **DfAM**. *"From a commercial standpoint, the adoption of AM in the commercial space industry urges the commercial aerospace industry to accelerate its adoption of AM – which is great to see. Moreover, there is a freedom of design when you are using AM for complex parts. In each of these paths, aerospace players are given the opportunity to create something new, something they have never done before, and AM is now giving them a myriad of possibilities to explore this potential"*, he adds.

Neff's explanations reveal that there is something appealing in **rocket applications** made possible via AM and the future of these applications is likely to be even more exciting. In the meantime, Sintavia's manufacturing investments help meet the demand of customers who are looking to create **advanced propulsion systems, combustion chambers for space launches**, (…), **optimise regenerative cooling passages** and, as a result, reduce lead times and complexity.

The commercial aerospace market is really a big market. Several players are trying to find their marks here and differentiate themselves from the crowd, but I believe Sintavia is doing so as they find value in looking beyond what they can achieve today.

AM WORKFLOW INTEGRATION IN THE AEROSPACE INDUSTRY : HOW DO WE EARN CREDIBILITY AS A VIABLE MANUFACTURING TECHNOLOGY ?

"We [the AM community], have homework to do to earn the credibility as a viable manufacturing technology", ***Dr. Melissa Orme****, Vice President, Boeing Additive Manufacturing.*

On the heels of my conversation with Sintavia's **Brian Neff** (pp 20-23), I sat down with **Dr. Melissa Orme**, Vice President, **Boeing Additive Manufacturing** to discuss another perspective on the use of AM in the aerospace industry. And I have to admit, it's quite fascinating to listen to each of these industry veterans as in the end, both points of view complement one another in a very seamless way.

What I like about Orme's background though, is that she has built up extensive experience in AM between academia, SMEs (contract manufacturers – Morf3D prior to Boeing) and final user (Boeing). This means that not only does AM run through her veins, but she is in a unique position to understand the synergy that must exist between these three stakeholders in order to make AM a viable technology.

Legend: Starliner Flies in Low-Earth Orbit
Photo credit: Boeing

As she explains, *"AM is a process-driven technology, where the mechanical attributes of the part are reliant on how it is built, which is not the case with conventional manufacturing, it is important that the final user closely collaborates with the part producer. Many times the part producers and the final users are one in the same. We rely on academia for basic science, or what we call 'low TRL'* research. It is important that academicians are tied into the equation so that the research they perform drives toward a solution to a problem encountered by the end user".*

*'Low TRL': Technology readiness level (TRL)**

While this vision should be an indisputable basic process organizations should go through to foster the adoption of AM in a more solution-oriented process, reality is often different.

In the aerospace industry for instance, the use of AM has first been stimulated by legacy systems that had gone out of production - (I am thinking of the Avro 146, or Airbus A310 as examples). For those systems, a small production batch achieved via AM turned out to be less expensive than setting up the original and traditional manufacturing process.

Dr. Melissa Orme,
Vice President, Boeing Additive Manufacturing

Furthermore, new programmes (re-engine options and new platforms) that were under development within aerospace companies or being fly tested for commissioning drove the developments of AM. For aerospace companies at the time, it made more economic sense to implement the technology this way – rather than investing efforts in existing systems which had only a few years of production left.

That being said, Boeing has always been amid the early adopters of AM. It was actually the first aerospace company to produce 3D printed parts for in-service aircraft and use them in commercial flights. About twenty years ago, the industry player developed an environmental control system duct for the F/A-18, which was later introduced on the Boeing 787. That environmental control system ECS duct was a polymer component developed and produced with Selective Laser Sintering (SLS) machines.

Today, over 70,000 3D-printed production parts fly through Boeing commercial and defense programs (AM Insight, Statistics, Boeing – Q4, 2019). Looking back, we can legitimately say the technology has evolved from research and development projects and low-cost tooling to printing high volumes of high-value metallic components and large families of tools.

Looking forward, it seems that there is still a long way to go when we look at the roadmap for AM workflow integration. How long? For Orme, the *"length of the roadmap depends on the application and the regulator. Different regulators have different requirements in the number and types of tests performed. However, what is common with most regulators is the following: for aerospace and defense, we need to show that our process is stable and repeatable. Stability and repeatability is the holy grail in Additive Manufacturing. Different regulators have different ways of determining stable and repeatable processes. One of the challenges in achieving stable and repeatable processes is that the machines are still produced as one-offs, making it difficult to have two of the same machines providing the same results within the small level of variation that the aerospace industry requires. Issues like this make scale with quality difficult, but not impossible."*

Yet Aerospace companies (be it part producers or final users) continue to invest in AM. Neff told 3D ADEPT Media (Interview with Sintavia - pp 20-23) that *"It can be frustrating, but to get there you have to invest in the void. It can be hard to do for some organizations because it requires a lot of money, time and dedication to see value and that's a risk many do not want to take."*

Orme unconsciously completes her statement by reminding of the *"immense value that AM can bring". "For example, it enables the design for parts that are built to fit into small and odd shapes in the vehicle, reducing overall volume. Aerospace companies see that AM creates the possibility to optimize the vehicle, not just the part. It provides the opportunity to create differentiating vehicles, providing a competitive advantage. It is also very important to mention that AM produces positive sustainability trades, which is a key focus for Boeing, as it is for all aerospace and defence"*, she adds.

As we assess the challenges that may arise when implementing this roadmap, we come to realize that, industry stakeholders necessarily take into account three main considerations.

Command Horn Antenna_Space – Image: Courtesy of Boeing

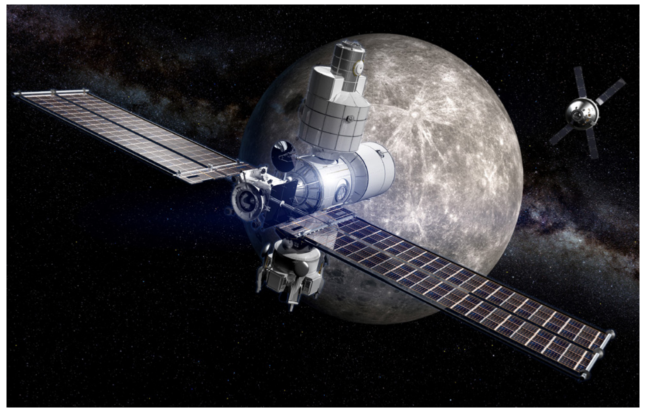
Considerations to take into account in the roadmap for AM workflow integration in the aerospace industry

Those considerations involve the economic standpoint, the conservative nature of Aerospace as well as the cost consideration.

The economic element brings us back to an argument we discussed with Neff. Rising production needs around the world continuously impact the way the business of aerospace and defence is transacted globally. And aerospace players such as Lockheed Martin, Airbus, Boeing, Northrop Grumman, and others who are at the forefront of commercial operations, spearhead new trade considerations. Needless to say, the current economic environment brought forth by the pandemic, requires us to be careful about how we do business. It may be difficult to have a general assessment of how this environment has impacted the aerospace manufacturing industry, but for Boeing there has been a positive turnaround.

"This is because we were able to focus much of our Additive Manufacturing work towards our Boeing Defense and Space division where we printed literally thousands of parts for satellites, drones, and vertical lift applications", the Vice President notes. Orme hints at the growing applications where they will further explore the potential of AM. (Indeed, the company previously shared that it will grow the capabilities of AM — *"in particular for its Millennium Space Systems subsidiary focused on the smallsat market, where 3D printing is proving to be an especially good fit for deploying systems on orbit faster than ever before"*).

In the meantime, the division also doubled down on maturing their internal core competency in Additive Manufacturing through the research that they perform and the databases that they create to demonstrate stable and repeatable performance. During all of this time – Orme states – speaking of what they achieved during the peak of the pandemic, *"our commercial airplane Additive Manufacturing applications continued along their development path and we plan for our first production airplane parts fabricated from powder bed fusion to be delivered one year from now."*



On another note, when it comes to accelerating the adoption of 3D printed parts in a vertical industry, cost – bringing down the cost per part – remains a touchy topic and that makes for a difficult conversation I often have with machine manufacturers regardless of the segment (3D printers, post-processing, etc.). Interestingly, the question is not only a matter of those who produce the AM technologies. As a final user, Boeing believes they also have their part to play in this conversation.

"We understand that our initial efforts into the additive arena will require a lot of developmental research. In the beginning, that research will be absorbed into part cost. We also understand that AM is not a « commodity. » We see true value in the innovation that AM allows. For example, some innovative solutions will likely consolidate many parts into one, which will enhance production. Some innovative solutions will be multifunctional, so that a structural element may also be heat exchanger, or may also be an electrical component. We may use AM to streamline our products so they produce less drag, requiring less fuel and making it cheaper and cleaner to operate. This will contribute to our sustainability goals. We have also found that we've reduced a program schedule by many months using additive solutions. This is a tremendous cost saving. So although the individual part may cost more, the overall savings to the program outweighs that cost", Orme points out.

The last consideration to take into account – the conservative nature of the aerospace industry – refocuses the debate on the "application vs regulator" argument highlighted above. **Where I see limitations, Orme sees opportunity to earn real credibility**. She does not deny this conservative nature and wouldn't have it any other way. Most importantly, she calls on the duty of the entire AM community to make sure that [AM] *"can earn the credibility as a viable manufacturing technology"*.

"In order to earn that credibility, we have homework to do. Additive Manufacturing does not enjoy decades of data that conventional manufacturing does. We need to make sure that we understand any risk associated with AM and that we know how to mitigate that risk. Only then will engineers opt to design for the additive solution and then we will find it easy to integrate AM solutions onto the airplane", our guest concludes.

BUSINESS

GO BIG OR GO HOME: WHAT DOES RAISING MONEY FROM VC FIRMS MEAN FOR ADDITIVE MANUFACTURING COMPANIES ?

Successful companies often convey the image that they are living a fairy tale which might sound like honey in the mouth to those who like fairy tales. To me, the most beautiful part of a company's journey is the path it takes to get there, a path where one of the most daunting hurdles is often that of **financing**.

With humble beginnings, start-ups with brilliant business ideas invest efforts; prove the worthiness of their business model and products thanks to the generosity of friends, family, and the founders' own financial resources. As their customer base begins to grow, their business begins to expand its operations and its objectives; companies start looking for additional capital through rounds of external funding.

This stage provides external investors the opportunity to invest cash in a company in exchange for equity or partial ownership of that company. This process of growing a business through outside investment is very common across industries, including the Additive Manufacturing industry.

It becomes essential to have a look at the process AM companies are getting into when looking for capital, when we know that last year has been marked by a great number of funding rounds across the industry. **AM Ventures** alone, a venture capital firm that only invests in forward-thinking AM companies conducted a dozen of funding rounds across the entire AM industry in 2021.

What does this process imply? What should AM companies take into account when looking for additional capital? How can they better prepare themselves in this process? Or what are the different resources they can leverage to look for money?

This article ambitions to draw AM companies and entrepreneurs' attention on the mindset they should have and the precautions they should take, when looking for money.

Despite the challenges that a company may face in being qualified for a loan, it should be noted that companies have so many routes to explore when they look for options to fund their start-up. In the AM industry, in addition to founders' financial resources, we have seen companies benefit from support from **incubators, angel investors**, and **Venture Capital** (VC) companies.

Replique for instance, is a Mannheim based venture of the BASF business incubator Chemovator. Spanish metal 3D printing company **Triditive** took part in the Stanley+Techstars program before raising money from Stanley Ventures. However, most AM companies that raise money in this industry do so via a **Venture Capital (VC) firm** – which is the perspective we would like to focus on in this article.

"What does it mean to acquire VC money"?

This is the question **AM Ventures** first asks entrepreneurs who are looking for financing. This might sound trivial, yet is very crucial when exploring the VC route.

The thing is, every (successful) company usually goes the bootstrapping route first before management accepts venture capital or other means of external funding. Reality is, *"VC funding is a game-changing process. It can be a dramatic acceleration of the business and it comes with certain expectations. A partner from a VC firm will not only invest his/her own money, they will invest money that they borrow from their investors"*, **Arno Held**, co-founder and Managing Partner of AM Ventures states from the outset.

Held's first statement highlights a standpoint that we rarely mention in funding processes. Each VC firm promises their investors a certain performance from the companies they are investing in and has to ensure that injected money is not going to be wasted. Therefore, it is crucial for start-ups to work out well thought through promises that they can achieve and that the investor can and will hold the founders accountable for. In most cases, it might be of great value to onboard VCs that understand the industry and markets a company operates in, and thus knows about how to set the bars right.

In the end, **having a win-win deal** for both parties – the funder and the funded – **requires the right investor and the right expectations/objectives**.

"Especially in early stage funding, it is highly important to align expectations very early in the process. But we at AM Ventures are convinced that we have the knowhow and the competences to help founders define clear, and measurable objectives that they can achieve with a specific amount of money", Held adds. Remember **how AM Ventures started**. Before co-founding AM Ventures, Held built extensive experience within Additive Manufacturing company EOS. Therefore, he and his team know a thing or two on product development, commercialization and R&D.

"We know it takes at least 6 years to develop a good hardware for AM, so we know how to help founders build realistic plans when it comes to product development. Furthermore, there should be a good timing between funding rounds. It's much more important to deliver a well-thought promise and ensure that your organization grows healthily. We saw some investments that have been made around a certain hype; investments that are made based on unreasonable expectations. And overpromising is easy to make when you have an investor who believes that promise. On the contrary, an investor who understands the game will not only help build a promise that you can deliver, but he/she will have the patience to go through difficult times", Held explains.

In what scenario do AM companies often find themselves when they want to raise funds (series A, B, C, D) ?

First, let's remember that the path for each company is somewhat different, as is the timeline for funding. Company X may spend months or years in search of funding, while Company Y will move through the process more quickly. In the AM industry, the process of finding capital often seems to go fast as technology solutions are often "revolutionary" and/or these ideas are often attached to innovators who have a proven track record of success.

Moreover, the more a company is mature, the more it advances through the funding rounds. Therefore, a company may begin with a seed round, and continue with A, B and C funding rounds.

Before they get there, founders often go through the funding stage of **"Pre-Seed Funding"** first, where they get their operations off the ground. There is no real exchange for equity as investors here are often relatives or founders themselves.

Seed funding comes next. This first equity funding stage represents the first official money that a business venture or enterprise raises. Sometimes, money entrepreneurs get in seed funding, helps them develop market research, product development, acquire new equipment and target industries for commercialization. **MetShape**, a manufacturer of indirectly 3D printed metallic components, went through this process last year.

Arno Held, co-founder and Managing Partner of AM Ventures.

In a **series A funding round**, the company has already built first traction in its market. The company already has here a Minimum Viable Product (MVP), an initial user base, consistent revenue figures, or other key performance indicators. It is now looking for money to further increase this user base and increase product offerings. In 2018, 3D printing company DyeMansion secured $5M in series A funding to implement an internationalization plan. In 2020, Medical 3D Printing Company Kumovis secured €3.6 million in a Series A funding round to enter new markets and more recently it was Conflux Technology that raised AUD$8.5 million to develop 3D printed heat exchangers.

Companies that undergo a **Series B funding round** are a little more established, and their valuations tend to reflect that. Usually, they already went through seed and Series A funding rounds and want to accelerate their performance on a larger scale. At this level, the company value is assessed based on revenue forecasts, assets like intellectual property, or the company's performance. For investors, there is less risk in investing at this level, and the funding amount is usually bigger. Last year saw a funding round of $25M in Series B secured by Mantle. In the construction 3D printing industry, we also saw ICON raise $200 Million in Series B Funding to meet Demand For 3D-printed Construction.

In a **series C funding round**, it's fair to say the company that finds itself in this situation is already a successful business. Those who secured money at this stage want to develop new products, expand into new markets or even acquire other businesses. Sometimes, the interest for certain investors here consists in receiving more than double the amount they injected back. Also, cash flow at this level often comes from hedge funds, private equity firms or investment banks. Last year, **LightForce Orthodontics**, a provider of custom 3D printed orthodontic brackets, raised $50 million in its latest round of Series C funding for example. In another segment, **ARRIS**, an advanced manufacturer specializing in high-performance composites, raised $88.5 million in Series C funding last year.

Funding rounds can continue with **series D or E**. Companies that look for more capital at this level, may do so to achieve certain objectives before going public or may be looking to achieve the goals they failed to achieve in their previous funding round.

According to **Arno Held**, *"AM companies that secure money for the first time in seed funding often look for capital that is between 700 000 and 2 million euros. In a series A, they often secure between 3M and 7M€ while series B funding rounds target a volume that is between 8 to 15 million €".* Interestingly, the expert outlines that these figures are just typical for Europe. In the USA, they can easily multiply. In the end, parameters that define the amount of money a company can get in funding rounds include the technology **segment,** the **targeted industries** or the **geography**.

The "valuation" question

Whether you secure money through funding rounds or not, your company's value grows as long as it exists and performs. However, Held invites companies to be cautious:

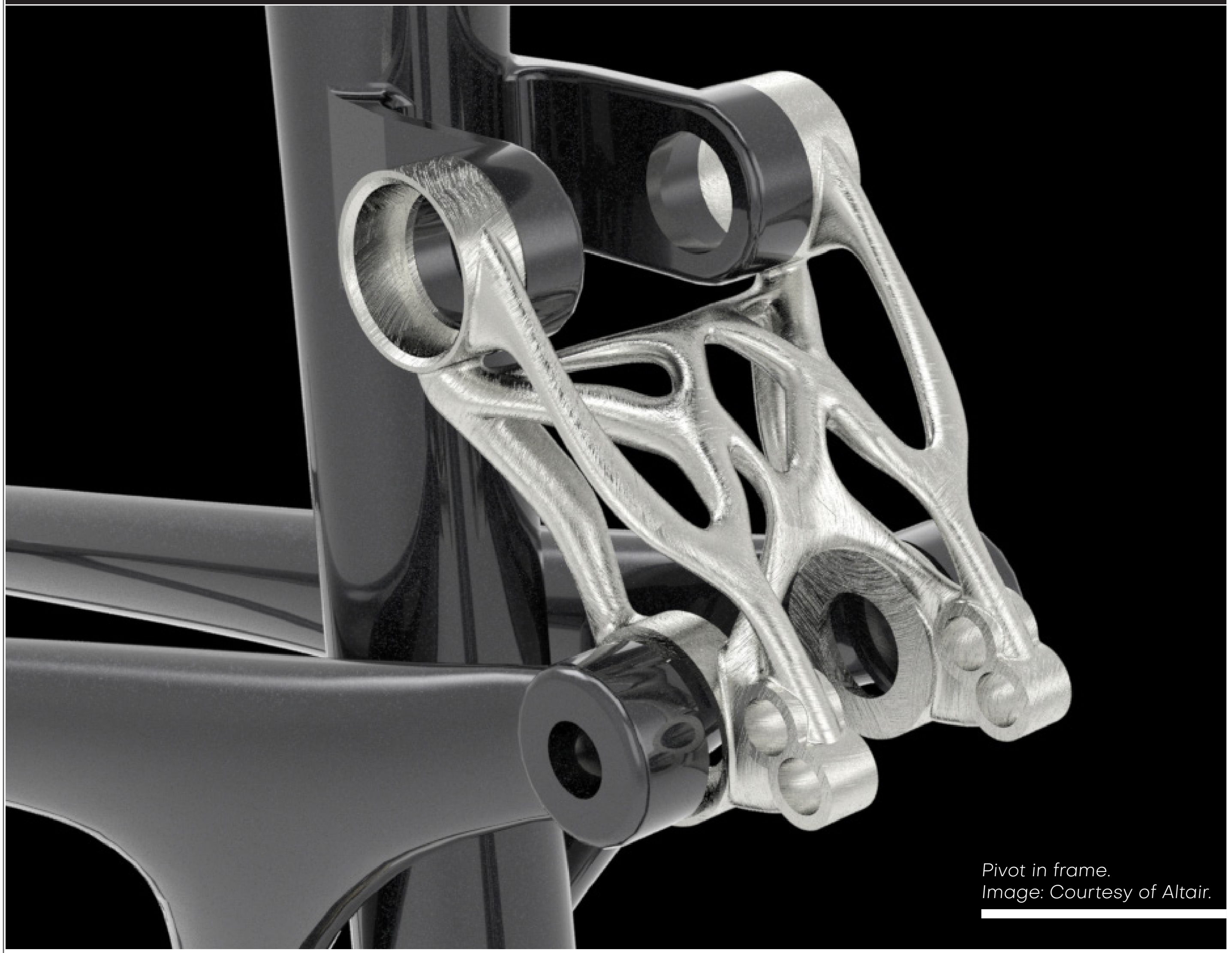
"Normally, a funding round increases the company's value. Indeed, with one funding round, you often acquire money to reach a certain target. You use the funds to achieve that target; you grow the organization as a whole. If things go as planned, the valuation will grow. If the plan is missed by a lot without good reason, this means that the last valuation was not justified." The possibility of a "low valuation" refocuses the debate on **performance and promise** set at the beginning of the investment (and this article). Held points out that at some point, the promise must be re-evaluated, if the company performs well, and most importantly, if it did not perform well. He then insists on the fact that *"early-stage start-ups are not cash-flow generating organizations. Therefore, each valuation a founder makes is based on hypotheses. Since they work on these hypotheses, it's of paramount importance to set a realistic valuation so that in the end, both parties should not find themselves arguing on an unrealistic promise that can't be achieved."*

Where is the market heading?

As we set eyes on what 2022 holds for the AM industry, we can't help but think that 2021 has been marked by over 53 acquisitions (reported by 3D ADEPT Media), 16 companies that went public be it via a SPAC or a traditional IPO process (Statistics of September 2021 reported by 3D ADEPT Media) and a great number of funding rounds.

While these changes can be described as a sign of maturity and/or a sign of recovery for the AM market, the most impressive observation in Held's opinion is the **growing number of applications-based companies** that receive fundings.

"It is a clear sign that people have realized what they can do with AM. We are finding ourselves at a major inflection point. There are hundreds of applications in the making right now, 50% of the startups scouted by AM Ventures in 2021 are based on additively manufactured products. Moving forward, I am very optimistic about the first half of the year. All teams in our portfolio have successfully raised funds or are about to close rounds. We could not be more proud of these entrepreneurs and it is very exciting to see how all companies are performing very well. The second half of the year is very hard to predict but we remain very bullish about the overall outlook for our industry. ", he concludes.



Pivot in frame.
Image: Courtesy of Altair.

CAD AND/OR MESH : WHY THE ROAD TO FILE PREPARATION FOR 3D PRINTING CAN BE CONFUSING ?

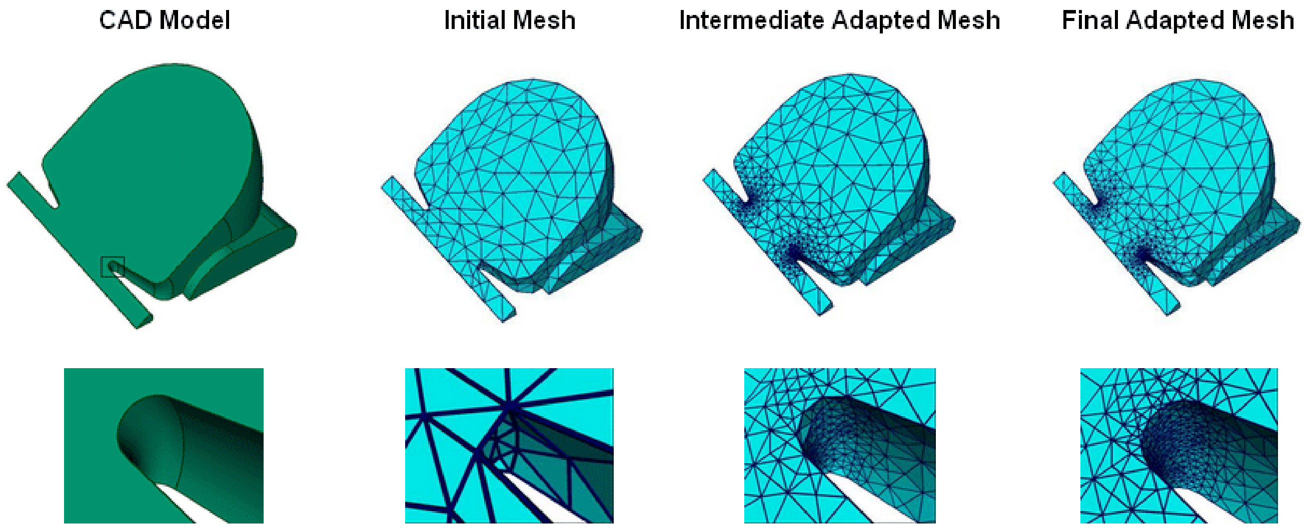
*One of the most fundamental steps in a product development process is the **modelling**, which entails creating 3D models of objects. Here is the thing, some designers believe that CAD is the only way forward - completely removing mesh workflows from the file preparation process while others think that MESH is slightly faster. The first step in building consensus is to clarify the importance of CAD & MESH – individually.*

The first observation we made in our team is that engineers have different understandings of CAD and mesh. The confusion may lie in this very first point, because how can you break down the difference between both concepts and their benefits if you do not understand them? Some engineers consider CAD and mesh as (3D) models while, in reality, they refer to processes that enable to create (3D) models. Literally speaking, Computer-aided design (CAD) is the use of computers (or workstations) to aid in the creation, modification, analysis, or optimization of a design. A mesh on the other hand, is a representation of a larger geometric domain by smaller discrete cells. A mesh model consists of vertices, edges, and faces that use polygonal representation, including triangles and quadrilaterals, to define a 3D shape.

When it comes to 3D printing, both concepts can be used in a file preparation workflow. *"Commonly CAD starts with sketching and then using subtractive tools to build 2.5D or 3D designs. Meshing starts with existing CAD, breaking CAD into fine elements to run mathematical calculations for different types of simulations"*, Jaideep Bangal, Design and Manufacturing – Global Technical Team, Altair Engineering states.

This means that CAD may exist on its own, but creating a mesh model often requires an upfront CAD work hence the concept of *“meshing in CAD software”*. Here again, several nuances should be made. Indeed, when talking about meshing in a CAD system, a design engineer may refer to triangularisation of a model to export it to other packages, discretisation of a model into elements suitable for a FEM package, or meshing of u- and v-parameter isocurves to let the user check the quality of a surface visually. For example, a triangularisation of a model can lead to the generation of an STL file, whereas the discretisation of a model can lead to the generation of mesh file with tetrahedrons.

Speaking of file preparation, Altair's expert states: *“engineers commonly use STL, CAD, 3mf etc file formats to prepare designs for 3D printers. They still need a mechanism to convert this data into printer specific format, which can be exported by these tools or printers”.*



Legend: Differences between CAD and Mesh.

Applications specific to CAD and Mesh

Meshes can serve different purposes including reverse engineering, dimensional analysis and 3D printing – which is the angle we focus on.

In reverse engineering, engineers use meshes as a template to draw usable CAD of the scanned part. This can help to replace lost CAD, or create CAD for legacy parts. As far as dimensional analysis is concerned, a mesh can be overlaid onto original CAD to generate a colour map that indicates areas of the component that deviate from the CAD and how far the scanned part is out of tolerance. Whereas for 3D printing, they are saved as STL files. This means, a designer can import a mesh to a 3D printer and fabricate the part from this model.

CAD on the other hand, can serve a different range of objectives: design creation, design modification, manufacturing or digital inventory. Be it for design creation or design modification, there are a wide range of suite-specific CAD that provide a variety of tools that will enable designers to create models from scratch, including prototypes, tooling, and much more – on the other hand, to modify the designs based on desired requirements.

As Bangal notes, *“almost every engineering company has some sort of CAD capabilities, engineers save their design work using PLM systems along with various design iterations during the product development process. On the contrary, CAE experts create mesh files from CAD provided by design engineers for simulations. They clean up CAD, prepare models, generate the mesh, and analyse performance using simulation solutions.”*

That being said, the various objectives that may lead to the use of CAD or Mesh are also the ones that help differentiate their unique advantage: “CAD is built upon geometry, which is enabling engineers to modify their designs quickly, even from neutral CAD file formats. But it also creates geometry nuances that might make it unusable for simulations”, Bangal comments. *“Unless engineers are using meshless technology such as Altair® SimSolid®, all simulation solutions create finite element models from CAD for performance analysis or to prepare the model for manufacturing, that's mesh”*, he lays emphasis on, taking the example of Altair's products.

A key focus on workflows for file preparation

When creating a file for 3D printing, most CAD programs convert the file to STL format (which converts it to a triangular polygon mesh). However, reality reveals that, *“both CAD and mesh are important depending on when it is used and who uses it. Typically, CAD comes first followed by mesh during the product development workflow. Design engineers prefer to work in a CAD environment while simulation experts use mesh. If CAD is king, mesh is kingmaker!”* So, what should we tell to design engineers who continuously compare both in order to decide which one they should go for?

To this question, Bangal recommends hybrid technologies. Just like a hybrid manufacturing approach brings the best of both AM and conventional manufacturing processes, a hybrid software technology would bring the best of CAD and Mesh. One company that is surfing on this concept is Materialise. For the software company, bringing together CAD and mesh during file preparation is like peanut butter and jelly - great on their own, but even better together.

“For example, CAD is known for its impressive capabilities while editing parts because it's of a higher resolution than mesh. It will be seamless to go from design optimization software to file preparation with Magics and complete tasks such as enhancing parts, creating fillets, and adding holes. However, there are also clear benefits when using mesh while preparing parts for 3D printing. It's crucial to complete certain steps with mesh, especially during build preparation and for applications with organic textures. It is also very powerful for operations where you want to ignore the complexity of designs, such as the wrapping of a complete engine assembly. Mesh contains all the information about the inside and outside of 3D models necessary to slice parts and begin 3D printing”, the 3D printing company explains.

That's the reason why, the company recently combined both into a seamless workflow within its Magics software solution – its data and build preparation software.

While we can't wait for design engineers to share their feedback on this, we are ready to take Bangal's statements as valid: *“combining the benefits of an easy alteration of parametric CAD and the flexibility of Polynurbs descriptions, to address the organic shapes resulting from topology optimization, as they are often found in designs for 3D printing.”*

USE CASE

Image : Courtesy of Ariane Group

Instead of producing 248 elements, Ariane Group 3D prints an injector head of a rocket engine as one single component

« All-in-one Design »

„Mission Critical" often refers to the Class 1 components used in the aerospace industry. These missions often cost hundreds of millions depending on the part to manufacture. **ArianeGroup** has recently reached a milestone in a "Mission Critical" project: rather than fabricating 248 elements, the Ariane team has produced an injector head of a rocket engine of a future upper stage propulsion module as one component. The injector head has been simplified and reduced to what is literally an **all-in-one (AiO) design**.

The European Space Agency (ESA) wishes to assume a strong and independent position in space transportation using efficient launch vehicle technology. In order to achieve this, ArianeGroup, a joint venture by the European aerospace company **Airbus Group** and the French group **Safran**, was commissioned to construct the next generation. Ariane is a series of European launch vehicles designed to enable heavy payloads, such as communications satellites, to be put into orbit around the earth.

In a propulsion module, tremendous forces develop under extreme conditions. This demands maximum levels of reliability and precision in a small space. The injection head is one of the core elements of the propulsion module, feeding the fuel mixture into the combustion chamber.

Its traditional design consists of 248 components, produced and assembled in various manufacturing steps. The different processing steps, such as casting, brazing, welding, and drilling, can result in weak points that can constitute a risk under extreme loads. Moreover, it is a timeconsuming and complex process. In the field of injector elements, conventional production requires over 8,000 cross holes to be drilled in copper sleeves that are then precisely screwed to the 122 injector elements in order to mix the hydrogen that streams through them with oxygen.

A glance at these figures clearly shows that, one functionally integrated component combining all the elements must be the obvious but ambitious goal. This could also release significant economic potential and cut the number of processing steps as well as production time, especially for a Class 1 component.

One part, same functionality

The **powder bed-based, industrial 3D printing technology** from EOS meant that it was possible, for example, to print the 122 injection nozzles, the base and front plates, and the distribution dome with the corresponding feed pipes for the hydrogen and oxygen fuels as one integrated component. Compared with single-laser systems, the significantly higher productivity of the EOS M 400-4 multi-laser system was able to cut construction time by a factor of 3 and costs by 50 % in the example of the AiO injector head.

The project team was able to clock up a whole series of additional successes. The simplified design and the improved material properties compared with the quality of cast parts allowed the additive technology to reduce the wall thickness considerably – without losing any strength.

Cutting weight significantly also meants a further reduction in construction time and, of course, costs.

Last but not least, additive manufacturing processes allow innovation cycles to be sped up significantly. **Structural improvements, design modifications, and the manufacture of test components in the development phase** can be put directly into production based on CAD data without requiring engineers to spend time preparing tools, as is the case when casting parts. Industrial 3D printing thus achieves a quantum leap in terms of lead time. Whereas each iteration generally used to require around half a year, one iteration now only takes a few days. On top of this, the entire manufacturing chain now unfolds in-house on ArianeGroup's premises.

Image : Courtesy of Ariane Group

ADDITIVE MANUFACTURING FOR AEROSPACE AND SPACE

Additive Manufacturing (AM) is the process of designing and building components layer-by-layer by using Computer-Aided-Design (CAD) software or 3D object scanners to direct hardware to deposit material in precise geometric shapes. AM includes not only the actual manufacturing, but also aspects of design, prototyping, post-process and quality assurance, with increased focus on certification and standardisation to ensure wider adoption.

In contrast to traditional subtractive manufacturing (which typically shapes pieces out of larger materials), AM allows for completely customisable, complex design, with the ability to change shape, structure, weight, strength, durability, and more. AM is generally considered to be faster, cheaper (following the initial high cost of the printer), and more flexible, with the process easier to review and customise, with less waste than traditional manufacturing. Parts can be built and changed at any point in the AM process, reducing lead-time signficantly, especially for unique or difficult-to-source parts.

Within the AM industry, the COVID-19 pandemic is being viewed as a 'break', resulting in wider adoption across numerous previously hesitant industries following the pandemic's disruption of traditional supply chains and manpower. This period has also been a time for the industry to push greater certification, standardisation and training efforts. AM also appeals greatly in this era of greater focus on sustainability, being dubbed 'sustainable by nature', especially when compared to other traditional manfaucturing methods. This is primarily due to its minimal waste potential, and ability to recycle waste or older AM products.

The Aerospace and Space industry has been increasingly utilizing AM since 2010, with AM initally only used for parts inside aircraft cabins and other interiors, and the primary focus being to reduce weight and cost. There has been a tentative expansion into using AM parts in engines, with greater exploration of AM's potential. However standardisation and certification processes are still long and arduous following hesitancy to change and accept the risk of AM.

The stagnations of the Aerospace sector during the COVID-19 pandemic caused a significantly lower rate of aircraft production, however this allowed for an increased use and wider adoption of AM for part replacement as an exploration of cheaper costs and disrupted supply chains. In contrast, the Space sector had massive achievements and advances in 2020-21 following the emergence of a new generation of private Space companies. The privitisation of Space has allowed for wide adoption and increased use of AM in rockets, satellites and other Space equipment.

AM is an exciting industry rich with possibilities and potential, with its versatility and flexibility making it ideal for the dynamic Aerospace and Space sectors. Following the COVID-19 pandemic, with greater advances and widespread adoption of AM, there have been vast achievements and acceptance of AM wtihin this field that the industry will be keen to discuss and has not yet had a chance to explore.

The Additive Manufacturing for Aerospace & Space conference is returning for its eighth iteration in 2022. In recent years it has firmly established itself as the premier forum for AM users, R&D experts, and industry partners within the aerospace and space industry. Defence IQ is delighted to host this conference, live once again in Germany.

Additive Manufacturing for Aerospace & Space 2022 Conference:

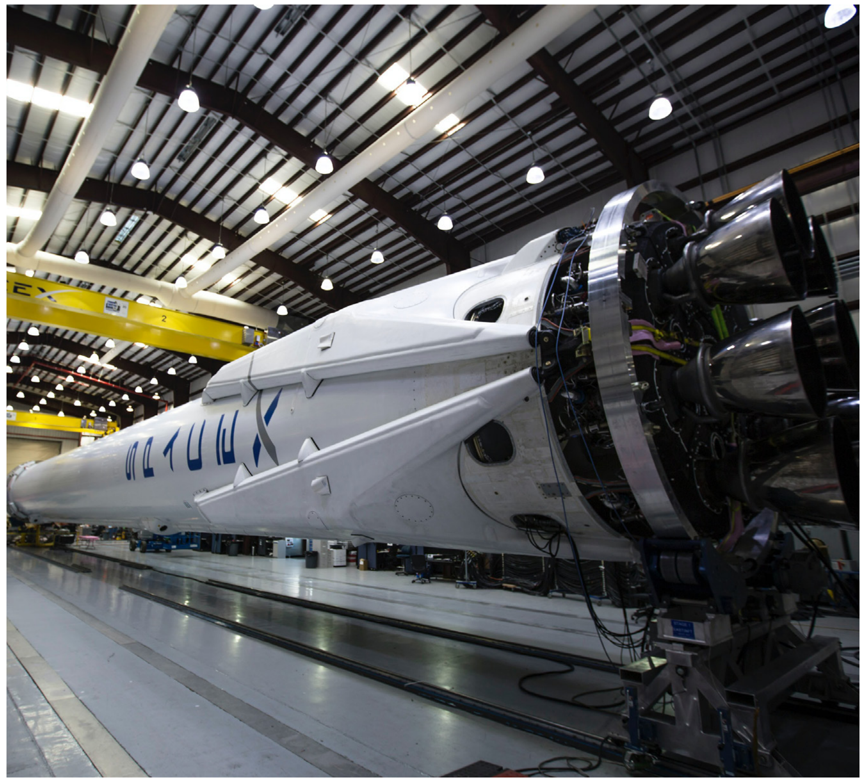
23rd - 24th February 2022. Site Visit: 22nd February 2022

Das Privathotel Lindtner, Hamburg, Germany

AM for Aerospace and Space is the leading conference platform for ensuring opportunities in high value manufacturing are secured to ensure that the aerospace & space industry is prepared to confront the challenges of wider AM adoption and development.

Over three days, we will host keynote presentations, panel discussions, round-tables and a state-of-the-art site visit to SLM Solutions' AM facility in Lübeck to facilitate discussion and collaboration within the industry.

This event will provide a platform to support opportunities in high value manufacturing and help prepare the aerospace industry to tackle the roadblocks of wider AM adoption. It is also a unique opportunity to maintain, strengthen and build connections across the industry following this challenging period.



EXCLUSIVE VISIT TO SLM SOLUTIONS SITE:

SLM Solutions is an integrated solutions provider and metal additive manufacturing partner. The company takes a vested interest in customers' long-term success with metal additive manufacturing. Robust Selective Laser Melting machines optimize fast, reliable, and cost-efficient part production and SLM Solutions' experts work with customers at each stage of the process to provide support and knowledge-sharing that elevate use of the technology and ensure their return on investment is maximized.

SLM Solutions provides consultation, installation, maintenance, training, and other learning opportunities for customers to harness the capabilities and exercise best practices with selective laser melting. Opening their new Lübeck global headquarters in 2018, the 24,000m² facility houses their research and development experts, production lines, spare part, and powder warehouses as well as engineering and service support.

Additive Manufacturing for Aerospace & Space is the leading conference platform for ensuring opportunities in high value manufacturing are explored within the industry. Confronting the challenges faced by the growing adoption of AM, including certification and standardisation, in situ montioring and sustainability, this conference provides primarily case study led presentations from both users and solution providers to provoke discussion, networking and opportunitines within Additive Manufacturing.

WHAT'S NEW FOR THIS YEAR?

1) SLM Solutions Site Visit Day for delegates

2) Case Study Focused Presentations to discuss achievements of the past 18 months

3) Cross Sector Panel to discuss how AM is being used and certified across the industry spectrum

Key themes will include;

· Space, air, land and sea applications for additive manufacturing processes.

· Training engineers and designers to 'think in additive manufacturing' terms to utilise AM's full potential.

· Innovation and new technologies developing additive manufacturing for defence, space & aerospace.

· Commercialisation of research and developing short-term additive manufacturing strategies.

Key speakers at the event will include;

· **Dr Mohsen Seifi**, Executive Director, **ASTM**

· **Dr Melissa Orme**, Vice President, Additive Manufacturing, Boeing

· **Hauke Schultz**, Additive Manufacturing Roadmap Leader, **Airbus**

· **Dr Mark D. Benedict**, AM Lead, **Air Force Research Laboratory**

· **Raphael Salapete**, R&T ALM Project Leader, **ArianeGroup**

Sponsors:

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Polymertal

Site Visit: Due to site COVID restrictions, there will be two sessions capped at 30 people.

Please ensure you register early to secure your place.

First half OF THE YEAR

CERAMICS UK

THE Advanced Materials SHOW

6th Additive Manufacturing Forum Berlin 2022

ADDITIVE MANUFACTURING STRATEGIES

AM Additive Manufacturing for Aerospace & Space

ADDIT3D INTERNATIONAL FAIR OF ADDITIVE MANUFACTURING AND 3D

YOU CAN PICK UP YOUR PRINT COPY OF 3D ADEPT MAG AT THE FOLLOWING PARTNER EVENTS :


Additive Manufacturing for Aerospace & Space, 22 – 24 February, 2022, Hamburg, Germany


Additive Manufacturing Strategies, 1 -3 March, New York, USA


Addit3D, 13-17 June, Bilbao, Spain


Advanced Materials Show UK, 29-30 June, NEC, Birmingham, UK


Ceramics UK, 29-30 June, NEC, Birmingham, UK


Additive Manufacturing Forum, 5-6 July, Berlin, Germany

NEWS ROUND UP

First month of the year was a busy month. Five new machines have already been unveiled alongside interesting applications across a number of vertical industries. We have summarized the ones you shouldn't have missed below.

3D PRINTERS

Nanoscribe launches new high-precision 3D printer for auto-aligned printing on fibers and chips

Nanoscribe, a **BICO** company, launches a new high-precision 3D printer intended for auto-aligned printing on fibers and chips. Named **Quantum X align**, the new 3D printer features capabilities that enable the printing of freeform micro-optical elements directly onto optical fibers and photonic chips. This brings the design and fabrication of micro-optical elements to new levels.

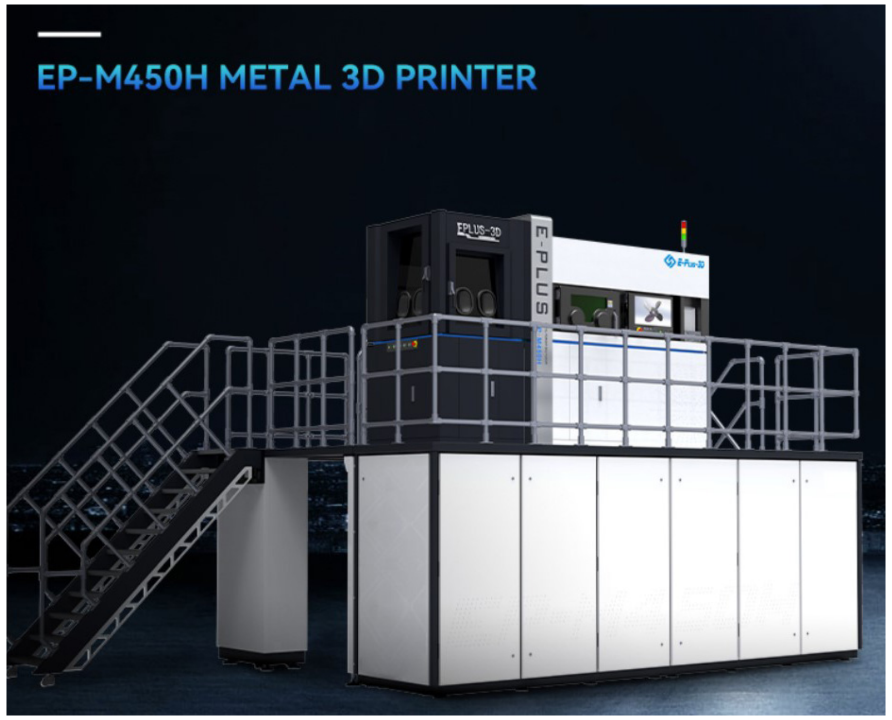
The Quantum X align provides robust and reliable alignment solutions for realizing efficient light couplers via Free Space Microoptical Coupling (FSMOC) between chips and optical fibers. The novel device opens up new horizons for imaging technologies using fiber and beam shaping applications, especially for hybrid packaging of photonic chips. The microfabrication system extends the capabilities of the groundbreaking Quantum X platform, allowing for a more straightforward process chain, relaxed assembly tolerances and no necessity of the costly and time-consuming active alignment and a further reduction of devices dimensions.

Masitte develops an Industrial-Grade Laser SLA 3D Printer

When it comes to the desktop option of laser stereolithography (sla) there is only one option to go for, why the laser SLA should not be more accessible? Compared with the other laser SLA option Masitte is lighter, quieter, and prints faster while matching the XY resolution for 25-micron print quality. Most importantly it helps users to save $1000+ for the printers $100+ for the resins per kilo, China-based manufacturer Masitte explains.

To address them, the engineers of Masitte have developed a machine that does not require any part for replacement. The 3D printer is made up of metal parts and integrates a laser that has 10.000+ hours of lifespan (min 2 years in very active usage). Early users have been using the printers for over a year, they did not change any part but FEP films, the company explains.

Meet EP-M450H, the tallest metal Additive Manufacturing machine in Eplus3D's portfolio



Chinese manufacturer of industrial 3D printers Eplus3D has released the newest member in its production portfolio: the EP-M450H machine. With a build chamber of 455*455*1100 mm³, the new machine is described as the tallest in Eplus3D's portfolio.

Like its sister machines, the EP-M450H is based on laser powder bed fusion. It enables the production of premium quality metal parts without requiring any tools. With this new solution, the machine manufacturer ambitions to provide tailored metal additive manufacturing solution to large scale parts to customers across the world – customers that operate in the aerospace, aviation, automotive and defense industries.

Carbon announces faster and more reliable DLS 3D Printing machines

Carbon, the US-based company behind the Digital Light Synthesis (DLS) 3D printing technology, has developed new and improved M3 series 3D printers. The latest 3D printers the unicorn unveiled on the market were the M2 in 2017 and the L1 in 2019 – production platforms used to fabricate products across industries.

Improvements in the M3 – which is already available for commercialization – include the printing process which is faster and the more consistent surface finish process. Apart from these advantages, the M3 Max 3D printer is equipped with a true 4K light engine, allowing double the build area with the same pixel size and density. With a build volume twice the size of the M3 – but delivering the same pixel size and density, the M3 Max facilitates the printing of larger applications. Both machines can meet the production requirements of applications in the automotive, life sciences, dental, consumer products and industrial sectors.

[Desktop Health Launches new series of Dental 3D Printers called Einstein – and new dental resin]

Desktop Health, a healthcare business within Desktop Metal, has announced a new series of products for dental applications. Named after one of the greatest physicists of all time, the Einstein™ series reaffirms the company's commitment to develop 3D printing solutions for personalized medicine.

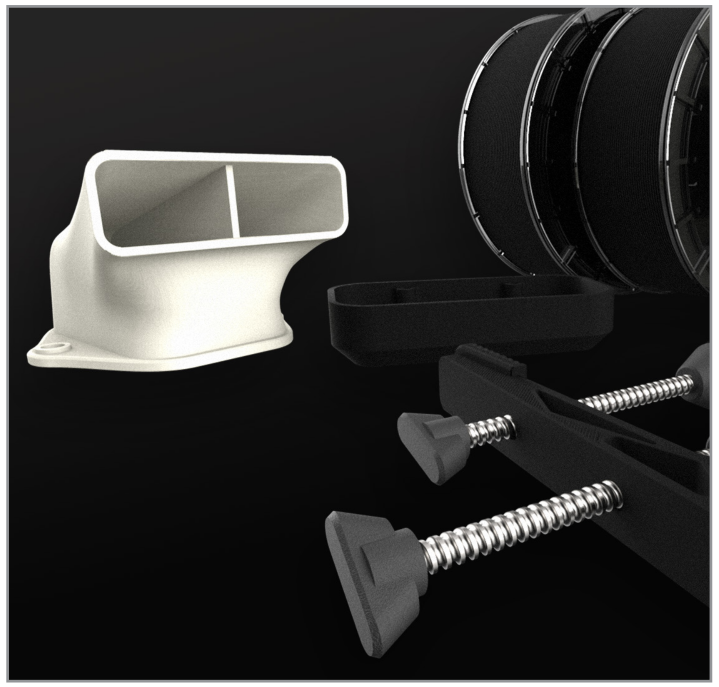
The new portfolio includes a high-precision family of 3D printers designed for dental professionals, and Flexcera™ Smile Ultra+, a strong dental resin that has already received FDA clearance for permanent use.

MATERIALS

[Photocentric launches a nanoengineered resin for LCD 3D printing]

Users of **Photocentric** LCD 3D Printing can now explore electronics manufacturing. The UK-based manufacturer collaborated with Mechnano for the development of a nanoengineered resin. Mechnano develops a proprietary technology, MechT that delivers static dissipative properties to 3D printed parts without compromising mechanical performance.

Mechnano's proprietary MechT technology – which is used in this material development - allows CNTs to be harnessed in additive manufacturing materials, delivering significantly enhanced strength as well as additional key desirable properties. The new material delivers Electrostatic discharge (ESD) properties that are ideal for electronic applications such as IC Trays, Part Retrievers, Grippers, ESD hand tools, and more.

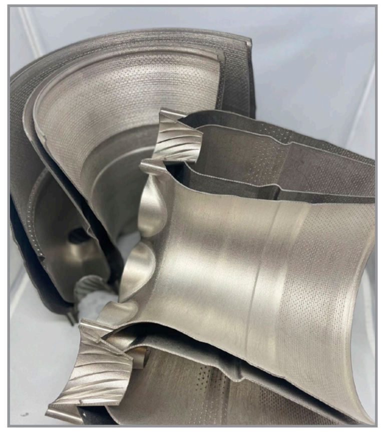


[MakerBot adds 3D printing Composites Materials from LEHVOSS Group to its materials portfolio]

3D printer manufacturer MakerBot has announced a new addition for its **MakerBot LABS**: three new LUVOCOM® 3F materials from provider of high-performance thermoplastics LEHVOSS Group. The new materials, named LUVOCOM 3F PAHT 9825 NT, LUVOCOM 3F PAHT CF 9891 BK, and LUVOCOM 3F PET CF 9780 BK can now be used with the MakerBot LABS GEN 2 Experimental Extruder for both the METHOD and METHOD X 3D printers. They share the same properties than their compounded versions used for injection molding.

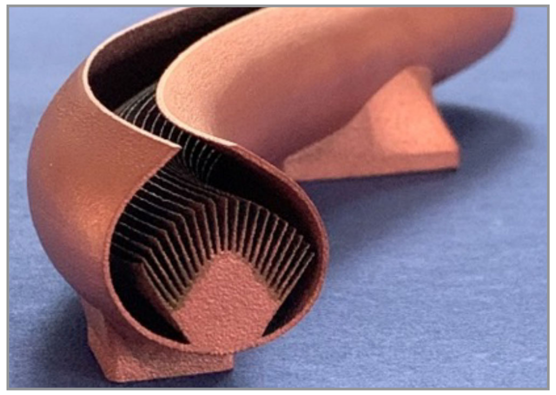
The new additions bring the number of materials that can be leveraged on MakerBot 3D printers to 30.

[Velo3D has qualified a nickel-based superalloy powder for its Sapphire® 3D printers]



Specifically developed for Additive Manufacturing, Amperprint® 0233 Haynes®282® (15-45um) is a strengthened nickel-chromium-cobalt superalloy for high temperature applications.

Developed by materials producer Höganäs AB, under license from Haynes International, the powder is now qualified for use in Velo3D's Sapphire® portfolio of 3D printers. The vacuum induction melted, argon gas atomized and spherical powder shows a good balance of creep strength up to 930 °C, thermal stability, weldability, and fabricability.



[Infinite Flex develops a pure copper powder for SLM 3D Printing]

Flex, a Germany-based producer of smart materials, has developed a pure copper powder for industrial SLM 3D printing.

Despite its popularity across manufacturing industries, pure copper remains tough to process in AM because of the strong reflection of the laser radiation in the machine and the high thermal conductivity of the material. The new INFINITE POWDER Cu 01 addresses these issues.

APPLICATIONS

[1016 Industries Crafts 3D-Printed Carbon Fiber-Clad Rolls-Royce Cullinan – Priced from $500K]

The Rolls-Royce Cullinan is already one of the world's most expensive SUVs, providing drivers with tons of personalization options but tuners do not lack ideas to make it even more special. The latest proposal comes from 1016 Industries, which announced a 3D-printed carbon bodykit for the Cullinan. Prices for a complete vehicle start from $500,000. Assuming that a normal Rolls-Royce Cullinan retails for $330,000 USD, the new customizable options announced, further increase the price of this SUV.

[Fraunhofer IAPT demonstrates a cost saving of 50% and a weight saving of 30% for an automotive 3D printed part]

Engineers at Fraunhofer wanted to highlight the factors that often influence costs in a production. They first used a special software tool developed by 3D Spark – a spin-off of Fraunhofer IAPT – to identify the ideal part.

Designed for a high-profile sports car, the 3D printed door opener demonstrates that the Fraunhofer IAPT team has been able to reduce costs by 50% while saving 35% of the part's weight.