MANUFACTURING

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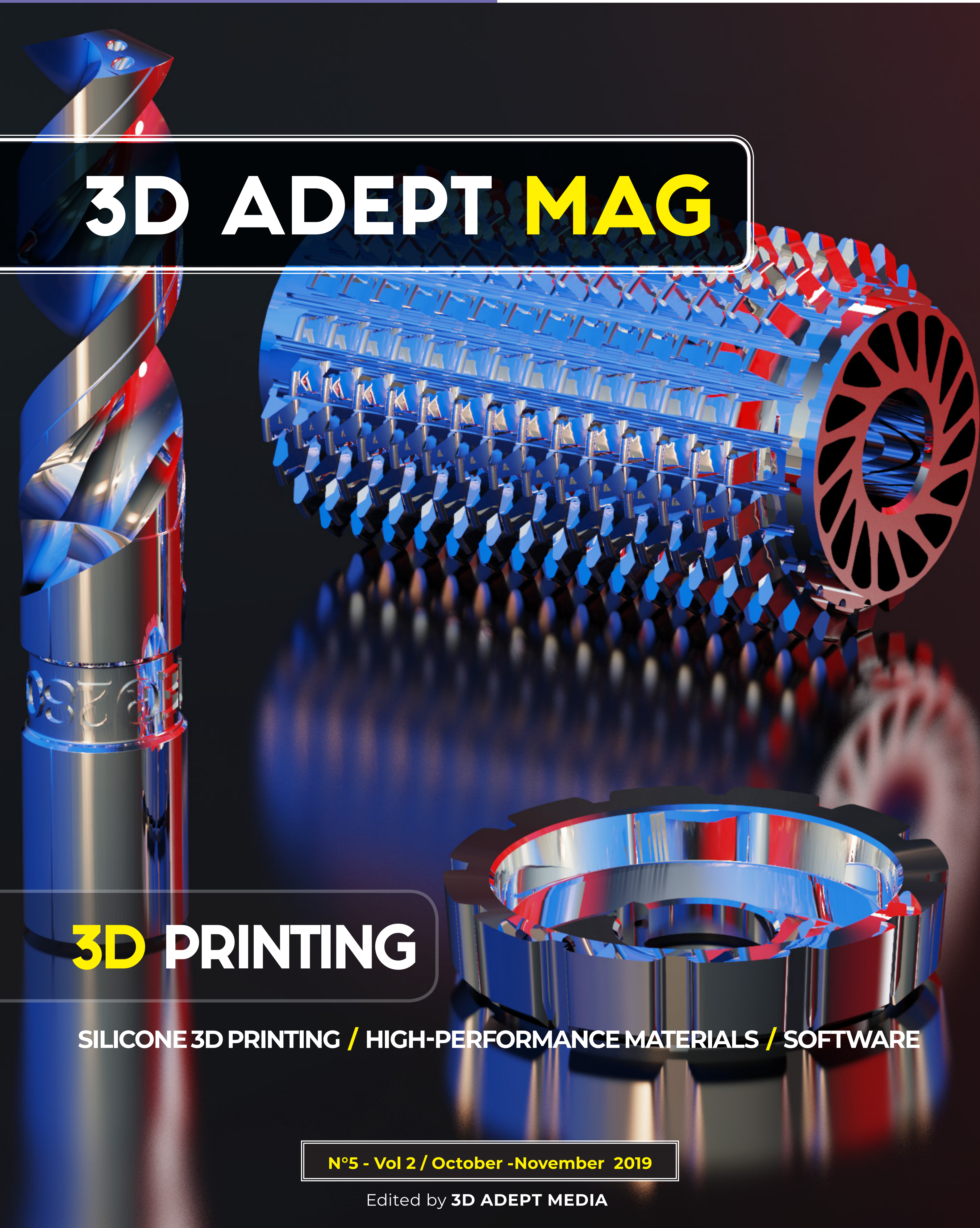

# 3D ADEPT MAG

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# Editorial

## It's bigger than we can possibly imagine.

If I had been told 10 or 15 years ago that we will be talking about additive manufacturing and its tangible integration into today's industrial sectors, or just into our daily life, I would not have believed it.

Twenty years ago, an industrial named Danfoss debuted in additive manufacturing. His quiet growth enabled him to meet real needs, sometimes challenging from his customers. He still has several challenges today, and his willingness to address one of them and the way he is addressing it, gives us a chance to share his story in the following pages.

In the same line, topics addressed by well-known players in this industry will still make the history of tomorrow's industry, because a lot has been said today and there is still a lot to say.

All of this helped me realized how much the scientist Roy Amara was right to say that "we tend to overestimate the effect of a technology in the short term and underestimate the effect in the long term".

For many people, additive manufacturing remains "a tool in a toolbox". Nevertheless, with regards to its continuous evolution, with regards to related technologies that get pulled into this adventure, not to mention the creation of new companies and the growth of others, it is a euphemism to say that it is just a tool in a toolbox. The truth is, it's bigger than we can possibly imagine.

The Formnext event that is in everyone's mind right now, will certainly prove it again.

So, as I am fond of saying, make the most of it, and most importantly, stay tuned.

Kety

# Content

N°5 - Vol2 / October - November 2019

# Additive Manufacturing

With contributions from **ACEO®, German RepRap** and **Spectroplast AG**

## Silicone 3D Printing, a newcomer in the additive manufacturing family

So far, the production of silicone parts has always been made possible via conventional manufacturing processes such as injection molding, casting and compression molding; processes that remain expensive given the high cost of molds. With the recent developments in the field of material science, scientists have been able to explore the use of silicone as a 3D Printing material. Manufacturers have gone beyond these possibilities and have explored the development of silicone 3D printers. So, 3D Printing silicone is now possible and given the nascent interest of industrials in this technology, it is time to dive into it and discover how, why and where this technology can be leveraged.

As this segment is still nascent, there is not yet a great number of players that specialize in the field. **ACEO®**, **German RepRap** and **Spectroplast AG** are part of this exhaustive list and we have invited them to share their expertise in this dossier.

**ACEO®** is a registered trademark of Wacker Chemie, a worldwide operating company in the chemical industry. ACEO® provides 3D printing with silicone elastomers that are comparable to liquid silicone rubbers that are used for injection molding. According to ACEO®, its technology achieves the same high-performance material properties usually found in conventional manufacturing processes. **Egbert Klaassen**, Global Marketing Director of ACEO® will speak on behalf of the company in this article.

**German RepRap** is a Germany-based manufacturer of 3D printing solutions based on the RepRap technology (Fused Filament Fabrication). The company also provides 3D scanners, filament, software and accessories. **Lena Wietfeld**, Head of Marketing, has been able to reply to our questions for this dossier.

**Spectroplast AG** is a spinoff from the university ETH Zurich that specializes in Silicone additive manufacturing service leveraging 3D biocompatible and high precision silicone material. The service provider has just completed a €1.38 million seed funding round led by the Munich-based investor AM Ventures to develop its services. **Petar Stefanov**, co – founder & CTO, shared their expertise in the field as part of this topic.

### Silicone, an "interesting" material

Interestingly, the interest in silicone as a 3D printing material is due to its material properties. However, it turns out that these same properties are also the reason why the material has never been considered as a viable option. So, what are these properties? And above all, what happened?

Silicone is a polymer that integrates repeating chains of silicon and oxygen. These polymers comprise synthetic compounds inert in nature such as siloxanes, which are made up of atoms of silicon and oxygen with carbon and hydrogen.

As mentioned earlier, the production of silicone parts was mostly achieved through conventional manufacturing processes. Indeed, it is not possible to melt silicone, as we know it, by exposing it to heat and then 3D print a part layer by layer like it is with plastics or metals. With the advancement in material science, researchers have been able to develop some exciting solutions compatible with 3D Printing.

These synthetic compounds deliver to the Silicone material semi-organic behaviour and specific properties such as biocompatibility (ideal for medical applications), chemical stability and resistance to natural ageing; thermal stability (from - 80 to + 300 °C); an ability to withstand fire without releasing toxic and irritating fumes, electrical insulation, elasticity and transparency.

Spectroplast AG's **Petar Stefanov** confirms this assertion while laying emphasis on the reason why silicone is used as a 3D Printing material: *"Silicone is a high-performance elastomer that exhibits many beneficial properties including biocompatibility, fatigue resistance, chemical resistance, high temperature stability etc. Conventionally, only rigid materials such as metals, plastics and ceramics are accessible by additive manufacturing while there is a growing need for soft and compliant elastomeric materials. Introducing biocompatible elastomers to the world of additive manufacturing opens doors to the next generation of customized, patient-specific healthcare products."*


Petar Stefanov

As you may know, 3D printing is a technology that can process different forms of materials: resin, powder and filament. Now that silicone has joined the ranks of 3D printable materials, it should be noted that *"the material begins its journey in liquid form and is selectively solidified using light." "Highly precise light exposure gives the printed objects exceptional spatial resolution and outstanding surface finish"*, explains Stefanov.

### How does the 3D Printing process work?

The 3D printing process of such material varies from one company to another. Indeed, an operator or a service provider, might either use a 3D printer that can process silicone materials or a Silicone 3D printer.

According to the spokesperson from Spectroplast AG, light-based additive manufacturing technologies such as SLA and DLP deliver excellent results in terms of resolution, surface finish and mechanical performance when they process silicone materials.

However, German RepRap and ACEO® have developed their own technology to produce silicone 3D Printed parts.

## The "LAM" technology from German RepRap

German RepRap has developed a Silicone 3D printer named L320. The system can build small and large objects, as well as small series and integrates a Liquid Additive Manufacturing Technology that can process liquid silicone rubber (LSR) materials. The manufacturer plans to develop other materials in the future for this technology. In the meantime, Lena Wietfeld explains below how the process works:

*"[Our technology] works with a material that is not - as with the FFF printer - melted and solidified again, but is liquid, and vulcanized under heat exposure. One speaks also of a thermal full network. This means that the individual layers that the printer deposits firmly connect to each other. In this way, it is possible to produce components that have almost the same properties as injection-molded parts – (...) a clear advantage because insights from the 3D-printed prototype can be transferred directly to injection-molded serial parts.*

*A special halogen lamp releases activation energy to accelerate the complete cross-linking, on a molecular level, between the two components. A finely tuned action, for both small and large objects, is ensured by the travel speed of the lamp. Due to this thermal cross-linking, the printing time is considerably reduced, at the same time the printing result, especially in terms of time savings, sets new standards. In comparison to conventional production methods, such as injection molding, a time saving of 50% and more can be achieved here. In addition, Liquid Additive Manufacturing eliminates the high tooling costs, which results in great price savings."*

*[This] is also very interesting for the development of new customer groups, since the process, even without an investment in tools or moulds, makes lot sizes of n = 1 possible or economical. That makes it very interesting for the bigger industries and I'm sure that this will lead to new possibilities for the additive manufacturing world."*

*As far as their LSR material is concerned, unlike other manufacturers that have developed materials that would simulate silicone although it was never truly the same, Wietfeld lays emphasis on the fact German RepRap's material is a real silicone, which is, as per her words, "thermally cross-linking".*

*"The material does not contain any acrylic hardener, does not become UV-crosslinked and is almost identical to injection molding in all properties. Especially for products that require a high degree of fineness, the material is a big advantage. Companies already using this silicone can now combine the unique benefits of*

Lena Wietfeld

*already used silicone with faster prototyping and small batch production of highly complex parts. The variation of different infill options of the same material, results in a wide range of possibilities, for example, for different damping properties. Depending on the mixing ratio, flexible products or even rigid printing results can be produced. This brings a decisive new possibility - away from the pure prototype process, individual parts can now be produced, in unit number 1, but with the technical requirements of injection molding quality"* explains GermanRepRap's spokesperson.


Although Wietfeld could only speak about their technology, she remains very optimistic with regards to the evolution of this new entrant into the industry, as its advantages might serve the demand in construction and electronics areas.

## ACEO® Silicone 3D Printing technology

The brand of WACKER is one of the first companies that paved the way to the possibilities offered by silicone 3D Printed parts. Indeed, the prospect of using 3D printing for the fabrication of silicone parts has long posed a challenge for the industry, due in part to the high viscosity of the material.

In 2016, through its registered trademark, WACKER therefore brings to the market a technology that can create 3D objects from silicone materials without thermal changes, a variation of the Material Jetting process based on a "Drop-on-Demand" principle.

*"The ACEO® technology is based on a drop-on-demand principle. The print head deposits single silicone voxels on a building platform. These voxels merge smoothly into a homogeneous surface. After each layer, the curing process is activated by UV light. (...)*

*Due to the high viscosity and low surface energy of silicones, the formation of droplets requires a dosing valve capable to shear and eject the material with high frequency. With this method, there is no contact between the nozzle of the valve and the 3D-printed object and consequently no string of material between nozzle and object. Equipped with several valves, the ACEO® printers can handle more than one silicone at the same time – a process we call multi-material 3D printing.*

*A three-dimensional object is printed layer by layer with the use of support material to create complex structures, overhangs or cavities"*, declares **Egbert Klaassen**.

The service provider of silicone parts leverages silicone elastomers that are available from 20 to 60 Shore A, available in different colours but also translucent.

## Applications and limitations

Despite silicone 3D printing is still in its infancy, tangible applications already exist.

According to German RepRap, the construction industry needs silicones for sealants, adhesives and coatings. The electronics industry on the other hand, uses silicones to protect electronic components from extreme heat, moisture, salt, corrosion and dirt. Indeed, silicones are included in computers, telephones, and LED lights.

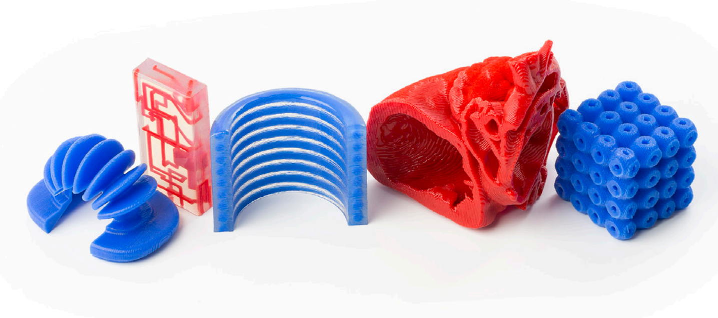
Spectroplast AG sees a great potential of the technology for life-enhancing healthcare products such as customized prosthetics and orthodontics on the one hand, on the other hand for patient-specific medical devices such as tracheal stents


Egbert Klaassen

and aortic heart valves. As a matter of fact, the company ambitions to develop extensive applications for this segment.

However, despite the increasing range of applications, ACEO® depicts the fact that due to the high viscosity of silicone elastomers, it is a challenge to improve the resolution which is currently ca. 0.4 mm.

Lastly, apart from the aforementioned example of German RepRap which is a manufacturer of 3D Printers, it should be noted that there is not really a wide availability of silicone filaments and resins as most 3D printers for Silicone have been developed by companies that are not machine manufacturers. Therefore, to avoid unfortunate situations, it is always wise to get further information about this material from service providers.




"We always keep in mind that technology can be used for a different market",

**Ronald van den Broek**, General Manager Sales EMEA

# At the heart of **Mimaki**

Colour 3D Printing is something unique, and, surprisingly very rare in this industry. There are only a few ways to 3D Print in full colour and we now have the confirmation that Mimaki's technology is part of them.

We first saw the industrial-sized full-color 3DUJ-553 3D printer of the manufacturer at Formnext 2017. The company made a real splash with this European launch, announcing this way, its official entrance on the 3D Printing market. Lost in this euphoria and the myriad of the technologies launched at the time, it was hard to remain neutral.

A visit to the European Headquarters of the Japanese company in the Netherlands, brought a different view of the company.

Mimaki Europe is located at Diemen, in Amsterdam. The offices are very accessible – about 30-40 minutes from the central station for those who are coming by train from another city. Amsterdam is seen as another tech-driven city and a prime area for companies to start, grow, and flourish.

## 10 000 possibilities

Mimaki's reputation in wide-format inkjet printers and cutting machines for the sign/graphics, industrial and textile/apparel markets has become an undeniable fact for the industry. Indeed, it is hard to not mention this expertise when we know that this giant leap into 3D Printing has been inspired by UV-curable 2D inkjet printing devices.

During the presentation of their company, Ronald van den Broek, General Manager Sales EMEA, explained that they learned about colour on the serigraphy market, a market that represents their most important sales so far (43% of their turnover), followed by Industrial Production (32.3% of the company's turnover) where we find 3D Printing. "Textile & Apparel" and "Factory automation", complete this board.

According to van den Broek, the company has succeeded in acquiring decades of experience in different markets because they have always kept in mind, they should launch a new product every year. That's how they develop a cross-platform that combines their 3 business units as well as their integrated solutions that include: product, ink and software.

## Full Colour 3D Printing

At Mimaki's offices we have been able to (re)-discover realistic 3D Printed samples made with the Mimaki 3DUJ-553 3D printer. The company is able to reproduce this level of photorealism thanks to several elements including a clear resin that they developed. The resin allows for the realization of fully transparent and semi-transparent colours. Jordi Drieman, the company's 3D Specialist spoke about the possibility to realize approximatively 84% of FO GRA 39L color gamut. For those who do not know, color gamut refers to the entire range of colors available on a particular device. A color gamut of 72% - 75% is typically considered normal. Being able to achieve 84% of color gamut therefore means that we are not only talking about simple colors, but lifelike colors.

The result of such printing result is backed by the company software, Mimaki 3D Lite that facilitates the import of 3D Files, and their rendering.

To clean up the model after the printing process, the specialist recommends water-soluble as support material during the post-processing stage.

However, based on Marketiger's experience, a customer of the company that shared his experience with the 3D Printing solution, it is possible to use a different post-processing solution to get the desired finish surface.

## A colourful 3D Printing experience

Maikel de Wit, Founder of Eindhoven-based 3D printing company, Marketiger, delivers full-colour 3D objects, including figurines (statuettes) and maquettes while leveraging the Mimaki 3DUJ-553 3D printer.

De Wit said they "*have been working for two years with a printer that could print 5 colors, and then they discover another one that could print 10 000 colors.*"

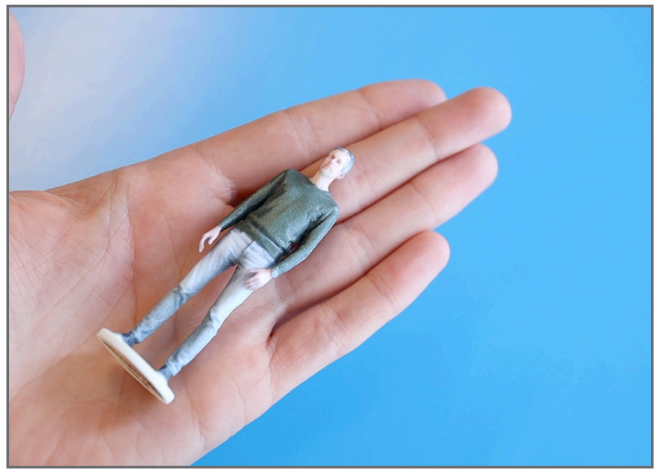
Investing in such a 3D printer (whose cost is around 200 000$) was a huge investment for a start-up like Marketiger, that has to integrate new services in its business model to be able to make the most of it. However, before diving into its experience with Mimaki, the entrepreneur had already experienced single-colour Prusa 3D printers for the production of various marketing tools.

However, for de Wit, collaborating with Mimaki goes beyond investing in a performant 3D printer, it's also embracing a new culture:

*"The company has a Japanese culture, which is reflected in everything it does. It takes time to get used to it, but we have quickly learnt to appreciate it. For example, sales managers will never promise something that they can't deliver. Their customers are important to them and they'll really go out on a limb for you, especially when disaster strikes. For instance, once they even removed a part from their own demo machine to help us out with our malfunctioning device."*

We have been able to attest to the importance of this culture in the way they work through the warm welcome we received.

Prior to the full installation of Mimaki's 3D Printer into their offices, Marketiger tested the printer extensively



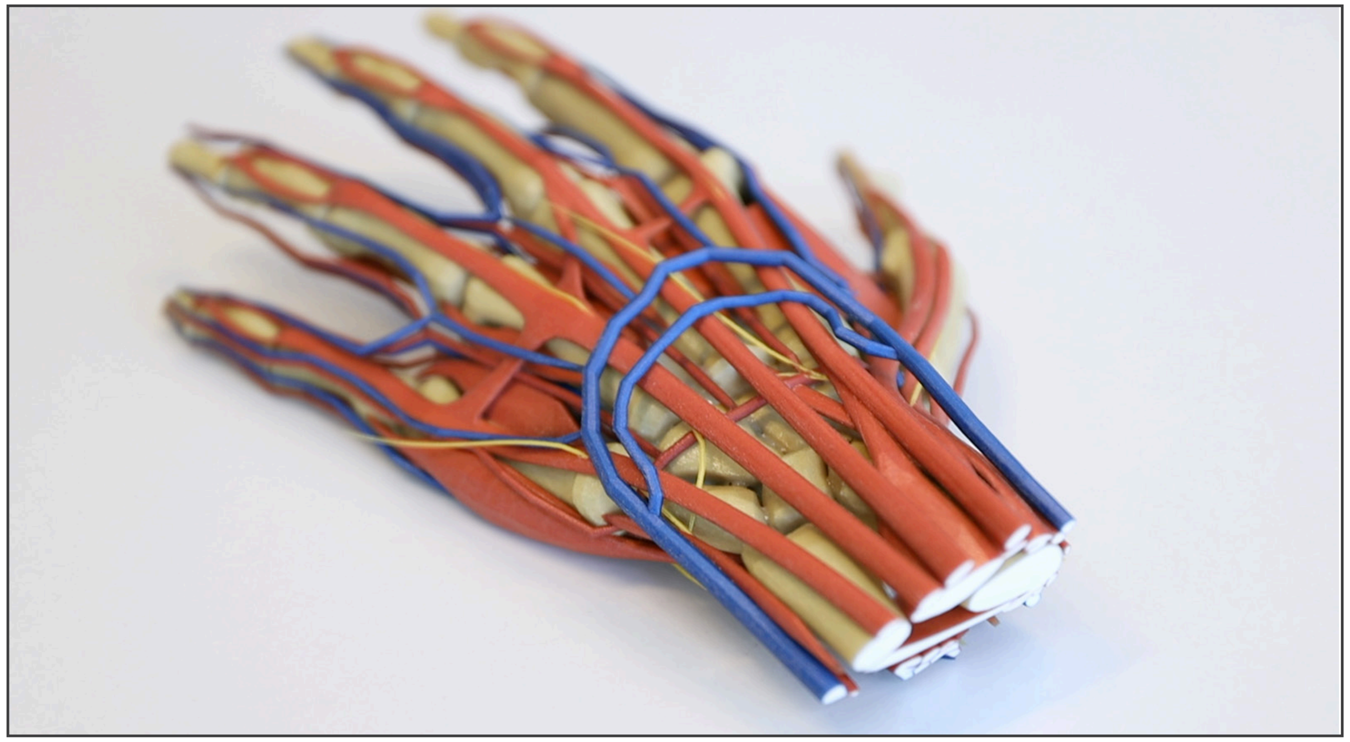
for two months, with the support of Mimaki to see if it could handle the desired production volumes.

Despite the process that he depicts as quite long for some services such as figurines (3D Scanning, optimisation via a software, printing and post-processing stages to achieve), de Wit remains satisfied with the quality of each print.

At the technical level, the only constraint he is still watching for, today is the space optimisation in the 3D Printer. Indeed, the capacity of the 3D Printer is limited, so the user always has to optimize its capacity to make the most of it.

In his own business, **Maikel de Wit** mentioned his struggles in convincing clients – but that's not really surprising as based on the experience of various companies (be it users or manufacturers of 3D printers), it takes time to help clients take a giant leap into a "new technology".

Lastly, apart from the applications mentioned by Marketiger, Mimaki's road to 3D Printing also enables various applications in prototyping, 3D art, tool and equipment design, as well as medical & education.



# Software

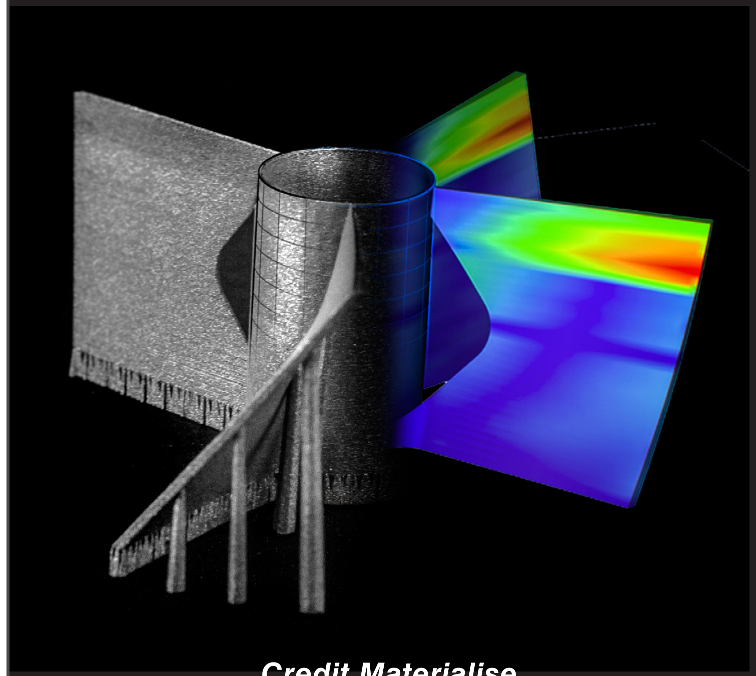
## Design for additive manufacturing: how to increase the value of the part through intelligent optimization

It is hard to recall that there was a time when we only talked about "Design for Manufacturing" (DfM). The concept of "Design for Additive Manufacturing" (DfAM) has emerged so fast that it seems to be on everybody's lip. Prominent AM companies do not only talk about it. Just like universities, they launch courses dedicated to DfAM – and with good reason: design is the primary step required to take a product idea and translate it into something that can be brought to life.

It is therefore crucial for companies to master this stage of product development.

Given the increasing demand for such expertise, and the lack of reliable resources, we have decided to address this topic in this Software Segment.

With the development of new materials and the rise of manufacturing requirements, the concept of "Design for Manufacturing" has led to the development of new concepts and techniques to achieve more sustainable products. However, the emergence of AM technologies has also brought its array of challenges, that are beyond the conventional well-known concept. Therefore, to understand how to "rethink design" while taking into account AM technologies capabilities, there is a need to understand this transition from DfM to DfAM. Furthermore, this transition inevitably raises the question of the real definition of DfAM: how should designers understand it? Are there specific principles they should follow when designing for AM? Moreover, in this quest for continuous improvement, how do we increase part value through the DfAM concept ?



Credit Materialise

We believe answering these questions, will be helpful to beginners and experienced engineers alike. This article also aims to be an introductory guide for companies that are interested in starting or improving their experience in AM.

Il would have been hard to discuss this topic alone, or with researches' results as examples. To combine theory with practice, three companies joined us in this initiative: Materialise, nTopology and Blueprint. A detailed presentation of their core business will be given at the end of this dossier.

### Transition from DfM to DfAM

Let's first try to explain what both concepts mean.

Design for Manufacturing should not be a new concept for most people that will read this paper. As a reminder, the concept refers to designing a product while considering manufacturing knowledge throughout the product development process.

Design for AM on the other hand, refers to a set of design methods or tools whereby functional performance and/or other key product life-cycle considerations such as manufacturability, reliability, and cost can be optimized to leverage the full capabilities of additive manufacturing technologies.

In other terms, to take full advantage of AM capabilities, DFAM methods or tools are needed. However, it does not mean that the concept is separated from the broader techniques of DfM. In fact, the manufacturing of some parts, sometimes require to leverage both additive and subtractive processes.

Furthermore, after further analysis, we can even say that both concepts somehow share the same goal: **reduce manufacturing cost and improve product quality by addressing the manufacturing constraints**.

According to **Loic Le Merlus**, Consulting Manager at Blueprint, *"when you design a part, you typically design for functionality, then figure out how to manufacture it. This often means changing geometries or even splitting a single part into several parts to be manufactured with different methods. Although you still need to design for manufacturability, AM can allow you to produce geometries closer to your design intent and can allow different optimizations than traditional methods. AM is a great tool for consolidating assemblies, reducing part sizes and weight, and creating prototypes close to the intended functionality."*

If functionality is a key goal when you design for AM, it should be noted that AM technologies are very different from conventional technologies. AM technologies for instance take into account different parameters that are not considered when designing for manufacturability, and sometimes, people do not take into account these differences at the level of design. That's exactly what **Stijn De Rijck**, Director Training and Consultancy at **Materialise** explains:

*"Every design is created with a specific combination of material and production technology in mind, and that is not different for AM technologies. A mistake that is often made is to take a product that was designed for a conventional technology and try to print it, for instance as a spare part, without changing the design. There is an obvious chance that it will not optimally function or that production cost will rise significantly. If such sub-optimal design is used as the basis for a cost-comparison, you can be sure AM will lose the battle. But turn this around: what if you take a design that is optimized for AM and try to make it with a mould or through milling? A complex shape that is a piece of cake for AM for instance, will create serious challenges in conventional technologies."*

nTopology's CEO and founder **Bradley Rothenberg** agrees with Stijn De Rijck regarding this point. Indeed, in DfM, engineers should address the issue of optimum design that is required by various applications. In other terms, they should continuously look for the best compromise between the size, shape or topology of a part and utilization of as minimum as possible material while ensuring the overall performance of the part. Those issues are addressed in the DfAM concept. Rothenberg takes the example of challenges materials might raise in a production process, to point out the differences between the two concepts and the type of parameters that should be taken into account when designing for AM:

Loic Le Merlus , Consulting Manager at Blueprint

*"The requirements that the design must fulfil are very different -- in fact even amongst conventional manufacturing constraints they can vary greatly -- For subtractive manufacturing, the requirements for a 5-axis CNC part vs even 3-Axis will produce a part that might look totally different. There is also, of course, the cost aspect that one has to look into.*

*You can think of the design as the result of putting material in the best place that is balancing a number of requirements, so the final shape of a part, or what the part looks like, is a result of balancing the things that are important: cost, weight, manufacturing process, even aesthetics could be taken into account. When designing a part for AM, the geometric requirements are generally more free because you are building the part up from raw material (additive) instead of starting with a block and chipping away at it.*

*Also, parts designed for AM can take an architected materials approach if the design software is capable."*

credit nTopology - nTop Platform Bracket

Our three experts in this dossier made it clear: when you design for a specific technology, you have different requirements to meet. Despite their common goals, both DfM and DfAM leverage different techniques and it makes sense when we know that the challenges of one lead to the development of the other.

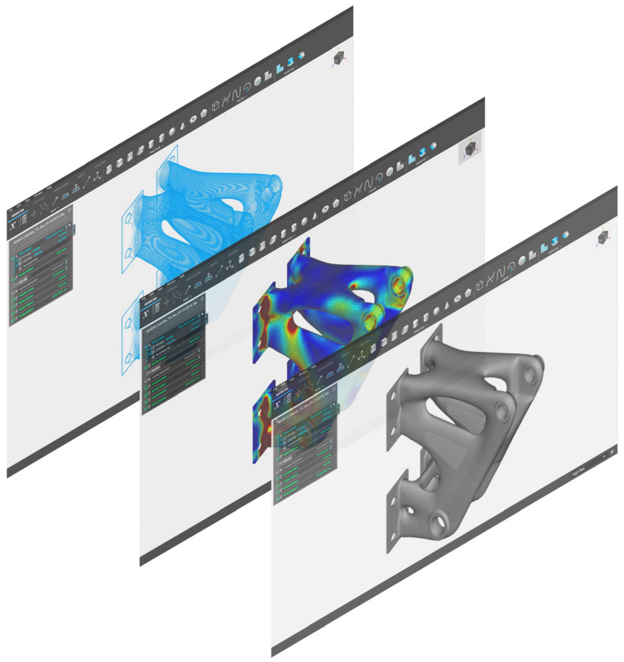
## DfAM: tools and impact on the part

You know you are designing for AM when your methods/tools make you take into consideration topology optimization, design for multiscale structures (lattice or cellular structures), multi-material design, mass customization, part consolidation. This list is not exhaustive since other tools can be added based on the AM technology used for a specific production or simply the development of the technology.

In this vein, the first step for designers is to keep in mind the capabilities of AM: **shape complexity, material complexity, functional complexity and hierarchical complexity.**

As far as shape complexity is concerned, AM enables to *"build near net shape, complex shape geometry and interconnected internal channels."*

*"AM has sort of flipped the relationship of software & hardware on its head -- it used to be that you could come up with shapes in the computer that would be impossible to make (for example topology optimization was popular amongst academics 30 years ago, but didn't really make it to industrial uses until recently). Today, the manufacturing process is capable of making shapes that the current standard of design tools are not capable of representing. This is because those tools were designed at a time when drawings and traditional manufacturing were the paradigm"*, explains nTopology's **Rothenberg**.



*credit nTopology - bracket workflow*

*Bradley Rothenberg*

Materials on the other hand are quite complex. They raise a lot of issues with regards to their properties, the amount used and even the type of AM technology used. Depending on the object to produce or the technology leveraged, they can be processed one point at a time as a single material or as an alloy. In fact, sometimes the aim is to observe their properties in different locations of a single part hence the need to be able to alter their physical, chemical, biochemical or mechanical properties locally.

*"Unlike subtractive manufacturing where removing material is expensive, with AM adding material is expensive. You also have the added complexity of support structure. The more material and support structure your part contains, the longer it takes to build. Tools like topology optimization can generate highly-optimized organic shapes, but often at the cost of requiring more support structure. Surface roughness is another limitation, but this can be mitigated with clever design. A designer can re-orient a part to reduce roughness on critical faces, avoid certain angles, or even add texturing to hide surface imperfections"*, explains Blueprint's **Loic Le Merlus**.

The functional aspect that AM allows has already been mentioned earlier by Le Merlus. Operators can produce fully functional devices in one build as the technology enables consolidation of parts. It is also possible to produce parts separately. In that case their assembly does not present much challenges.

As for the hierarchical complexity, researchers from the University of Stavanger in Norway explain that features can be designed with complex shapes across multiple size scales. Internal structure for instance, can be changed using cellular structures including honeycombs, foams, or even lattices, to fill certain regions of a geometry. This increases a part's strength to weight or stiffness to weight ratio so that excess use of materials is avoided thus cost is saved.

Reality shows that it is interesting to know all these unique capabilities of AM. They are certainly a great help for engineers that want to design for AM. However, for Materialise, something more valuable is also important when it comes to DfAM: experience and creativity. As per the words of **Stijn De Rijck**:

*"Design engineers are trained to deal with the limitations of conventional production technologies. Thinking in limitations instead of opportunities leads to limited use of the design freedom of Additive manufacturing. You need to build up experience and use your creativity to look beyond the limitations, and start to make use of the real strengths of the technologies. Take the example of the mid sole we created with Adidas in the Futurecraft project: at the time we had no AM material available that was enough soft to create the right cushioning in the mid-sole, so at first sight, we would never reach the requirements for optimal performance. But instead of getting blocked by that limitation, we created a structure that changed the flexibility of the part and as a bonus we also reduced the weight of the running shoe significantly."*

These capabilities are interesting to keep in mind. But what happened when different AM processes are involved?

## Impact

We looked at the impact "Designing for AM" can have at two levels: the first one consists in knowing if the concept is the same for different processes and the second one consists in determining the impact on the part.

### *When different processes are involved*

Our experts shared different views regarding DfAM and AM processes. When asked if the design remains the same whatever the AM process is, Blueprint for instance said it depends on some conditions:

*"For simple parts that haven't been optimized to a particular AM process, yes. If you are just looking to print a one-off part, then it often does not make sense to optimize for a process. But there are a lot of different AM processes, each with different materials and mechanical properties.*

*If you want to start using AM as a production technology then, like with every other manufacturing*

Stijn De Rijck

*technology, you should spend the time, resources, and energy to make sure your part is optimized for the exact manufacturing process you are using. This is how you get the cost and business benefits of the technology."*

nTopology on the other hand remains categorical. For the spokesperson, the design does not remain the same whatever the AM process is:

*"No, each process has different requirements -- you might have heard of terms like "support structures" or "laser toolpaths" or "bead diameter" -- there are many new design variables, or things that can be changed that affect the output and quality of the part. Understanding these variables and the limitations on them will produce in some cases variations on the same design (like using a different machine but with the same process). For example, building on two different industrial-scale polymer FDM machines, or an entirely new design or, as another example, building two metal parts using binder jet vs laser powder-bed fusion. Each AM process makes more sense for some parts and not others, depending on the requirements of the part, like if you need 10K of the parts or if you need really high-quality material properties for strength."*

Materialise on its side presents a balance between the two arguments. For the company's expert, *"AM is a group of production technologies that have the basic principles in common, but that each have their own characteristics, possibilities and design rules."*

It is important to note that different technologies require different optimization techniques. We understand our experts' thoroughness regarding this point. Indeed, the path the operator chooses to implement AM will determine how a great tool the technology can be in a given project.

For instance, for some people, AM just replaces traditional processes. This might be true but it is not enough as people need to be able to leverage all tools to improve manufacturing aid functionality and cost. So, if an engineer takes an existing part that he designs and simply prints it off, he will certainly get his part, but one that has not been optimized. It is therefore, very likely that he can't make the most of it. That's a poor way to deploy AM, which brings us to our next part, the impact on part quality.


*credit: Blueprint*

*Part quality*

What's the impact of designing for AM on the part? That's a crucial question because in the end, the most important is the result, the part value. If it is a success, then everybody is happy. If it is not, it is a waste of time and money. Answering this question inevitably raises the question of intelligent optimization. Is intelligent optimization a synonym of topology optimization? What does it really mean?

The **Consulting Manager at Blueprint** outlines the distinction between the two terms:

*"Software that can create highly optimized structures isn't necessarily intelligent; it could be like your car's navigation system, following a human-defined algorithm, to produce a result based on initial inputs. A more accurate label would be "algorithmic optimization." This can encompass all manner of optimization methodologies including topological, generative, and structural. Further, the geometry generated from such an algorithm doesn't necessary ensure the manufacturability of the part. The intelligence still resides with the designer who sets the starting parameters or boundary conditions and then must interpret, approve, and sometimes tweak the output of that algorithmic process to ensure the design meets requirements and is manufacturable."*

The CEO of **nTopology** this time, agrees with Blueprint. The founder explains that topology optimization can be a part of an "intelligent optimization": *"I would define intelligent optimization" as a workflow, or process that captures engineering intent within it in order to make a better part faster. This can be a manual process, a hybrid of some manual & some algorithmic, or fully algorithmic. Ideally, the inputs would be defined, and if changed you get a new output, a new part. Topology optimization can be one component of an "intelligent optimization."*

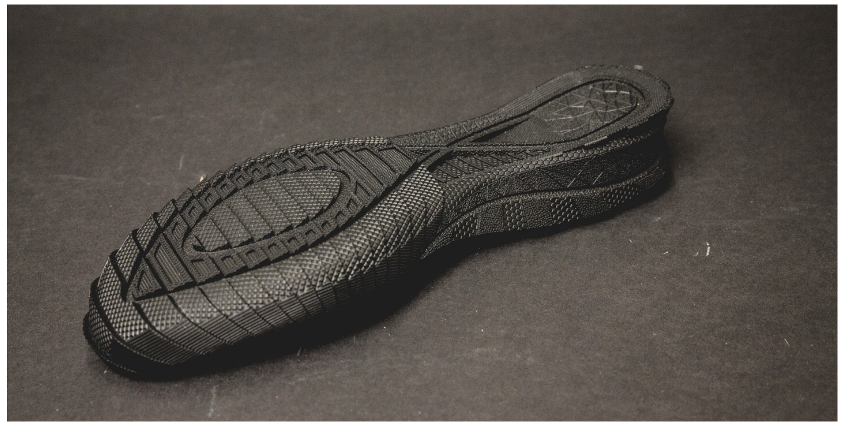
Intelligent optimization therefore lies in the ability to create a "smart" design and make it work perfectly on an AM system. As **De Rijck** said while warning designers: *"One thing is to create an intelligent design, the other thing is to prepare parts for successful building in AM. You should consider this build preparation work to be a design process as well. Take for instance metal 3D printing: each component that goes on a metal AM machine needs to be printed with a support structure to anchor the part to the build platform and to control the heat dissipation. The ideal support structure is strong enough to anchor the part, but very light, so it does not consume valuable machine time and material. Searching for the optimal combination is a daily challenge if you run a metal machine in AM."*

In the end, the impact of the DfAM" concept is huge. As per the words of Rothenberg, "its bigger than any of us thinks." It looks like we are just at the beginning of a big chapter in the engineering software industry. The DfAM concept involves new tools and new ways to increase part value while taking into account materials and hardware. In terms of part quality, we do not only talk about higher performing parts anymore, but, according to Rothenberg, we also talk about the speed that these new parts can be iterated on.

## Future prospects

Even though there is still room for improvement, the toolbox designers used for traditional manufacturing does not raise much questions. In general, everything is integrated into their design environment.

In the additive manufacturing industry, there is still a long road ahead. Software companies and consultants are certainly here to guide and advise but a fast learning curve begins by the willingness of the user. In the meantime, to drive the adoption of AM into production lines, our experts believe the issues below should be tackled to enable improvements:



*credit Materialise - Mass textured sole*

*"The data exchange between AM machines and ERP systems needs to be improved. Nowadays, companies want to know what is happening on the manufacturing floor all the time to identify problems and bottlenecks as fast as possible. AM is still too much of a black box to get all the required production intelligence", said Blueprint.*

*What nTopology hears the "most often as barriers to wider adoption are: the need for more automation in design process (DOEs, etc.); STL files introducing uncertainty into the build process and causing data handling and build crash issues; part complexity making design process really long or really difficult and, in general, existing design software holding back engineers from optimizing parts to take full advantage of AM processes."*

For Materialise, connectivity is the key issue to tackle. *"Connecting additive manufacturing into manufacturing setups, linking it to other technologies and business systems, is allowing fast-growing applications to grow even more rapidly. It allows scaling and fast adoption and it allows to combine technologies and software systems to get the best of all worlds in one production flow. Next to state-of-art software, in-depth knowledge of the AM-specific process, the adoption of industry standards like MT Connect & OPC-UA and last but not least access into a broad network of partnerships and collaborations, are crucial to turn Additive Manufacturing into a widely trusted manufacturing technology and create applications that open up new possibilities."*

## A few notes on the participating companies

Blueprint, Materialise and nTopology joined us to address this issue of our Software segment. If you do not know them yet, the notes below might enable you to understand the reasons why we invited them.

### Blueprint

Blueprint is a Stratasys company that provides companies with strategic, operational and applications consulting that help them to navigate the additive manufacturing world. The company first appeared on our radar when they launched its "Think Additively program" but it traces its beginnings to early 2015 when Stratasys Services Group integrated the Econolyst team.

As part of this dossier, the company firmly believes that, *"while there are software solutions to help with certain elements of design for additive, such as topology optimization to minimize material, or simulation to predict deformation or defects, there isn't a single, turnkey solution for all the steps in the design process. The human element is still very much at the heart of designing for AM. As an industry, [they] can build better tools, but [they] must teach people how to use them. Currently this skill shortage… the lack of knowledge of how to use the tools… is slowing down AM adoption."*

### Materialise

It may be not necessary to introduce Materialise but we will do it again. The Belgian company brings three decades of 3D printing experience into a range of software solutions and 3D printing services for medical and manufacturing. To help companies to make the most of AM, the company recently entered a new phase of co-creation with companies that collaborate with them.

Several reasons raise Materialise's interest in this topic:

- First, they guide companies through the design process, and make sure to tailor the knowledge transfer to the specific technology-material combination for their specific case.

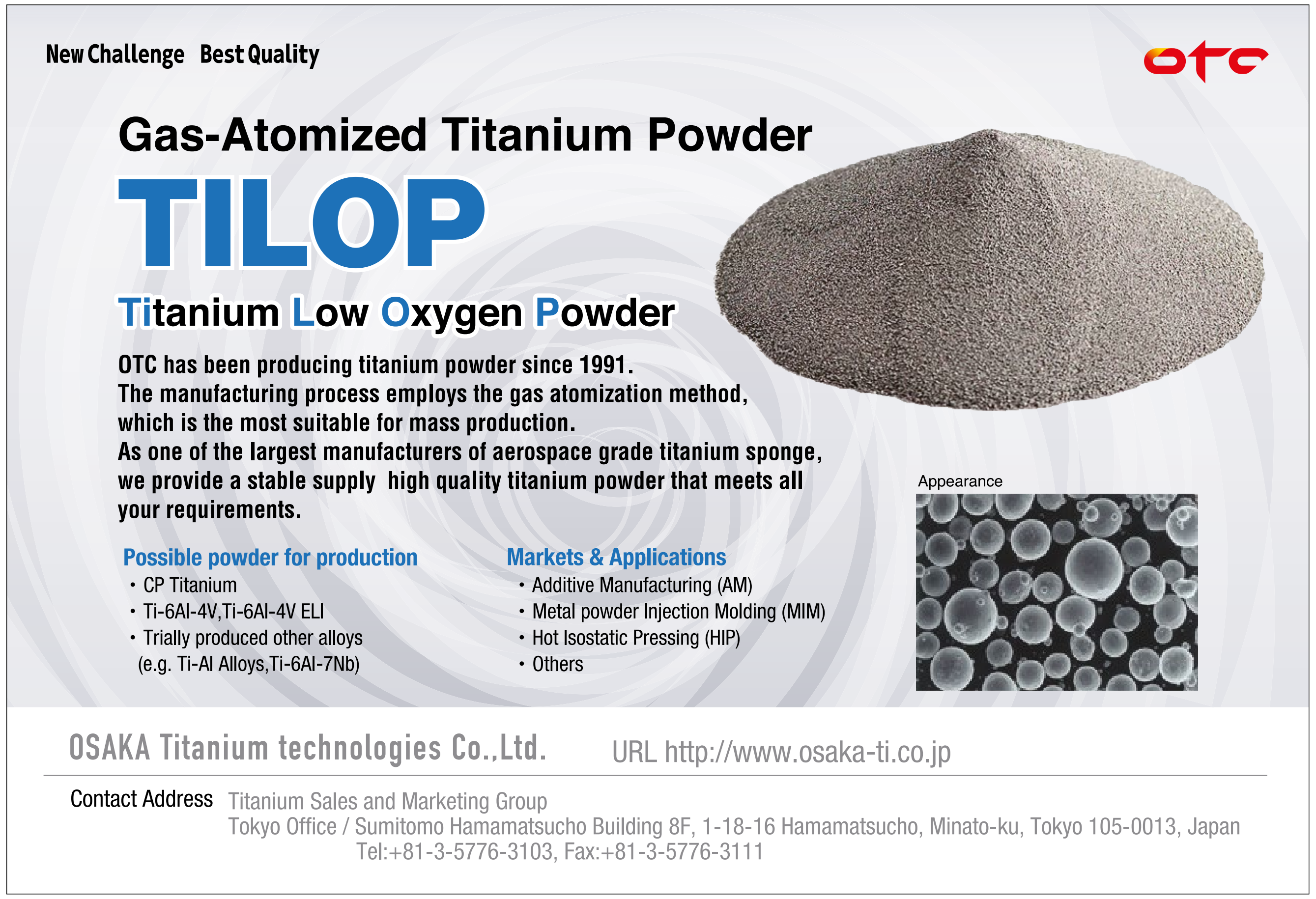
- Secondly, they *"have created software tools that help designers and manufacturers to cope* *with the specific needs of AM. Materialise 3-matic for instance, is a package that allows [users] to enhance [their] design by creating 3D textures on surfaces or lattice structures in volumes, [just to name a few examples]. With the scripting function in 3-matic [the user] can easily automate repetitive tasks, [and] focus on the more creative part of Design for AM. Materialise Magics is [a] software used to prepare parts for production. It helps [the user] choose the orientation of parts and guides [him] in designing smart support structures. The recent simulation module allows manufacturers to predict and thus avoid build failures, so there is significantly less down time with machines."*

## nTopology

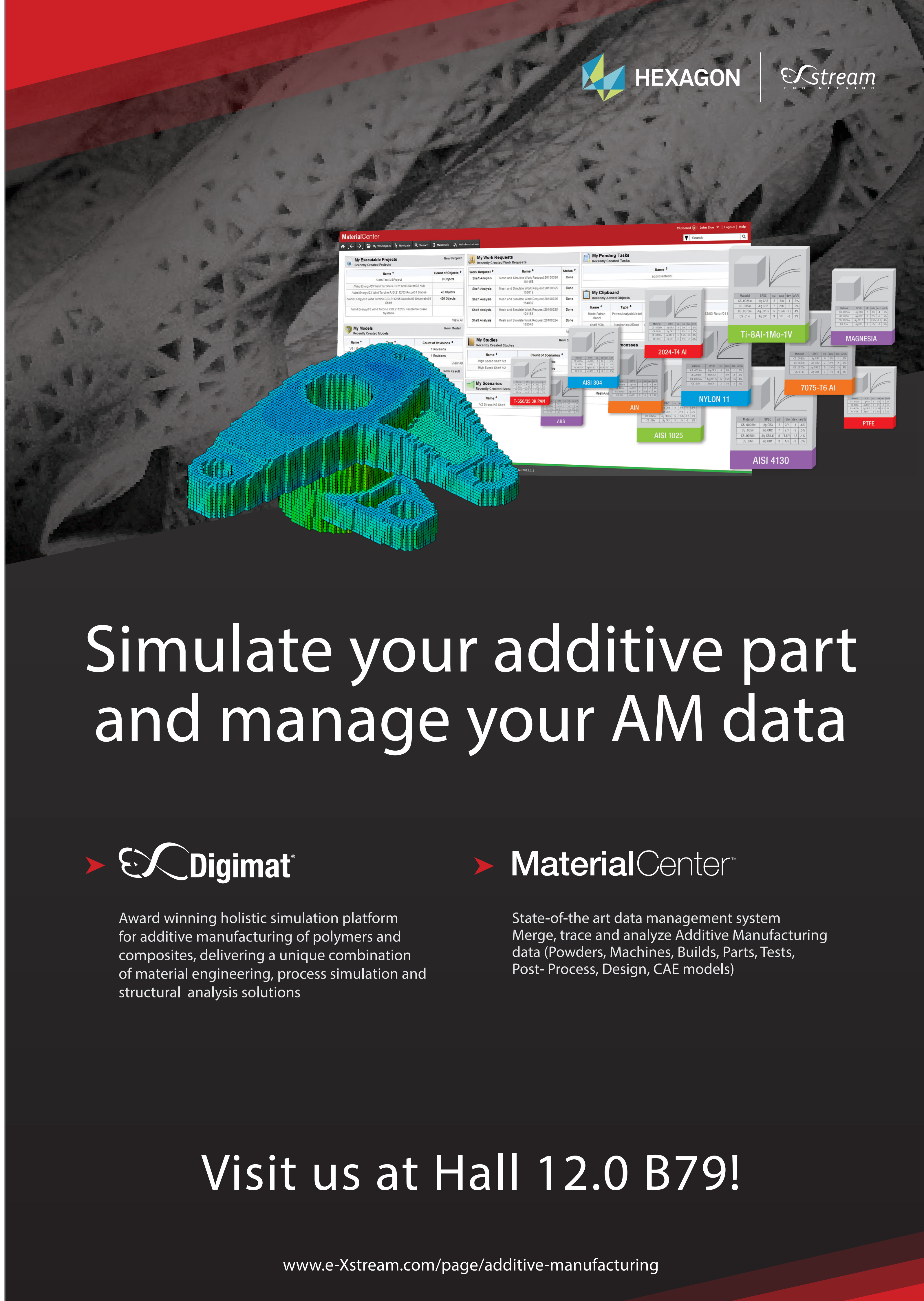
nTopology is a young entrant into this niche market. Founded in 2015, the company is significantly gaining momentum thanks to the ability of its generative design software to break the main barriers engineers currently overcome in manufacturing. With a total of $31 million raised to date, the company has recently expanded its reach into Europe with new office in Germany and plans to accelerate its growth with a focus on expanding its customer base.

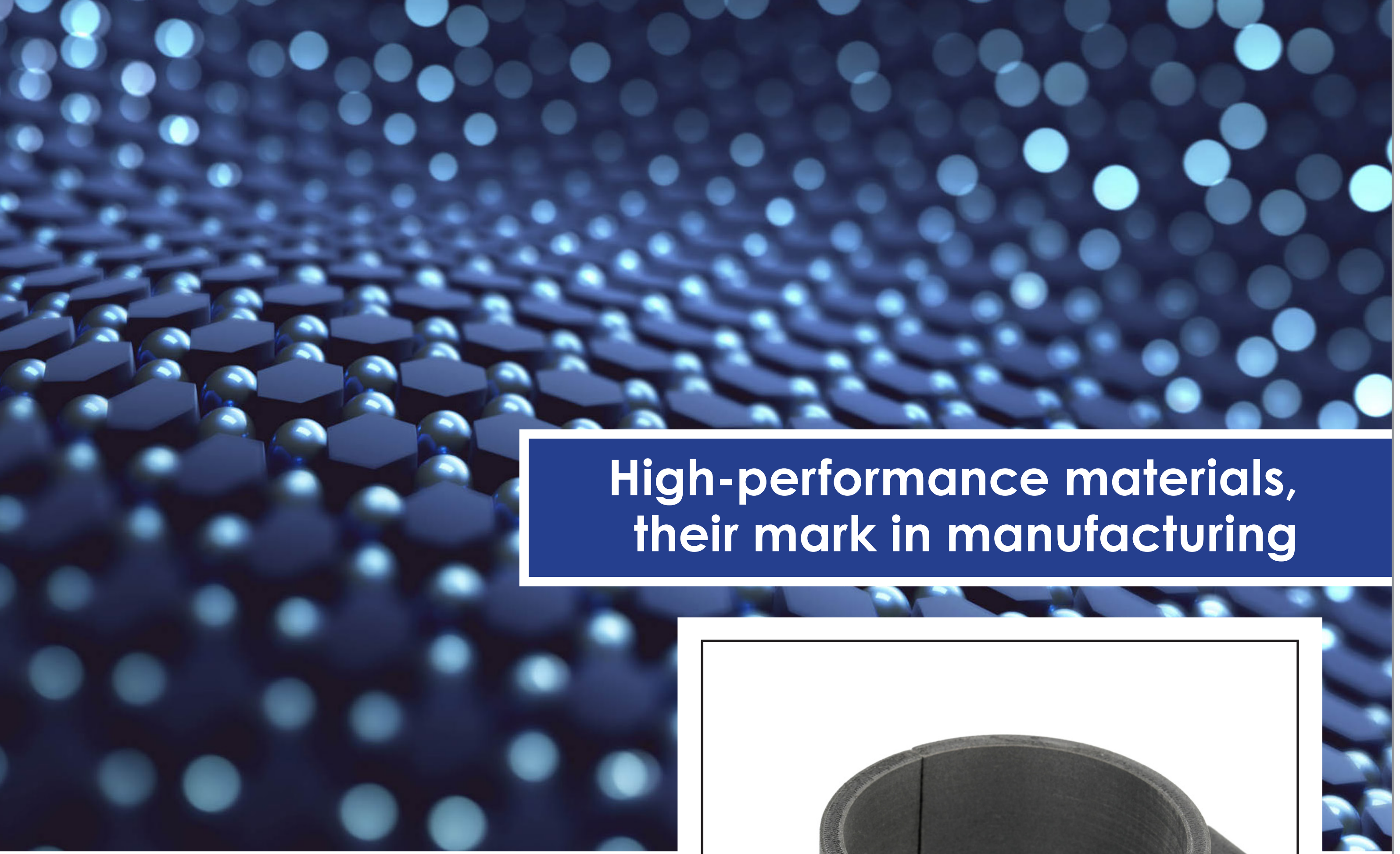
The main features of the company's software include lattice design, topology optimization, and direct output to manufacturing, in other terms, no more unreliable STL files required to go from design to manufacturing. Furthermore, the company claims that modelling operations like unions, offsets, fillets are reliable and never fail.

With regards to this dossier, Rothenberg strongly believes that *"the impact that [has] the ability to take an architected-materials approach to part design is game changing and it is the combination of AM hardware and nTop Platform software that makes this possible."*







# High-performance materials, their mark in manufacturing

*Imagine if the security scanner that detects gas residue in a public environment malfunctioned due to the breakdown or failure of a material used in the manufacturing process of a given part. When we put it this way, we immediately perceive the importance high-performance materials can have in the fabrication of a part.*

When leveraging additive manufacturing technologies, multinational companies usually have various experts in-house that will be able to bring their expertise in the choice of the appropriate system, the right material and the appropriate pre- and post-production systems. Imagine now a situation where an SME does not have these experts in-house to facilitate the decision-making process. Choosing an industrial or a professional 3D Printing system is already not an easy task. This task gets harder when it comes to materials.

Indeed, as technology advances, the rise of technical terms such as high-performance materials, engineering materials or advanced materials, is gaining momentum. In an era where companies tend to claim to be the "first" to launch their technology onto this market, it is easy for the prospective end-user to get lost by the (sometimes) abusive use of technical words by companies.

Credit Armor Group - PEKK Carbon

This article, therefore, aims to clarify the meaning of high-performance materials. It aims to help users identify the various types of high-performance materials, to understand materials characterization and to determine the additive manufacturing technology that suits those materials best. To discuss this topic, we have asked a number of questions to VBN Components, Armor Group and Malvern Panalytical B.V.

## High-performance materials, engineering materials or advanced materials?

Over the millennia, human beings have harnessed various substances to develop new and useful materials not ordinarily found in nature. The truth is, nobody expects the explosion in materials research that marked the 20th century. From automobiles to aircraft, sporting goods to skyscrapers, clothing to computers and a host of electronic devices—all bear witness to the potential of materials.

Several types of materials can be leveraged to manufacture parts of these industries. However, the demand for higher quality components is driving manufacturers and suppliers to master machining and assembly procedures of high-performance materials.

High-performance (engineering) materials aim to achieve the higher performance of engineering materials in the areas of: **material strength, deformation resistance, functionality, light-weighting, corrosion resistance, high-temperature capability, materials processing efficiency, sustainability and multi-functionality.**

According to **Pierre-Antoine Pluvinage**, Business Development Director at ARMOR GROUP, for the AM brand KIMYA, thermal resistance, mechanical resistance and shock resistance are often the first key performance indicators taken into account to identify high-performance materials:

*"High-performance materials are first characterised by their thermal performance. Another key performance indicator may be their chemical or mechanical resistance, or shock resistance properties.*

*However, thermal performance is not necessarily the only defining feature of a high-performance material: it can provide functional properties that other engineering materials or readily-available materials would not provide."*

Furthermore, it should be noted that several terms including engineering materials or advanced materials are often used to designate high-performance materials. Yet, a slight difference can be observed between the two terms:

Engineering materials are a broad term that refers to selecting the appropriate materials for the application in which the engineered part is being used. It requires to focus on a particular grade of material based on its properties such as malleability or tensile strength.

Materials that are utilized in high-technology applications are referred as Advanced materials. They are typically traditional materials whose properties have been enhanced, and also newly developed, high-performance materials. Simply put, when the focus is made on a particular grade of material, or when new properties have been developed based on traditional materials, the new material is termed as *"advanced material" or "high-performance material"*. Those materials are, for instance, metallic foams, magnetic alloys, special ceramics etc. They are used in High-Tech devices like computers, aircrafts, electronic gadgets, etc. Some of their applications include integrated circuits, lasers, LCDs, fiber optics and many more.

***Pierre Antoine Pluvinage** , Business Development Director at ARMOR GROUP*

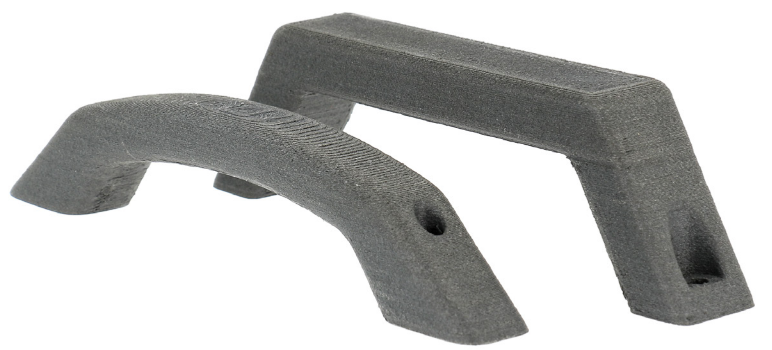
Engineering materials that might derive from them include metals (ferrous and non-ferrous metals), ceramics, polymers, composites, semi-conductors and bio-materials. However, as part of this article, a key focus will be made on polymers and metals.

## High-performance materials: polymers (plastics, thermoplastics, polycarbons)

A material is more complex than just its chemical composition. Its properties depend on its microstructure, which can evolve - during the process - or the life of the material.

The challenge is even bigger for material producers of polymeric high-performance materials. Indeed, for demanding industries like transport, automotive, or even aerospace, industrials are continuously looking for lightweight materials as efficient as metal, glass or rubber.

Credit: Armor Group



In this vein, the Business Development Director of ARMOR Group explains that we do not only talk about high-performance materials when it comes to additive manufacturing. As a matter of fact, high-performance materials are used in several production processes like metal injection moulding or machining processes. *"The challenge is to assess how to use these materials and adapt them to 3D printing technologies while maintaining their native properties"*, said the expert from **ARMOR Group**.

Their increasing use in additive manufacturing demonstrates that the most coveted materials can withstand high temperatures. These materials include: PAEK (PEEK, PEKK), PEI or ULTEM as well as PPSU.

When one or more polymers or additives are added to a resin, this combination results in an engineering plastic that integrates high-strength and several good properties. For example, to develop the material Kimya PEKK-A, Arkema Kepstan PEKK Resin has been added during the manufacturing. The final material integrates a slower crystallization ratio, which leads to more effective adhesions. Furthermore, it is acknowledged for its high resistance to high temperatures (260°C), and its ability to receive other functionalities.

Now, to attest to the quality of this material, and its ability to be processed on various 3D Printers, materials characterization comes into play.

## Materials Characterization

As technology advances, material characterization increasingly becomes sophisticated. Several techniques exist to study and measure physical, chemical, mechanical and microstructural properties of materials. The process can be applied at several stages of materials development.

However, whatever the process is, the overall goal is, on the one hand, to understand key elements required to resolve important issues, such as causes of failure and process-related problems, on the other hand, to make critical materials decisions.

Both standardized analytical methods and specialized application-specific advanced techniques can be applied during such process.

When it comes to 3D Printer filaments, mechanical properties such as strain stress, yield strength, hardness, impact strength or bending are first tested for all newly manufactured materials. Their tests enable to range the materials according to their specifications and to determine if the material meets the customer's requirements. Furthermore, material scientists carry out a tensile strength test to compare the commercial and manufactured filament.

As far as ready-to-commercialize materials are concerned, Pierre-Antoine Pluvinage mentioned some of the criteria that are taken into account to attest to their quality :

*"There are several criteria to consider when it comes to monitoring filaments' quality: diameter checks, ovality checks, imperfections checks (air bubbles). We might also add printability, as well as the evaluation of the functional attributes linked to the product's technical specifications"*, explains ARMOR Group.

## The ideal additive manufacturing process

Polymers-based high-performance materials can be processed on either an FDM 3D Printer or a SLS Technology. However, in this specific case, let's see their prerequisites on an FDM 3D Printing solution.

Despite their ability to withstand high temperatures, the AM operator should pay attention to three temperature environments: the extrusion temperature, the printing plate, and the printing chamber. A nozzle that presents a too high temperature might lead to a partial deformation of the printed part or a material's seepage. A low temperature, on the other hand, does not enable a perfect cohesion between layers.

As far as the printing plate is concerned, if the temperature is too high, it will not be possible to remove the printed part easily. Indeed, the first player would have adhered so much to the printing plate that the latter could be damaged. A low temperature will cause an adherence issue and will lead to part deformation.

As for the heated chamber, its temperature enables to obtain good adhesion between layers and prevents shrinkage when the melted material becomes solid.

In addition to these temperatures, the AM operator should also pay attention to the crystallization phenomenon of the materials. Semi-crystalline materials like PEKK tend to form crystals in environments hotter than their glass transition temperature. This phenomenon might first lead to a shrinkage and part deformation, and at the end, lead to a failure of the printing process.

*"High-performance materials benefits lie precisely in their versatility and wide range of possible applications. Semi-crystalline materials typically offer outstanding chemical and mechanical properties including [the ability to withstand] high-temperature conditions. They can be used in structural applications as well in applications that imply rubbing and erosion. For example, PEKK-SC presents a high chemical and thermal resistance combined with electric and dielectric insulation properties. Amorphous materials such as PPSU or PEKK-A perfectly maintain their mechanical properties until glass transition temperature and present excellent electrical properties. Thanks to their exceptional dimensional stability, these materials are suitable for precision components"*, concluded ARMOR GROUP's spokesperson.

## High-performance materials: metals

Although thermoplastics drew the most attention in the early days of 3D printing, metal AM remains the technology that drives the most the additive manufacturing industry.

Metals are known as ductile materials. In other terms, they can easily withstand tensile stress. However, the more technology advances, the more issues including high melting points, layer thickness, print speed and production capacity, are addressed.

A number of different metals are available in powdered form to suit various processes and requirements. Those powders include titanium, steel, stainless steel, aluminium, and copper, cobalt chome, titanium as well as nickel-based alloys. Those materials also include precious metals like gold, platinum, palladium and silver.

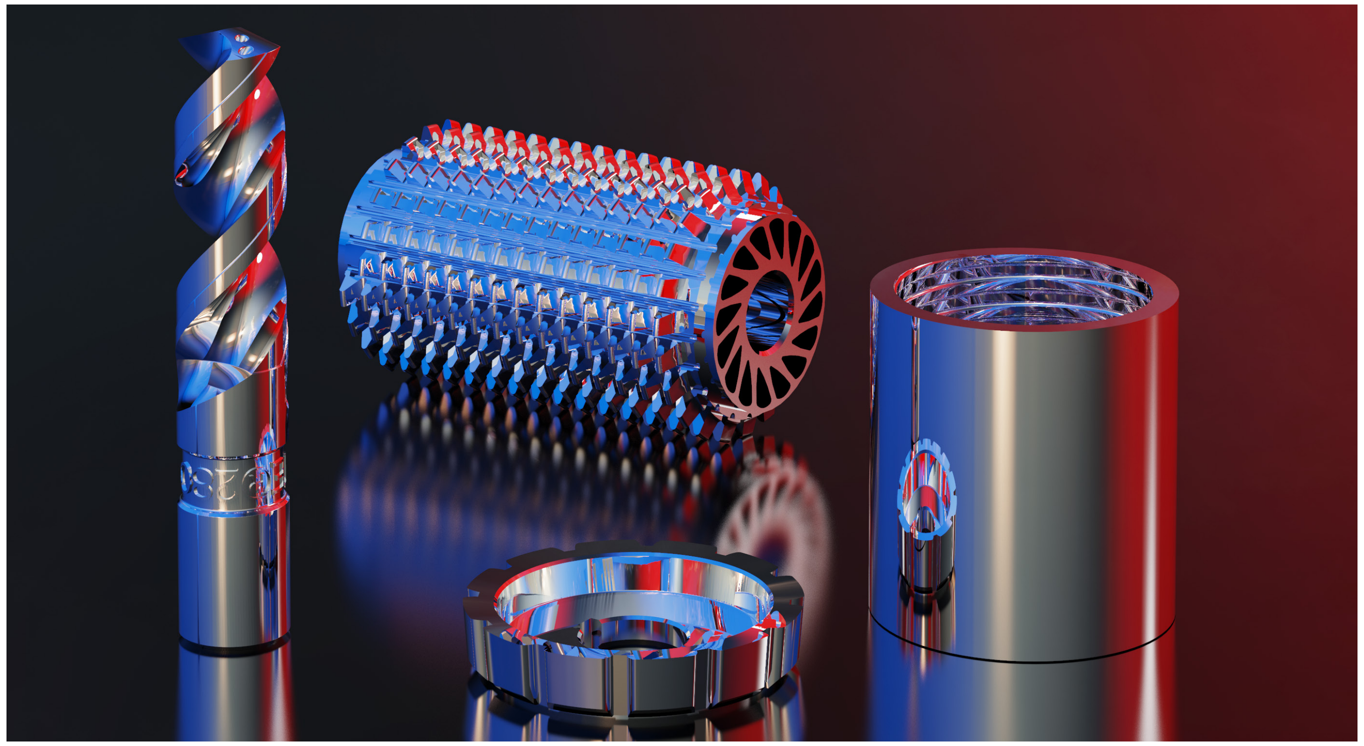
The increasing interest in high-performance materials made with these materials lies in the fact that those

Isabelle Bodén

3D Printed components are not often reproduced. In the long-run, if the operator has succeeded in taking advantage of all stages of the manufacturing process, he can benefit from low production costs.

In the same vein, it should be noted that to attest to the quality of the aforementioned powders, the same properties are not necessarily always tested.

**VBN Components** for instance, develops a high-speed steel named Vibenite® 280, **Isabelle Bodén**, Customer



*Credit VBN-diversity landscape final halvsida beskuren* relations manager, explained that for this material, the actual wear in usage ("how much material is worn off when exposed to i.e. abrasion") and the long-term hardness are key characteristics that should be taken into account to attest to the quality of this material.

*"Our materials are extremely wear-resistant. For example, our high-speed steel Vibenite® 280 is used in a gear hob, cutting twice as deep and lasting twice as long before needing regrinding, compared to a top, traditional steel in the same application. The carbides in our materials are very fine and well-dispersed, resulting in hardness levels up to 72 HRC and higher toughness than you would expect from such hard materials"*, explained the spokesperson form the Sweden-based company.

## *Materials characterization*

For the AM of a given part, the cost of the powder represents up to one third of the production cost, not to mention that commercial viability should be backed by a robust supply chain and effective powder recycling strategies. Moreover, there are over 14 metal-based AM technologies today. However, we will take into account powder-bed fusion technologies to discuss these analytical techniques.

According to Malvern Panalytical, *"the chemical and physical properties of the powder directly impact the build process and final component quality and must be controlled and optimized to ensure process robustness and consistency. To achieve this powder, properties must be characterized at various stages in the supply chain, from new alloy development through to powder recycling. Laser diffraction, automated image analysis, X-ray fluorescence (XRF) and X-ray diffraction (XRD) are four key analytical techniques that are commonly used to characterize additive manufacturing powders."*

Laser diffraction is interesting to measure the particle size distribution of metal, ceramic and polymer powders for additive manufacturing. In powder-bed fusion processes, particle size distribution affects powder bed packing and flowability which in-turn impacts on build quality and final component properties. Using a laser diffraction process enables to achieve particle size distribution in a few minutes using either wet or dry dispersion techniques.

*"Automated static image analysis can be used to classify and quantify the size and shape of metal, ceramic and polymer powders by combining particle size measurements such as length and width, with particle shape assessments such as circularity and convexity on a statistically representative sample (>10,000 particles)"*, explained **Malvern Panalytical**.

Lastly, if XRF helps materials scientists to determine the elemental composition of metal alloys and to detect the presence of contaminants or inclusions, XRD provides information about the micro-structural characteristics that can be influenced by thermal and mechanical processes.

To sum up, the development of AM machines is an important area of focus as technology is continuously adapted to deliver higher throughputs. However, the properties of the powders used are increasingly taking a big part of the production strategy. Materials characterization is just the beginning of the story. #StayTuned


VBN COMPONENTS

# SLM Solutions: Holistic Solutions Provider and Partner for Metal Additive Manufacturing

One of the most important current trends in 3D printing is the advancement of functional parts into series production, aided by consistently improved machines with increased productivity, robustness and stability. SLM Solutions is a leading supplier of metal additive manufacturing systems that partners with customers to utilize selective laser melting for qualified production processes. Headquartered in Germany with global representation, SLM Solutions holds the base patent as the inventor of the selective laser melting process and to this day, only focuses on the advancement of this production process.


SLM Solutions was the first to develop and introduce multi-laser systems to the market, with the twin-laser SLM®280 in 2011 and the quad-laser SLM®500 debuting in 2015. As the innovation leader in the industry, SLM Solutions also offers patented bi-directional recoating to reduce laser-off times, overlap stitching to ensure part quality and ensures operator safety and process integrity through closed-loop handling. This unique approach isolates operators from metal powder during powder fill process and unpacking after a build. Qualified SLM® systems are used worldwide by customers in a wide range of industries, including aerospace, automotive, tooling, energy and healthcare. In the research field the open parameter nature of all SLM® machines help further advance process and material development.

SLM Solutions offers selective laser melting systems in four sizes, the SLM®125, SLM®280, SLM®500 and extended z-axis SLM®800, which all offer the same cutting edge technological process, differing mainly in the size of the build envelope as well as the number and power of the lasers processing the build.

All machines enable qualified production in a variety of materials and almost any weldable alloy can be processed. SLM® machines are available with 400W or 700W lasers and fully automated powder sieving and supply systems that ensure safe and reliable powder supply without manual refilling during the build.

As a complete partner in developing additive manufacturing processes, SLM Solutions also offers software solutions to ease the path to successful selective laser melting builds, track melt pool and laser data outputs and streamline plant production. Consulting offerings further lower the learning curve and assist customers in developing their production processes.

For more information visit us at
Booth E03, Hall 12 at formnext.


| Machine Name | Machine Size in (mm; w x d x h) | Build Envelope reduced by substrate plate thickness ($mm^3$; w x d x h) | Build Materials | Layer Thickness |
|---|---|---|---|---|
| SLM®125 | 1400 x 900 x 2460 | 125 x 125 x 125 | Titanium, Aluminum, Tool Steel and Stainless Steel, Cobalt-Chrome, Copper and IN. Parameters for other alloys available on request. | 20 µm - 75 µm |
| SLM®280 | 4150 x 1200 x 2525 (incl. PSV) | 280 x 280 x 365 | | 20 µm - 90 µm |
| SLM®500 | 8600 x 4500 x 2700 (incl. permanent filter module, chamber re-moval station, powder sieve and operating space for all peripheral equipment) | 500 x 280 x 365 | | 20 µm - 90 µm |
| SLM®800 | Varies depending on machine setup and automation options | 500 x 280 x 850 | | 20 µm - 90 µm |

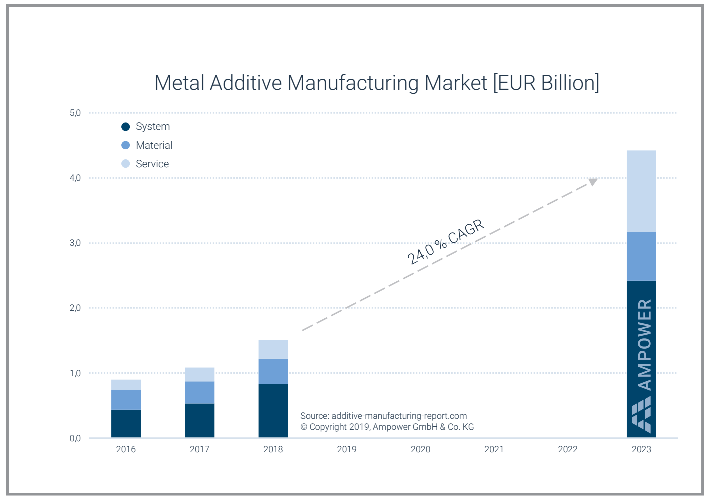
# METAL AM

## Ampower market report expects metal AM to annually grow by 24 %

At Formnext 2019 the Germany based Additive Manufacturing consultancy Ampower publishes an industrial metal Additive Manufacturing market and technology report. The report focuses on industrial metal Additive Manufacturing and provides a deep dive into the current state of the industry.

Ampower was founded in 2017 as an independent consultancy which specializes in metal Additive Manufacturing. The company offers trainings, market analysis and qualification support for user and supplier of the industry. In 2019, Ampower took the challenge to conduct their first global market report which will be published at formnext 2019 in November. This article gives an overview of the key findings of the report.

The Ampower report is structured into two sections, the Technology Section and the Market Section. The technology section covers the different Additive Manufacturing processes as well as deep dives into cost, design for Additive Manufacturing and material aspects. The market section gives access to the market numbers segmented in regions, industries, technologies and other aspects.




### Maturing market characteristics

Key findings of the market analysis are the total annual revenues and growth rates. In 2018 the metal Additive Manufacturing supply chain industry reported revenues of 1,5 billion EUR and projects a CAGR of 24,0 % to surpass 4,4 billion EUR in 2023. End-users second this by expecting a yearly growth of 23,6 % of their metal Additive Manufacturing business. Market expectations of align supply chain and users closely which indicates a maturing industry, where market push and pull are almost even. The largest part of the supply chain consists of system sales with a total revenue of 830 million EUR in 2018 followed by materials with 390 million EUR. The report goes more into detail about the different segments of the market in terms of regions, technologies, materials and industries.

Besides the overall market numbers, the derived survey data also allows for more in-depth conclusions. The staff analysis, for example, leads to a total of over 40.000 employees directly working in metal Additive Manufacturing on user and supply chain side. The ratio of people employed by this market versus the total market volume shows the still early R&D stage of the technology. Many users have less than 5 metal systems and currently go through extensive R&D and qualification work. Only a handful of users run over 10 systems in a production environment with over 7000 h of annual run time.

The current status of the industry can be described as "on the threshold of production". While industries like medical are already in full production, most applications are in R&D or qualification status. Machine sales are expected to grow slower in 2019 and 2020 due to ongoing R&D activities, but the report suggest an increase in sales in 2021 once many applications in industries such as aviation and oil & gas are expected to pass the qualification requirements.

### Diversity of technologies

By covering more than 15 different metal Additive Manufacturing technologies, the report provides an overview of the whole diversity of the industry. The report lists over 120 system suppliers for Metal AM technologies with more than 50 % of metal AM suppliers located in either USA, Germany or China. Laser Beam Powder Bed Fusion (LB-PBF) is the most represented metal AM technology with over 40% of the listed suppliers. Around 58 suppliers are providing systems with this technology. The most maturing technologies besides LB-PBF are Electron Beam PBF, Laser Metal Depositioning (LMD) and Wire Arc Additive Manufacturing (WAAM) technologies. On the other hand, many of the known technologies are still in an early development stage with no or very few systems on the market.



The applications section contains a catalogue with over 40 different metal Additive Manufacturing applications with industrial relevance. Prototypes or study parts are not part of this application catalogue. As expected, most industrial applications are based on LB-PBF technology. However, the number of Metal Fused Depositioning Modelling (M-FDM), Binder Jetting and WAAM applications is increasing.

The cost section contains data about the cost aspects of the different metal Additive Manufacturing technologies. Readers of the report can calculate cost estimations for their components with a simplified cost tool. Most new technologies are focusing on cost advantages compared to LB-PBF. This is most evident for Binder Jetting. With a high packing density of the build envelope, cost can potentially be reduced by over 50% in comparison to LB-PBF.

### Technology and market outlook

With more new technologies maturing over time, the diversity of the metal Additive Manufacturing market is expected to increase. Novel applications will drive the technology and each industry will readjust their focus. While medical will remain focusing on LB-PBF and EB-PBF, in aviation, the WAAM and LMD technologies will receive more attention for a wide range of applications. In consumer, automotive and other high-volume industries, sinter-based technologies like Binder Jetting are expected to surpass LB-PBF.

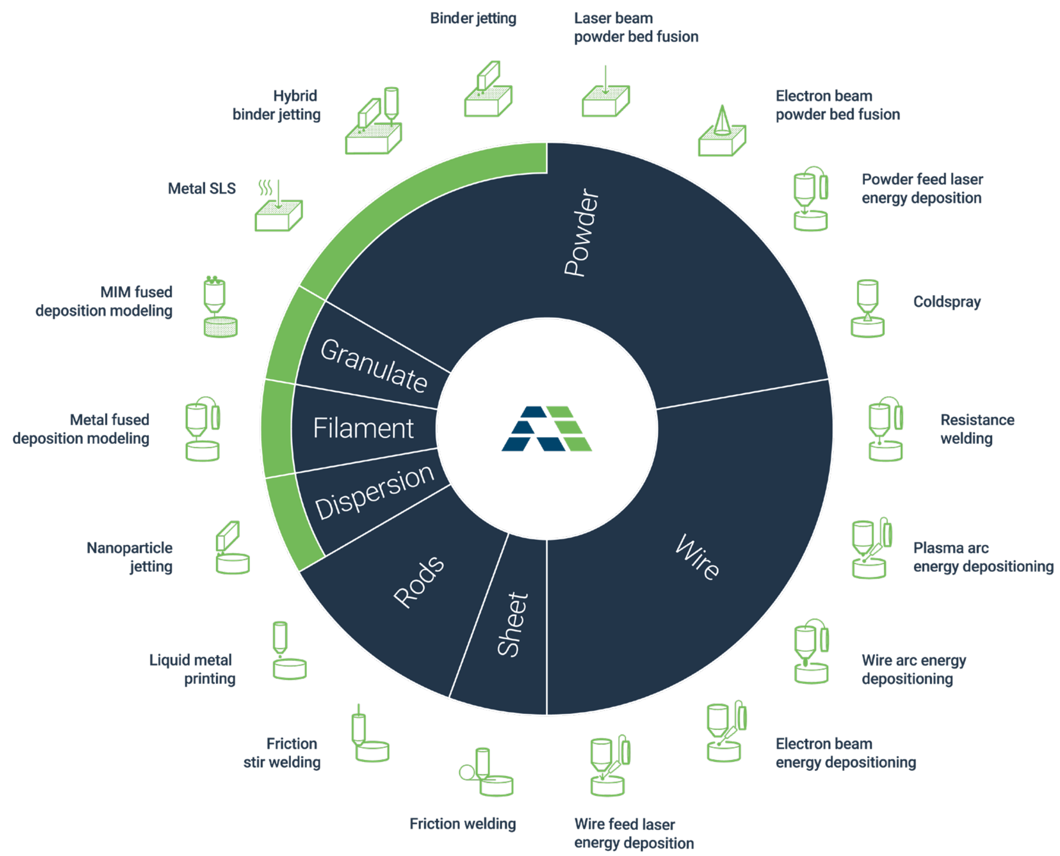
### Personal interviews lead to reliable insights

For this market report, Ampower relies on over 150 personal interviews with suppliers and users in the metal Additive Manufacturing industry. The interviewed users cover more than 10 % of the worldwide installed AM system base. 16 industry experts and partner institutions like the German Mechanical Engineering Industry Association VDMA and the American Society of Mechanical Engineers ASME contributed market insights and network to the report.

*"We believe in gathering survey data through personal interviews, so we know, who is actually providing the answer. Our report is based on such personal interviews with suppliers and users to get a comprehensive insight into the current market and future expectations."* says **Matthias Schmidt-Lehr**, one of the managing partners of Ampower and author of the report.

Another novelty of the report is the online availability. Schmidt-Lehr explains *"We know from our daily work we do not want to browse through endless pages of a PDF document to get the data we are looking for. With our online report platform, you can get access to the full report and the key facts within a few clicks. Also, you are sure to always have up-to-date data."*

**Matthias Schmidt-Lehr**
AMPOWER
www.am-power.de



# MBFZ toolcraft and Morf3D achieve successful beta test of Solukon's SFM-AT800-S depowdering system

One company that literally opens our eyes on the second-rate treatment given to post-processing solutions is Solukon.

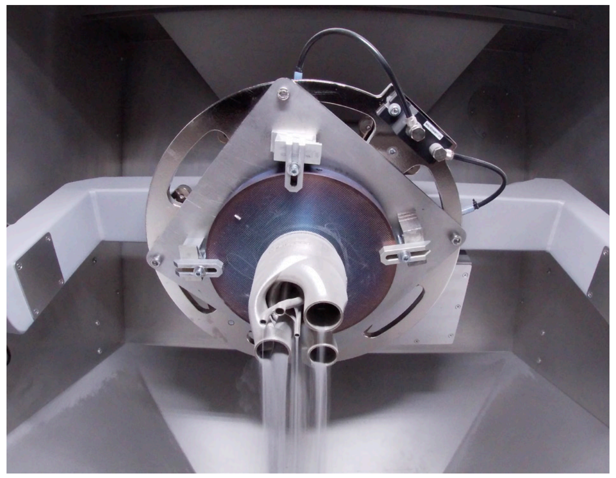
Last year at Formnext 2018, the company unveiled their depowdering unit SFM-AT800-S, developed in collaboration with Siemens, a system that aims to "ensure safe, complete powder removal and recovery of internal channels and structures of high complexity in one automated process", as per the words of Andreas Hartmann, CEO and co-founder of Solukon.


SOLUKON
SFM-AT800-S

Today, both partners have already made the pride of two companies: MBFZ toolcraft and Morf3D.

MBFZ toolcraft manufactures complex components for a wide range of industries, from small series to serial injection moulded parts in batch sizes of thousands of pieces in almost all common industrial production processes. The contract manufacturer leverages laser powder bed fusion process in its AM production portfolio.

Acknowledged for the manufacturing of complex aerospace parts, Morf3D provides a variety of fully-integrated additive design and manufacturing services including conceptualization, parameter optimisation, metallic 3D printing, finishing, metallurgical examination, certification and data analysis. So far, the company's experience in post-processing lies in a series of manual operations, with issues including lifting and handling, containing the loose powder, and having to document successful steps and recreating. They were therefore looking for reducing manual work while reducing manual work and potential errors that may occur with a system that could deliver reproducible results.



*Automated powder removal in progress in a Solukon SFM -AT800*

*"The benefits of this new complete production process include eliminating the human element and associated sources of potential error, having a stable, repeatable operation, and having an ergonomic and environmentally friendly solution. A reproducible result pushes the quality forward. The new technology helps to build confidence in the AM powder removal process, and therefore confidence in the end product. A programmable solution that consistently repeats will establish confidence in the operation and reduce the amount of scrap hardware. AM allows for complex geometries that are difficult or impossible to manufacture conventionally. The Solukon/ Siemens SFM-AT800-S allows for more reliability which moves one step closer to customer adoption of the technology"*, explains **Ivan Madeira**, their Operations Manager.

MBFZ toolcraft that discovered the system at Formnext 2018, decided to carry out a beta testing after a convincing presentation by Solukon's team.

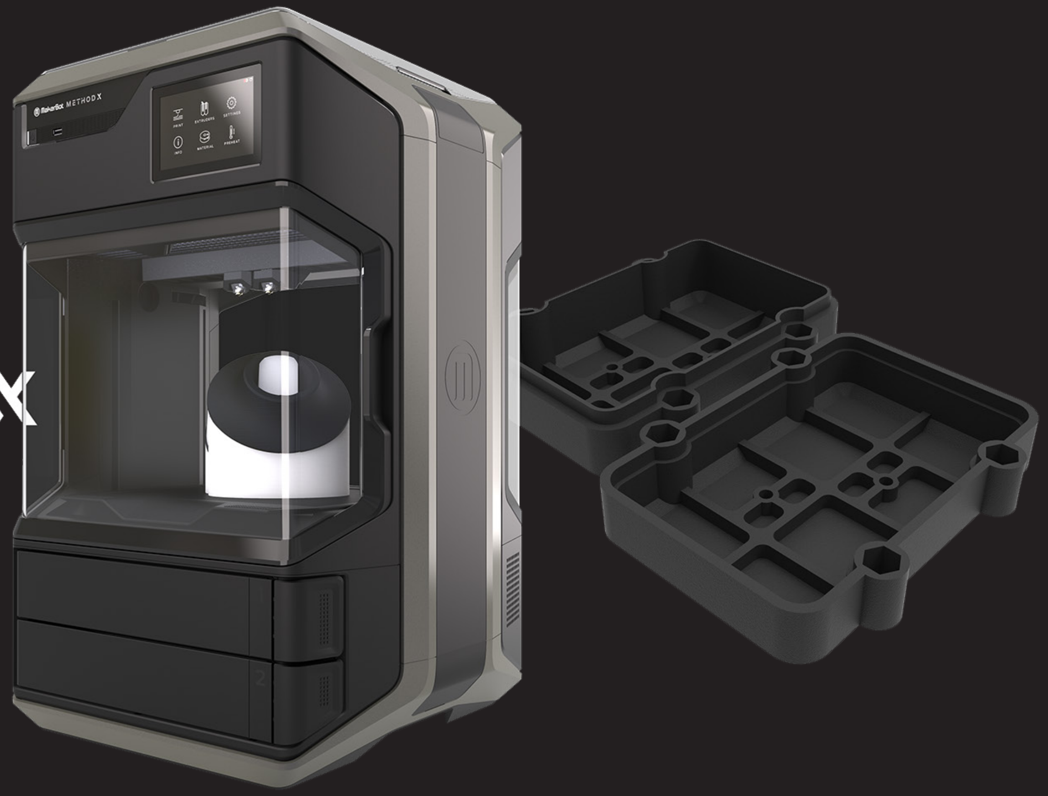

IVAN MADEIRA
OPERATIONS MANAGER

Following the pilot program, Uwe Schulmeister, Head of Metal Laser Melting at MBFZ toolcraft, comments: *"the results are really convincing. Besides the requirement to remove material in order to avoid problems in post-processing, the system has a few other distinct advantages. Firstly, residual powder material is extracted and saved for reuse, which is a clear economic advantage for expensive materials. Secondly, post-processing is less problematic because there is less material to be disposed of. This is a very important ecological aspect for us. In additive manufacturing there are few clear standards in many areas, including for environmental issues. This will change sooner or later, but we are very keen to implement solutions up front that take environmental concerns into account. We tested the system with a wide variety of components. For example, we tested complex components such as a biology-inspired, flow-optimized combination burner from Siemens. But even with much simpler parts, we showed that the SFM-AT800-S is much faster and more efficient than any other method. For us, this means a considerable simplification of our manufacturing process because we no longer have to worry about the quality of the results. It also allows us to define a workflow that enables us to offer our customers a clear line in quality assurance as well."*

We couldn't agree more with Hartmann that believes *"it is always more credible if the performance of a solution is evaluated and confirmed by an external source. This gives us the confidence, and a clear conscience, that we are providing our customers with a tried and tested solution that they can rely on in practice. Stringent testing under production conditions has resulted in the placement of additional SFM-AT800-S beta machines in the international market for evaluation in other industries and applications"*, concludes the CEO.

*Andreas Hartmann, CEO and co-founder of Solukon*

MakerBot
METHOD X
POWERED BY stratasys



# MakerBot, a company that believes there is an innovator in everyone

MakerBot believes that there is an innovator in everyone. The manufacturer is one of the companies that tried hard to initiate makers to the 3D Printing technology. It's been ten years that the US-based company supplies 3D printers and its commitment to advancing tomorrow's innovators and institutions has been translated in the continuous enhancement of its technology and its ability to expand into several markets across the globe.

Rather than solely focus on hardware, MakerBot offers connected solutions that address the wider needs of professionals and educators. The company's solutions provide a faster and more effective way for engineers and designers to test ideas as well as help educators to prepare students for the jobs of tomorrow.

However, despite this exciting development, the company is well aware that the creation of a new product for a new market can be challenging. At times like this, the team prides itself on being able to rely on the industrial expertise of their parent company Stratasys.

## MakerBot's offering to the 3D printing market

MakerBot's solutions include the MakerBot METHOD platform, MakerBot Replicator+, MakerBot Replicator Z18, MakerBot Cloud, MakerBot Connect, MakerBot Print, Thingiverse Education, MakerBot Certification Programs™ for students and educators, MakerBot Precision and Specialty Materials, and more.

Over the past year, the desktop 3D Printer manufacturer announced several new solutions for professionals that will enable it to accelerate their production processes and bring products to market faster. This includes the availability of METHOD and METHOD X, new model materials including ABS, PETG, and ASA, and support materials including PVA and Stratasys SR-30.

Engineered as an automated, tinker-free industrial 3D printing platform, METHOD X first promise to users is accessible manufacturing with real "ABS", not to mention that with a 100°C Circulating Heated Chamber, the technology reduces part deformation while increasing part durability and surface finish.

Just like the other technologies from the manufacturer, METHOD X underwent several trial and error testing which enabled the team to know the key industrial tools and tips required to ensure that users achieve consistent print accuracy, speed, and reliability.

## A mature company for a mature market

As mentioned earlier, MakerBot debuted this adventure in a more consumer-oriented market segment. Today, as additive manufacturing matures, the company more and more refines its focus while keeping 3D Printing education in its DNA.

It is too soon to predict the company's outlooks for 2020, but under the parent company's wing, Stratasys, it will certainly be exciting.

MakerBot
www.makerbot.com
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MakerBot. stratasys

# ADDITIVE MANUFACTURING **CONFERENCE**

## How was the First Additive Manufacturing Conference in the Benelux?

*For this first experience, HP, BASF, Siemens and Materialise, the "Big Four" gathered around a hundred guests in Utrecht, The Netherlands*

In major European cities, AM conferences are organized to raise awareness on the potential of the technology and to discuss the current challenges companies still have to overcome. In the Benelux, we didn't have a dedicated event of this kind yet. Until September 18th, when HP, BASF, Siemens and Materialise joined forces to make it happen. For this first experience, the "Big Four" gathered around a hundred guests in Utrecht, The Netherlands.

While no particular reason explained the choice for the Netherlands' fourth-largest city, it should be noted that the inspirational environment of the NBC Congress Centrum paved the way to innovations we discovered.

Four main points shaped this gathering:

-Around snacks and drinks, guests networked with peers in the exhibition hall, while discovering HP's recently released Jet Fusion 5200 series 3D Printing System, BASF's material developments, Siemens' end-to-end integrated system for industrializing AM as well as Materialise's inspiring power of co-creation.

-If the plenary session was an interesting "recall" of each company's services, it demonstrated something much more important: their complementarity and willingness to continue pushing the boundaries of industry 4.0 together.

-Every group of guests, (dispatched according to their colour badge), attended break-out-sessions designed to deepen their understanding of what each company brought to the industrial and consumers markets.

-A panel and a cocktail allowed attendants to sympathize and better know each other at the end of the day.

Despite the strong complementarity between the partners of this conference, one-to-one conversations with representatives of each company revealed insightful and forward-looking strategies.

**HP & Digital Production on-Demand**

Acknowledged as one of the leaders in the 2D Printer market, HP entered the 3D Printing market in 2014, at the end of its fiscal year. This timing was perfect for those who were interested in specializing in metal additive manufacturing market as patents for several technologies including binder jetting began to expire, allowing new companies into the market. More importantly, it was a real challenge to leverage the company's 2D Printing knowledge & expertise to help industries shift towards smart manufacturing.

Interestingly, at the head of HP 3D Printing Business, we do not always find veterans of the AM industry, like in most AM companies. Do not get me wrong, veterans bring an array of advantages to a business but an outsider like Philipp Jung brings a fresh look that is also necessary to help HP envisions a long-term future in the industry.

The Chief Strategy Officer has been working for 6 years in the company. Rapidly involved in the customer success journey, P. Jung realized that transforming a company's manufacturing production required to take into account two main factors:

- "It's not just about the printer." This is an indisputable fact for Jung. Indeed, Hewlett Packard's ability to create value is driven by business cases that have something in common: leveraging the capabilities of several tools of a bigger system – which includes: design, software and materials.

"The technology might be advancing at a fast pace, but it still takes time to implement real and complete digital production into companies' facilities", said Jung.

People's mindset is not just ready yet. Furthermore, those who are ready do not have the required skills. Digitalisation does not aim at removing jobs but at creating new ones while improving old tasks.

In this vein, to help students and professionals to better embrace additive manufacturing, the Multi-Jet Fusion specialist decided to launch its education program in collaboration with some universities. We might expect further information on this program next semester.

- Jung's second factor to take into account consists of "advancing the value proposition of the technology by improving productivity". Although 3D Printing is several decades old, it came to disrupt facilities that already integrated a range of manufacturing processes.

For Jung therefore, "it is crucial to make additive manufacturing more attractive". The best way to do so is to highlight and lay emphasis on the technology's strengths that other manufacturing productions do not have.

Achieving dimensional accuracy with parts and increasing productivity even further are key benefits that can tip the balance in favour of additive manufacturing.

**What enables this ecosystem to last over time**

While there are certainly great success stories in the industry, reality also depicts a great number of companies that filed for bankruptcy. According to Jung, those who are still in the game today are those who have been able to keep "an entrepreneurial mindset". Only an entrepreneurial mindset provides an inherent need to approach challenges & mistakes, to improve skills, to try and try again.

In five years in the industry, HP has surrounded itself with collaborators in-house and partners like materialise or BASF that have this mindset. Its portfolio today illustrates this mindset in its evolution:

The HP JET Fusion 500/300 Series, for instance, enables functional prototyping. It was designed with colour in mind. "If you scratch a part produced with this system, the color will still be there", explained the expert.

The HP Jet Fusion 4200 series is ideal for low-volume production whereas the latest released system, the 5200 series, enables to achieve volume production. Moreover, "it includes what's required to transform manufacturing. This system comes with a solution that integrates software capabilities."

Launched last year, the HP Metal Jet Fusion, on the other hand, enables mass production. It is currently being harnessed as part of the production service of a few manufacturers of the industry (like GKN).

With these assets in its portfolio, HP is more than ready to change the manufacturing world.

# BASF & its innovative materials

> " One year in AM is 10 years in traditional chemistry "

Baden Aniline and Soda Factory aka BASF is an empire in the chemical industry. With subsidiaries and joint ventures in over 80 countries, the company has more than 390 production sites around the world. For several years, the chemical giant has been involved in high-profile partnerships in AM with partners like HP and Essentium but September 1, 2017, was a decisive year for the company as it announced the effective creation of its business dedicated to additive manufacturing.

BASF 3D Printing Solutions GmbH entered the additive manufacturing market when there was a high demand for more functional plastics and powders.

However, *"generating complex geometries in an increasing variety of materials, including polymers, ceramics and metals, requires a certain level of experience and time to translate molecular interactions into practical materials and devices"* explained **Rüdiger Theobald**, Senior Manager Sales & Marketing 3D Power Solutions.

Moreover, having a functional material is not enough, producers need to ensure their compliance with specific standards for safety, quality or performance. That's the reason why BASF 3D Printing Solutions GmbH decided to position itself as a full solution provider for industrial 3D Printing.

The company is currently working on a *"third-party certified materials program"*. It also provides integrated engineering and simulation services to support companies in their AM workflow. Indeed, the 3D Printing business unit has understood the importance of every step in an additive manufacturing process. Therefore, its engineers' role consists of but is not limited to, supporting customers in the optimization of part designs, part simulation and process properties. They can also test part behaviour under load, and consult on the best-matching 3D printing process.

BASF portfolio includes a comprehensive range of engineering thermoplastics, polyurethanes, acrylate systems, functional additives, stabilizers & pigments. These products are a basis for ready-for-use formulations for 3D printing.

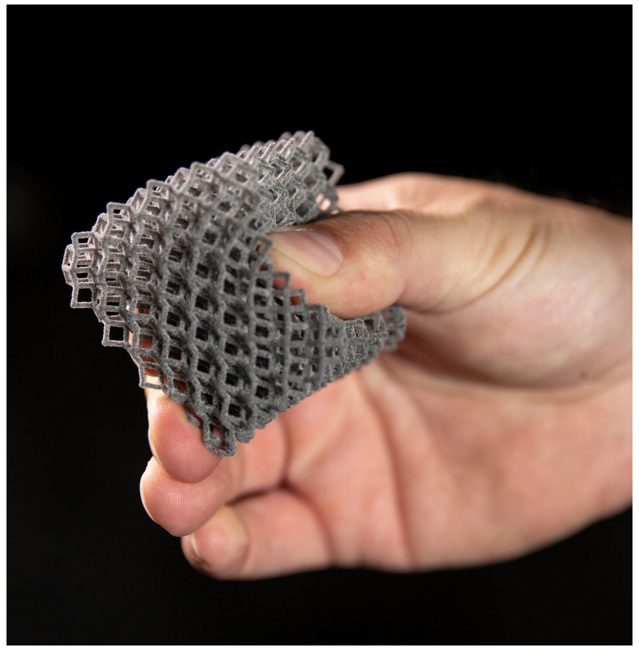
It takes so much time to develop a 3D printing material that producers need to be able to seize market opportunities when they saw one. Theobald related one of these opportunities during the development of the famous TPU.

Four years ago, BASF strengthened its collaboration with HP for production-ready AM materials development. HP asked BASF to develop an *"easy to print TPU material"*. For BASF, that wasn't their first experience with this material.





Indeed, first tests regarding the Ultrasint®TPU material were carried out 6 years ago. The material is known as a *"granulate [ideal] for flexible applications that require rebound and shock absorption. [As part of this partnership with HP] the challenge was therefore to make a powder that is compatible with HP MJF Technology"*, explained **Theobald**.



A wide range of materials was in the pipeline but the new thermoplastic polyurethane (TPU), Ultrasint®expands the breadth of applications on the new Jet Fusion 5200 Series systems.

*"Today, there is a large number of AM systems available on the market. Each of these systems should be able to achieve high reproducibility and mass production of materials. BASF's goal is to enable this mass production. More importantly, we want to be the first to achieve this goal. You have to be the first if you want to innovate."*, concludes **Theobald**.

## Materialise & the Co-creation journey

Bart Van der Schueren is the veteran of this group. With a 29-year experience in this industry, the CTO has built this company alongside Wilfried Vancraen. Talking to Van der Schueren was like talking to a wise man that shared his industry experience so that anyone can make the most of it.

*"It was tough and it still is. You have to comply with new rules and new languages. Furthermore, the manufacturing world is something and the prototyping world is another one"*, explained the expert.

In three decades, Materialise has managed to create and to deliver a range of software solutions and 3D Printing services that constitute the backbone of the 3D Printing industry. According to Van der Schueren, each decade came with its array of challenges:

- During the first decade, the goal was to *"make it work"*. Being able to successfully connect their software solutions with AM systems. The market volatility was not reassuring and there were only two companies that provided services at that time.

- During the second decade, the focus was on finding the range of applications that could leverage additive manufacturing. The company achieved significant milestones by discovering the technology potential in eyewear, sport, consumer goods, prototyping, fashion, industry, design and healthcare industries. More importantly, the more they discovered applications, the more they were able to customize and develop new tools of their software platform. New tools have been developed for instance for the dental and the design fields. Today, *"our software connects design creativity with what is printable"*, said the CTO. Furthermore, another important issue the industry faced, was dysconnectivity. *"To achieve rapid and volume production, all tools need to be connected and work as if they are part of a unique system. It was therefore vital to connect our software tools with companies' product portfolio to enable viable AM production."* To illustrate this point, Materialise' spokesperson recalled how their technology has been integrated into Siemens' NX™ software, streamlining the design to the manufacturing process for the growing range of products produced using AM.

- This third decade came with one goal: *"make the industry scalable"*. Across the industries that leverage additive manufacturing, professionals keep facing cost and predictability issues. To address these issues, the Belgian company decided to apply a co-creation approach. Materialise' s co-creation journey is an ideal way to identify how a project can benefit from 3D Printing. Moreover, an interactive session between Materialise's experts and experts from another industry is a tangible way to appreciate the company's extensive knowledge regarding additive manufacturing. The collaborations with Hoet & Safilo in the eyewear industry are a few examples that illustrate this point.

### The place of Benelux in the global AM industry

As Materialise is a Belgium-based company, and as this was the first AM conference organized by the four partners in the Benelux region, it would have been weird to not mention the place of the Benelux region in the AM industry.

Speaking of this positioning, reality shows that when it comes to the integration of AM, the Benelux region is still a nascent market compared to neighbouring countries like Germany or France.

*"From a technology perspective, there is a clear additive manufacturing footprint in Belgium and the Netherlands through the presence of some leading companies. From an application perspective, I remain sceptical regarding the integration of AM in Belgium. The Dutch industry is much more receptive to industrial change. Belgian companies, on the other hand, should realize that it is time to invest in technology. At present, we do not see yet the transformative power of AM in Luxembourg"*, said **Van der Schueren**.

Materialise has proven it won't stop addressing the challenges of AM. The next issue in its agenda is the technology value in sustainability. AM has an important role to play in this issue and Materialise aims to be part of this change.

Credit Materialise

### Siemens and the integrated end-to-end solution for industrializing additive manufacturing

Siemens is a lot of things. It might take more than one article to draw a decent description of the German multinational group. However, it is interesting to keep in mind that the technology company is mainly active in industry, energy and healthcare.

The company was first an AM user before being a key player in this niche market. As a software company, the technology expert provides its solutions under the brand Siemens Digital Industries Software, formerly known as Siemens PLM Software.

Dr Tom van 't Erve, Global AM Director at Siemens Digital Industries Software makes it clear from his first statement: "Additive Manufacturing is not the centre of our universe. It is a tool in a bigger toolbox." Indeed, Siemens lays emphasis on industrialization as part of its services. Through its integrated end-to-end system for industrializing additive manufacturing, Siemens supports companies at every single step of the value chain, starting from the design to the production of the end-product.



*"Once you have designed a part, you need to prepare it for production and this requires communication with the machine to ensure traceability, machine monitoring but above all, managing and executing a professional process", explained van 't Erve.*

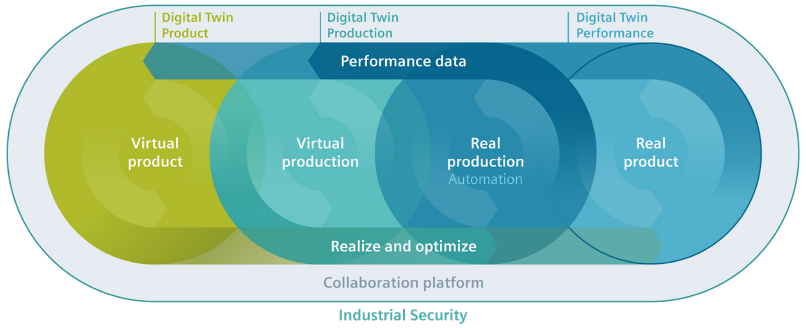
*Such type of preparation may require the use of various tools. Furthermore, operators often compare AM with conventional manufacturing processes. The expert demonstrates that this comparison cannot not only be seen at the level of the machine but also the software level. Indeed, even though there might be AM-specific challenges at the software level, "during the use of AM software specific tools, implementing a change does not require to change the production process, which is often the case with traditional software."*

More importantly, envisioning all challenges that may occur during a given production process, be it AM or CNC process, may help professionals to save a huge amount of time during the production.

### The value of digital twin technology

Tom van 't Erve discussed a concept that consists of tying digital designs to their physical counterparts. The concept is not new but is gaining momentum as it has proven its viability by collecting and analyzing real product data during operations. Siemens' vision of digital twin technology, therefore, consists of a virtual replica of a physical system, process or product. The technology expert, therefore, explores the opportunities of this technology at three levels: Digital Twin of Product – Digital Twin of Production and Digital Twin of Performance.

According to van 't Erve, this technology "delivers a real-time look at how a physical asset is performing. Using this technology would enable an operator to identify where improvements can be made to reach more favourable outcomes."




In other terms, the digital twin of a product will consist in the creation of digital models that can accurately predict the behaviour of these products. "Improvements can occur at the level of weight, performance or even stress", said Siemens spokesperson.

The digital twin technology of production would enable any operator to virtually produce the part before he even buys the desired equipment.

The digital twin of performance takes into account the performances of both production and product. The operator can analyze and predict improvements based on data from the product and the production facilities.

Depending on the need of the user, those three technologies can be used singly or jointly. In addition to ensuring predictability and repeatability, Tom van 't Erve said Siemens Digital Twin Technology enables to "automatically remove the part, ensure part safety and is environmental-friendly."

Siemens is clearly at the forefront of industry 4.0. The company demonstrates how intelligent industrial communication networks are used to digitalize the industry's entire value-added processes. And this is not a simple matter. Companies should better be ready to embrace this innovation.

In the end, there is no doubt participants learned a lot among HP, BASF, Materialise and Siemens' experts. They certainly left the conference with lots of answers and ideas. Only one question remained unanswered: are we going to have a second AM conference organized by our "Big Four"? – If that's the case, where will it take place?

**XYZ PRINTING**

## From Desktop to Industrial 3D Printing, XYZprinting makes 3D printing possible for everyone

Founded in 2013, XYZprinting is a leading global provider of comprehensive 3D printing solutions. It is the number one global brand in desktop 3D printing products and services, and is now moving decisively into the industrial additive manufacturing arena as well to support professional manufacturers.

XYZprinting is backed by the world's leading electronic manufacturing conglomerate, New Kinpo Group, which earns more than $36 billion revenues annually and has more than 8,500 engineers in research and development across four continents. Much of its printer production happens in Thailand, while its sales and marketing operations are largely run out of The Netherlands. With nearly two decades of design and manufacturing experience, New Kinpo Group is a recognised manufacturer of many of today's printers for both personal and commercial use.

### Background & Development

XYZprinting's mission is to constantly innovate and break down the barriers to 3D printer ownership. Coupled with XYZprinting-owned factories, the company's unrivalled expertise enables it to quickly implement the latest trends and technologies, and its goal is to continue to develop the most advanced consumer-grade, professional and industrial 3D printer product ranges on the market, all while maintaining unbeatable prices. Over the years, XYZprinting has filed over 1,215 patents worldwide with over 322 patents granted in various 3D printing technologies and is now one of the worldwide leaders of patent holding in the 3D printing industry.

*Fernando Hernandez, EMEA Managing Director at XYZprinting*

### Main activities developed throughout the year

While the company will still manufacture and develop its desktop range, for which it is best known following the success of its da Vinci series of printers, 2019 has also seen XYZprinting expand its offering in the industrial market to meet growing demand in this area and seize on the strong market opportunity. A number of these printers were released mid-year, but another printer be officially unveiled at Formnext: the PartPro120 xP. This fast build speed DLP 3D printer will have a large print area, enabling high resolution desktop manufacturing, all at a more affordable price.

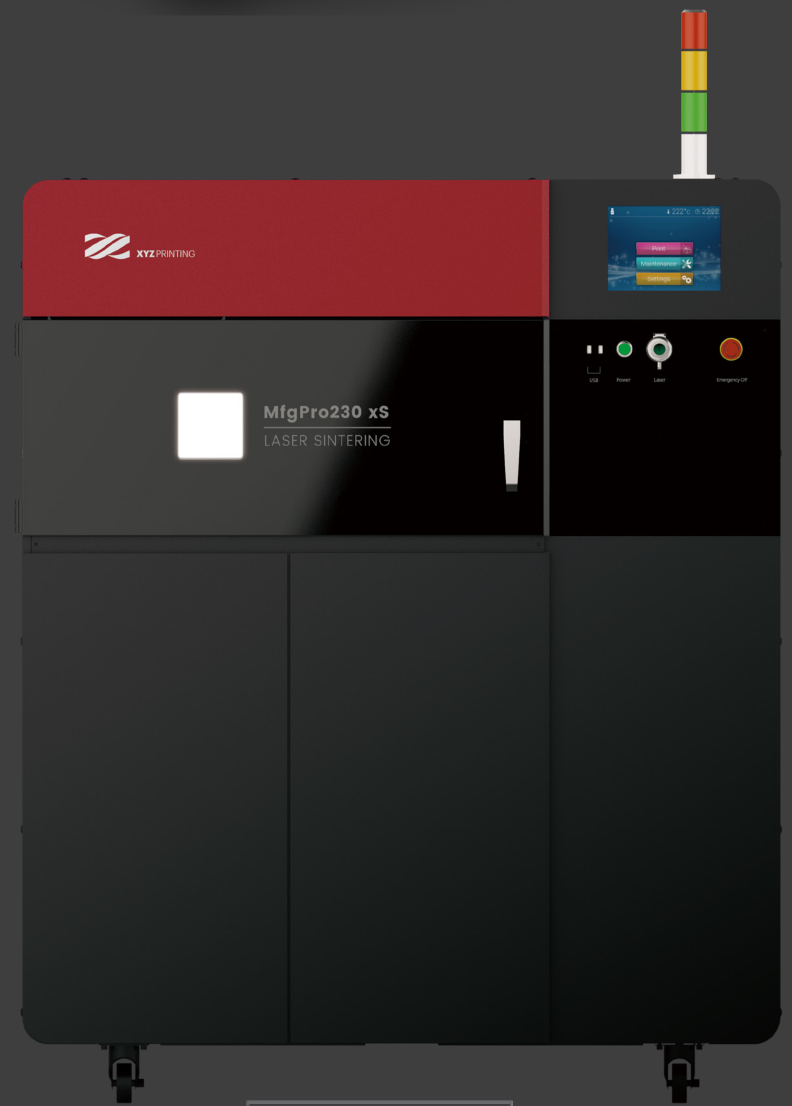
The expansion builds on XYZprinting's existing range of industrial printers and materials, which it previously developed after a thorough R&D process. These printers cater for every type of business, from individual entrepreneurs looking for an easy and affordable way to print prototypes to automotive manufacturers looking to make precise and technically advanced parts for their vehicles.

### Outlooks for 2020

XYZprinting's goal for 2019 was to make its mark in the industrial printing space, which it has achieved with the launch of a new range of professional printers to its broader 3D printing portfolio. With the PartPro120 xP set to launch at Formnext in November, the company is set for a strong 2020. XYZprinting will also be entering a number of strategic materials alliances with companies, the first of which is with BASF. The alliance will ensure XYZprinting can provide its customers with a broader range of materials to print with, allow people to create with more sustainable materials, and ensure future printers have greater materials compatibility.

PartPro350

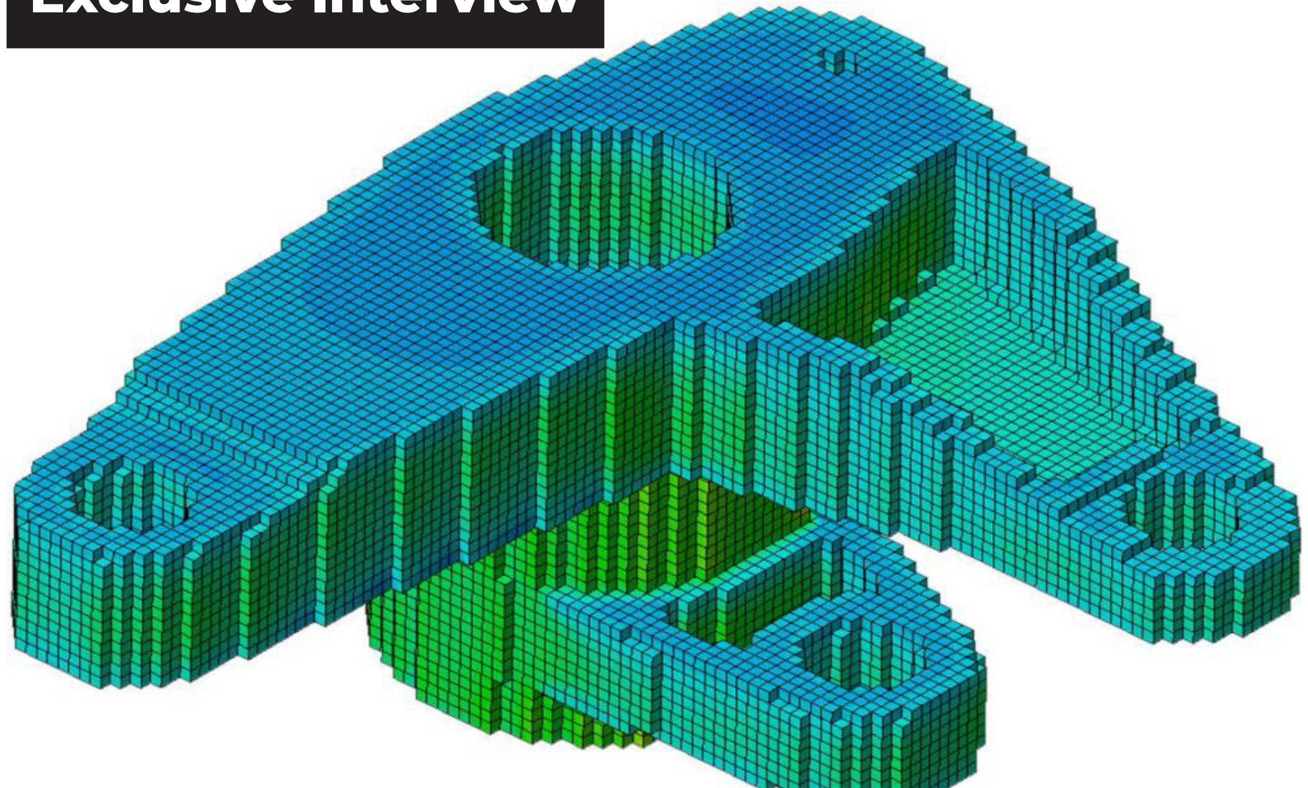





MfGPro230 xS


PartPro300

Exclusive Interview



# PREDICTING COMPOSITE ADDITIVE MANUFACTURING PERFORMANCE WITH SIMULATION

**Exclusive interview on a tripartite collaboration of MSC Software, Markforged and Danfoss that's leading to the delivery of performance optimisation tools for Markforged users.**

While no one can say with certainty what will happen in the (near or distant) future, technology experts provide more certainties with regards to the future of manufacturing – especially additive manufacturing (AM). Additive Manufacturing has been around for decades. However, in the last five years, we've seen a groundswell of manufacturers turning to AM as affordable, industrial-grade printers have entered the market.

Industrial 3D printers can print complex parts with materials and processes that are reproducible, consistent and provide high-quality results that mirror the intent of the engineer that designed them. However, just as reductive manufacturing processes have been refined and perfected, know-how and experience are essential to ensuring a part performs as it should when it is 3D printed.

This is exacerbated if manufacturers have limited knowledge of the materials involved. When the desired result is not achieved, it is not only frustrating; you might not know the reasons why. There are many factors that could affect how a part performs under load such as an incompatibility between material properties and the AM technology, or if a complex part topology is not well optimized for the print process that is used. The difference is that new AM processes are data-driven and the materials can also be encoded digitally, so a design can be modelled and simulated precisely before a single part is printed.

Danfoss, a global industry leader that provides hydraulic and electronic solutions for mobile equipment, was an early adopter of this new technology, and they soon found that even the best designs required iterations of these challenges. One of the company's objectives was to test the parts were ready to be added to the manufacturing line. So, the company set out to reduce the number of build trials per part and find a Finite Element Analysis (FEA) tool that might lead to a "right first time" approach while using AM technology.

The Danish company has, therefore, decided to leverage the expertise of its two partners, Markforged & MSC Software, to address these challenges.

We sat down with **Craig KLOCKE, Tripp BURD & Olivier LIETAER**, respective representatives from Danfoss, Markforged and MSC Software to discuss these challenges and the unique solution that will be made available to a larger public in the future.

*Olivier LIETAER from MsC Software*

*Tripp Burd from Markforged*

*Craig Klocke from Danfoss*

**How did Danfoss initiate the partnership between Markforged and MSC Software?**

The Danfoss Group has a solid footprint in the additive manufacturing industry. The company is known for its comprehensive range of products and services in cooling food, air conditioning, heating buildings, variable frequency drives, gas compressors and powering mobile machinery – in other terms, a wide range of industries where they can explore various applications of AM.

Three decades ago, the company started using additive manufacturing. The Danish Group has explored several types of technologies such as SLA, FDM, MJF and composite printers, as well as partnering with Fast Radius to accelerate the adoption of AM.

Moreover, 2017 was a decisive year for the industrial manufacturer that took a giant leap into its digital transformation with the opening of the first of three global 3D printing centres in Nordborg, Denmark, and later on, in North America and Asia.

To date, the Group recorded over 15,000 3D printed parts manufactured around the world. However, despite the current – yet – quiet success of its digital transformation, Danfoss still encounters challenges in its path to optimize production efficiency.

**Optimizing production efficiency with metal AM and appropriate software tools**

Just like several industrial manufacturers, the multinational has relied on AM to accelerate its digital transformation. Indeed, metal AM remains a key factor influencing market demand, and Craig Klocke's team is completely aware of that. The Head of Additive Design and Manufacturing declared:

*"Everyone knows the advantages of AM: its flexibility, its added value for customers. Metal is required in some applications because of its general properties and its ability to meet requirements in terms of strength and stiffness, although polymers and composites have incredible capabilities.*

*Furthermore, another reason why we need metal 3D Printers is that our current materials are metals. Plus, it's quite ironic, but we need to have all capabilities in metal 3D printing to secure the majority of our requests. Indeed, our clients believe we need to have it, so we make sure we have it; otherwise, they would not want to deal with us. Actually, a small percentage of our requests end up in metal 3D printing applications, however, it is increasing!*

*Leveraging metal 3D Printing capabilities can quickly become costly if the user does not have the appropriate tools, not to mention the time invested in production processes and testing, but the team has been impressed by Markforged's affordable technology. Danfoss harnesses both metal and composite printers from Markforged in its facility. The team found that Markforged's composite parts were as strong as aluminum when reinforced with carbon fiber, but they didn't have any experience in polymer and composite parts when they started. The Head of Additive Design and Manufacturing mentioned, "Without this experience, the trial and error cycles are much longer and harder. As we are already a customer for both Markforged and MSC Software, it was easy to connect our three companies, to discuss this issue.* ***The challenge was even bigger for Markforged and MSC Software that needed to develop a solution that would better improve our ability to predict, but also to integrate the detailed fibre path of the printer into the software***", continued **Klocke**.

### The partnership between Markforged & MSC Software

Markforged is one of those manufacturers who firmly believes that a robust additive manufacturing solution could make a major difference in the race against digital transformation. Acknowledged for its metal and carbon fibre 3D printers, the manufacturer has raised a significant amount of new capital this year ($82 million in a Series D funding round, making its total raised $137 million since 2013) to lead innovations.

MSC Software, on the other hand, is part of a big family, whose functioning is crucial to understand to be able to make the most of it. The company develops simulation software technology that enables engineers to improve quality, save time, and reduce costs associated with design and test of manufactured products. Simufact Engineering simulates metal manufacturing processes, while e-Xstream engineering provides the composite and advanced materials modelling platform called DIGIMAT. All companies are part of Hexagon, a global provider of sensor and information technologies in many industries (aerospace, automotive, healthcare and many more).

To address Danfoss' need, Markforged and MSC Software have decided to work together on the validation and optimisation of designs before they're printed on Markforged 3D printers.

It looks very simple saying this way, yet we are talking about a long process that requires a full understanding of the printing process and the integration within numerical simulation workflow such as a Hexagon Additive Manufacturing Solution.

*credit Markforged*

### Building an additive manufacturing solution

The development of Digimat for Additive Manufacturing started a couple of years ago. As the technology and market expand, the company developed a solution dedicated to AM. "*Five years ago, we started discussing with key customers for Digimat Additive Manufacturing. They wanted to benefit from the same numerical chain that we propose for injection moulding, but in this case for AM*", explained **Olivier Lietaer**, Business Development Engineer at e-Xstream Engineering.

MaterialCenter is a material lifecycle management platform developed by e-Xstream Engineering, known for its Digimat product, that aims to track, collect and store all material-related data.

*"Specifically for AM, MaterialCenter enables manufacturers to improve the print quality and ensure the traceability by capturing all AM data. Those data can be linked to the material (the batch number), the machine (the type of 3D Printer used for the production, its serial number), the process settings, the number of parts in the build or the testing*", continued the Business Development Engineer.

In other words, this centralized data management system would enable any user in a few minutes to find relevant data that are fully connected and traceable across the Company.

*"If the user wants to compare different builds, or if there is an issue with the production of a given part, the user can easily go back to the part manufacturing data and discover what was the cause of the problem*", said **Lietaer.**

With the recent acquisition of AMendate, a Germany-based company that specializes in topology optimisation, MSC Software is now able to provide a holistic generative design software solution called Apex Generative Design that automates the design of 3D printable designs. Furthermore, backed by its parent company Hexagon, MSC Software is increasingly able to provide industrial manufacturers end-to-end solutions for AM that incorporate scanners and metrology software to close the design process loop with inspection of the produced part and finishing.

*"With the recent acquisition of AMendate, we are now able to propose topology optimisation capabilities. Whatever the technology used to create the part (metal, polymer or composite), we are well-positioned to help the engineer make the right choices through the use of the data management system, process simulation with Digimat or Simufact and as-printed part performance. The reason why we have various solutions is more historical: we are coming from the materials engineering world and Simufact is coming from the metallic manufacturing world. It makes sense that each of these companies develops dedicated solutions. Moreover, we absolutely have to see things at a higher level: whether the user leverages Digimat or Simufact, they belong to our End-to-End Solution, the most important thing is that we are helping engineers to produce their parts with more efficiency, by lowering their cost, and the amount of materials that is usually used*", declared e-Xstream Engineering's spokesperson.

### The potential of numerical simulation: Material Engineering, Process simulation, and Part Performance

To help Danfoss predict what will happen during the production process with Markforged's 3D printers, MSC Software and Markforged are currently working on three important stages: Material Engineering, Process simulation, and Part Performance.

The process simulation was also a key issue raised by Danfoss. Their engineering team wants to know how the part will exactly be printed – If there will be a risk of debonding for instance – and any other issues that might prevent a failure. As for part performance, Danfoss' engineers need to know how to optimize the part performance for a given amount of material. The Onyx and continuous carbon fibre materials are the two materials whose data were analyzed as part of this partnership.

*credit Danfoss*

MSC Software's strategy is, therefore, to leverage a Digital Twin technology to collect and analyze real product data during operations. As per the words of Lietaer, they develop *"Digital Twin (DT) of materials by creating materials models which can be used for the simulation."* It is also possible to create a DT of the printer. *"With this digital twin, [it will be possible for Danfoss to] first virtually investigate and understand the process, define what is the best workflow, what is the impact of changing any aspect of the design [in their] process, before physically evaluating and testing the part."*

Markforged and MSC Software have only been working for a couple of months. *"We have already made huge efforts and progress in terms of steps we need to achieve to get the right numerical simulation tools. We started with mechanical testing of the materials, both the Onyx and the continuous fibre. The testing campaign includes different configurations, with respect to the toolpath orientation"*, explained e-Xstream, although they could not reveal more about the details of the test.

However, the company affirmed that the materials models have been integrated into the new Digimat version released on October 24th (the first step), allowing advanced users to benefit from the technology.

*"We are now working on an interface that allows users to exchange toolpath data between Markforged's software and Digimat. Taking into account the materials behaviour and the toolpath data are the two key ingredients to predict the parts' structural performance and validate that the composite part can replace metal. Lastly, Markforged printers and processes will be integrated in our standard FEA validation tools that are easy and efficient to use for anyone"*, continued Lietaer.

### Concluding thoughts

Although the MSC numerical simulation discussed presents advantages when it comes to determining the ideal weight or defining the best part layup to reduce printing time and material usage, it will not be a requirement for Markforged's existing or future customers.

*"The partnership with MSC Software is very exciting"* noted Tripp Burd - Manager, Strategic Application Engineering at Markforged who is happy that a request from their mutual customer enabled them to work together. *"Partnering with technologies like the Digimat allows our customers to better understand and increase confidence in the performance of the printed parts. AM is a quite new technology, and there is still much to learn about this area. The application of software simulation for the production of components is*

credit Danfoss

*a great addition to our technology that delivers parts that were not possible to deliver with other technologies."*

*"The materials of Markforged are advanced and quite challenging to model. So, there will be a continuous effort to improve the accuracy of the solution. Over time, we will be able to achieve the same level of accuracy that we have for other traditional techniques. Our goal is to accelerate the adoption of AM by helping the engineers to make the right design choices and increase the aperture of AM applications. We trust that numerical simulation, and such partnerships are key to achieve this"*, concluded **Olivier Lietaer**.

*"My vision and hope are that FEA, AM and composites become automatic activities just like it is today for traditional manufacturing. With traditional FEA, we have eliminated the test cycle, build cycles by using numerical analysis. And I am confident that we will get there very quickly with AM as well. That means, as part of our development, reduced costs and reduce risks. It's green and effective. I am very pleased that Markforged and MSC Software enter a partnership and that we have been able to initiate it. I am really excited to continue the partnership that we have with both companies. I can't predict where we will be in five years for now, but I know it will be a better and more exciting place than the one where we are today"*, said **Klocke**.

# MARKET REPORT
# EUROPEAN TALENT MARKET ANALYSIS

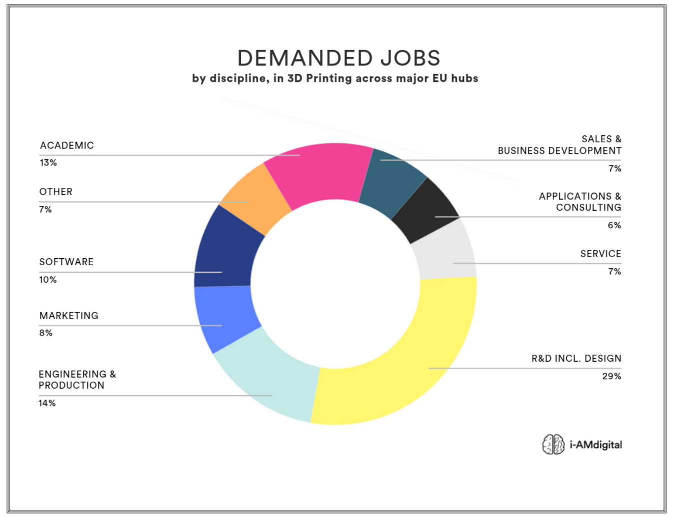
The European 3D printing market is booming, and regional as well as key global players are all competing for market share, adoption, and talented professionals. The latter, the competition for talent, is a widely discussed topic and a pronounced problem amongst expanding additive manufacturing organisations; AM organisations are seeing their growth limited by the shortage of qualified professionals to help them accomplish their business goals. Moreover, the high demand for talent has put a strain on the existing talent market, as the pool of experienced additive manufacturing professionals is limited and is growing at a slower rate than the market demands.

In the attempt to specify and quantify this ongoing war for talent, i-AMdigital has researched the European talent market, basing the conclusions of analyses of the demand and supply of talent.

i-AMdigital

## The Demand for Professionals

Looking at the current available jobs across the major European AM hubs (Germany, France, UK and Spain), reveals the most in-demand type of professionals. The graph below shows the distribution of the different job disciplines.




## Demand for R&D including Design

This graph shows how R&D including Design is a major area of demand for additive manufacturing employers across Europe. This high demand is explained by the increase in adoption of the AM technology as well as the R&D happening in major OEMs. The increased adoption of AM has brought with it the need to establish efficient AM processes, and because of this, companies are demanding talented professionals with Design for AM (DfAM) skills. Moreover, all the 3D printing manufacturers are investing heavily in developing their technology, improving their existing technology platforms or working on future product solutions, thus requiring R&D professionals.

## Demand for Engineering and Production

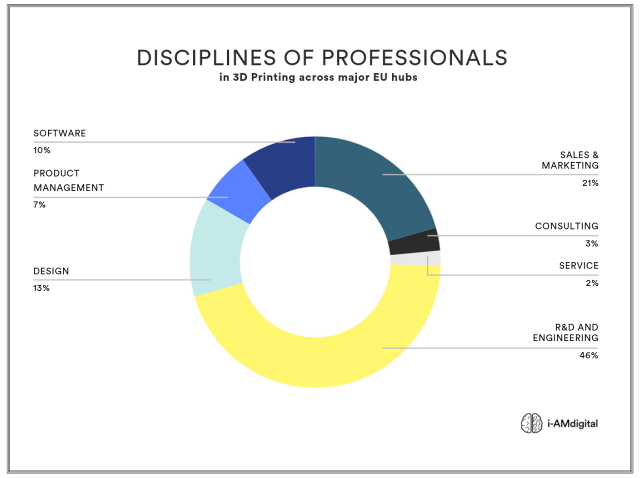
As the additive manufacturing industry is moving increasingly towards serial production and industrial solutions, there is an increased demand for engineering and production professionals who can help companies improve their processes.

## Demand for Academic

Academic related roles take up a significant 13% of all roles in the major European hubs – this number is largely powered by the German market, where academic related roles take up 30% of the jobs. These jobs include Bachelor, Masters and PhD offerings where companies support working students through a university degree. As these students' progress through the programs, they gain invaluable job experience, combined with learning, that will help bridge the skills gap and challenges that AM employers are currently facing.

## The Supply of Professionals

According to data retrieved from LinkedIn, i-AMdigital found the following split of dicsiplines that the professionals are working within (in the major EU AM hubs).




A significant 47% of the AM professionals work within R&D and Engineering roles, which includes Application Engineering roles. This is no surprise as additive manufacturing is heavily reliant on and attracts people with engineering skills and backgrounds. Sales and marketing is the second most dominating discipline amongst AM professionals, making up 21% of the market. Following this discipline is design, taking up 13% of the occupancy of the AM professionals. These three disciplines dominate as they are arguably the most crucial disciplines that most organisations working in or with additive manufacturing employ.

Having knowledge of the talent market and the in-demand skills and roles, is crucial for AM employers to understand what type of professionals they can hire, and where there might be a skills gap. The same analyses are crucial for AM professionals to understand which areas or skills are highly sought-after and thus where they might want to develop skills in order to become attractive to employers.

i-amdigital.com has conducted similar research in other major 3D Printing hubs including USA, France, Germany and Spain.

***Signe Damgaard***

*Alexander Daniels Global*

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# DELETE AFTER READING III
## ON PIONEERS AND DESERTS

Dear adepts,

Things aren't going as well as we hoped. Sometimes it feels like we're selling fertilizers in the desert: theoretically, there's an enormous market potential, but customers aren't anywhere in sight. And if there are customers: even with our fertilizer, nothing 's growing due to the lack of water.

We have meanwhile learned that we should be selling our fertilizers to customers on the edge of the desert: our solution supports the growth of their gardens, and they flourish. Additive Manufacturing technology makes that happen.

But now they, too, are lacking customers and water, and why would they spend money on fertilizers for a garden if they anyway can't sell its fruits?

So, anyhow: sales aren't at an all-time high, to say the least. We're feeling it in the market. And as we mentioned earlier: if the economy is going well, no one has time for innovation. If the economy is going down, nobody has money for innovation. And "innovation" is how our business is labelled – rightfully or not. How are we all going to cope with this situation? We all realize that we are on the verge of a massive expansion, if it weren't for these challenging economic tidings.

Here are a few suggestions that we've been thinking about and perhaps the industry and research community can share their suggestions with 3DAdept, too:

- Let's lobby. One of the issues we had to deal with as a sector, is the limited resources for and investment in Additive Manufacturing education and training. It has led to a myriad of projects, quite often supported by the industry, quite often with limited impact. It's time for governments to integrate AM schooling into curricula at different levels. Some companies in Additive Manufacturing have sufficient impact to successfully advocate for this. Call your MP, e-mail your governors, text your prime minister or president (depending on your president, you might want to consider Twitter). Smaller companies shouldn't remain quiet, though: the more noise, the better.

- Let's not break ranks. It's tempting to lower prices, and the one with the deepest pockets wins the game. That would be a pity, wouldn't it?

- Governments, please stop counterproductive

subsidies. Sure, there are good options to spend that money in AM. But if you partially subsidize a printer for a school (research institute, university...), and you push the school to fund the other part with industrial projects, you are merely organizing unfair competition and making life hard for the entrepreneurs and educational institutes alike.

- Let's not forget the SME's. They're essential in the AM-story. They're the main sales channel, they are often the trusted providers at large companies, introducing our technologies. Don't see pioneers as pawns. It's great that many large enterprises have stepped into the AM-world, and it's even greater that many of those have understood that this challenge is best tackled through collaboration.

- Let's get rid of STL. It's served its purpose, it's been great. But it's time for a more efficient file format. We should push this through as it will enable a much larger uptake of the technology.

Sit down and sweat it out? Let's not go there. Let's all delete this text and get back to work. Passionately.


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# ADDITIVE MANUFACTURING EVENTS IN 2020

**Pick up the latest issue of your trade magazine in all the major events dedicated to additive manufacturing**

Prototyping - February 5-6, 2020 - Kortrijk, Belgium

3D Medical Printing Conference - Feb 04-05, 2020- Perugia, Italy

Advanced 3D Printing- Feb.26-28, 2020 - Tokyo

Military Additive - Feb. 5- 6 Feb. 2020 - Florida, USA

TCT Shanghai - Feb.19-21, 2020 - Shanghai. CHINA

RapidPro 2019 - 4-5 March - Veldhoven, The Netherlands

APS MEETINGS - 10-11 March- Lyon , France

Additive Manufacturing Forum - 11-12 March 2020 Berlin, Germany

GLOBAL INDUSTRIE- 31 March - 03 April 2020 - Lyon, France

3D PRINTING EUROPE- 13 -14 April 2020 - Berlin, Germany

Hannover Messe - April 20-24, 2020- Hannovre, Germany

MECSPE - March 26-28, 2020 - Parma, Italy

Rapid Tech- May 5-7, 2020 -Erfurt, Germany

Spar3DExpo - 21 - 23 May - Anaheim, Los Angeles - USA

Technology Hub - May 2020 - Milan, Italy

Advances in 3D Printing & Modelling - May 2020 Amsterdam, The Netherlands

Advanced Engineering May 2020 - Ghent, Belgium

3D PRINT Exhibition 2020 / 16 - 18 June - Lyon, France

ROSMOULD 2019 -8-10 June - Moscou, Russia

Experience AM - September 22-24, 2020 - Messe Augsburg, Germany

TCT Show 2020 - September 29 – October 1st , Birmingham, UK

Euro PM2019 Congress & Exhibition - 4- 8 October Bilbao, Spain

IN(3D)USTRY 2020 - 27- 29 October- Barcelona, Spain

FORMNEXT 2020 - November - Frankfurt, Germany

Metal Madrid 2020 - November - Madrid, Spain

Metal Additive Manufacturing Conference - Vienna

## 3D ADEPT MEDIA

3D Adept is a Communication Company dedicated to the 3D printing industry. Our Media provide the latest trends and analysis in the 3D printing industry in English & French. 3D Adept Media includes an online media and a bimonthly magazine, 3D Adept Mag. All issues of 3D Adept Mag are available to download free of charge.

Our mission is to help any company develop its services and activities in the 3D printing industry.

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