MANUFACTURING additive

3D ADEPT MAG

3D PRINTING

COSTS AND CONSIDERATIONS FOR INVESTING IN AN ADDITIVE MANUFACTURING SYSTEM

N°2 - Vol 3 / March - April 2020

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Editorial

“The Country Focus”

As 3D ADEPT Media is one of the leading media globally of the industry, it partners with the most important additive manufacturing events in several countries. Given that reality, last year, we received several calls from different country managers of additive manufacturing companies who wanted to have our view on AM in specific markets.

In that regard, I recently had a conversation with the Global Marketing Manager of a company and it has been the straw that broke the camel's back: why not share this view with everyone?

This issue of 3D ADEPT Mag therefore marks the beginning of the “Country Focus” as a new segment of our magazine. The Country Focus aims to provide a content that will help both international (and national) companies to take a leap into a new market. It will provide a state of the art of a country as well as different business approaches applied in a given country that will help decision-makers to explore prospects for developments for their company.

As charity begins at home, we kick off this new segment of our additive manufacturing magazine with Belgium. What are the opportunities for companies in this market? What are its weaknesses and its strengths? The Country Focus will provide key insights into this market.

Delve in, and please, share any feedback that might help us deliver the content that you deserve, with regards to this new segment – and obviously, any other segments.

Kety SINDZE

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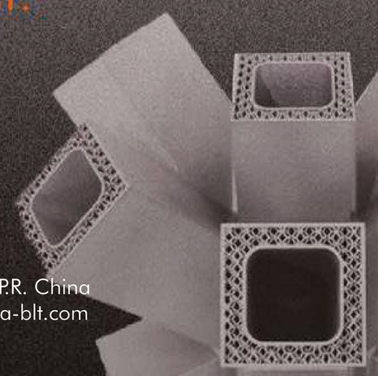

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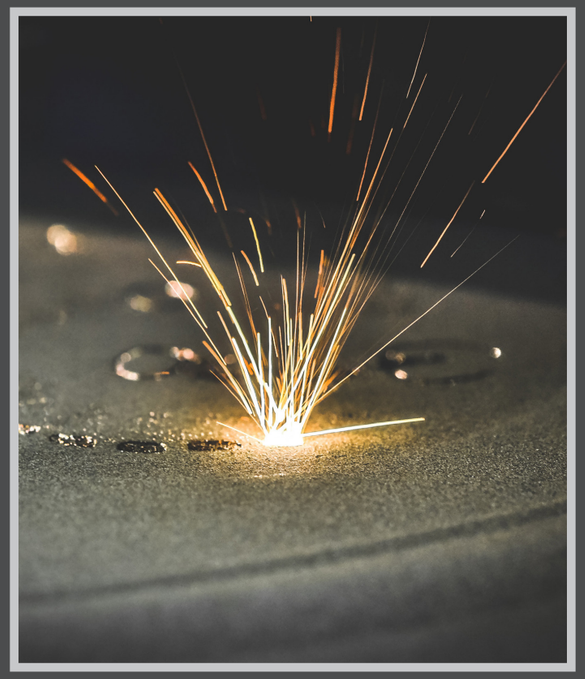

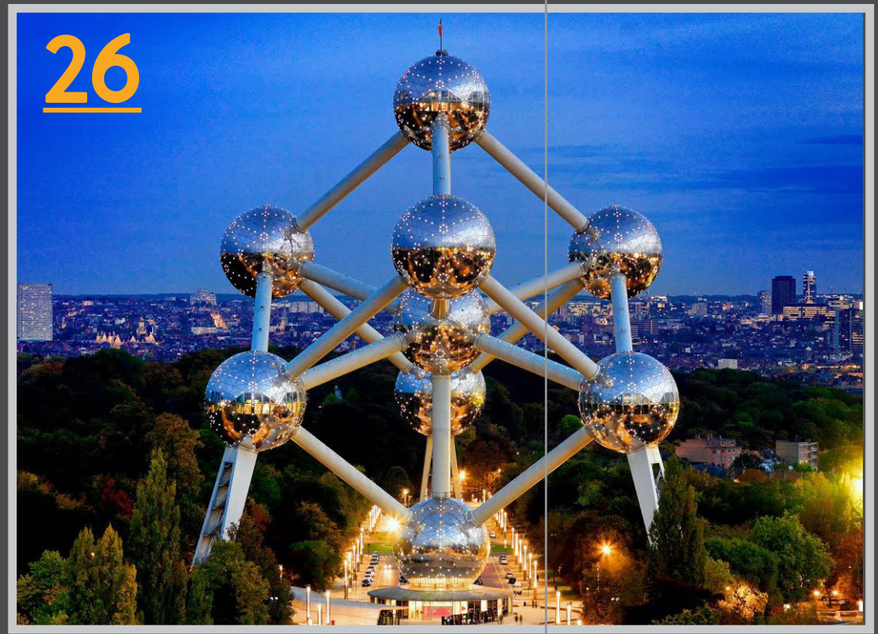

Additive Manufacturing

Costs and Considerations for investing in an additive manufacturing system

Among the additive manufacturing technologies that exist, 3D metal printing and 3D printing of high-performance polymers stand out. Some processes, such as powder-bed fusion, are sufficiently mature to enable mass production. With the development of applications in various industries, manufacturers are increasingly considering this technology as a viable option in their production workflow.

However, investing in a metal AM technology is the first step in a journey towards a true understanding of how technology can transform a business. Several considerations should be taken into account prior to investing in a metal AM segment. They fall into four main key areas: **machine and tooling costs, production environment, design for additive manufacturing, and post-processing.**

To analyze these cost drivers, we invited SLM Solutions to share its expertise in this dossier. Given the complexity of the topic, we will focus on the costs and considerations involved in the acquisition of a metal AM system.

Metal AM systems

Most metal AM systems are based on Powder-Bed Fusion (PBF) and Direct Energy Deposition (DED) technologies.

With such a competitive market, manufacturers do not only have to deliver high-performance systems, they must also provide the necessary support to facilitate the rapid and optimal appropriation of their technologies.

To successfully complete an acquisition project of a metal additive manufacturing system, companies must focus on the applications they would like to achieve and consider the entire AM value chain while taking into account costs related to the system itself and its tooling, workforce, materials and post-processing.

Machinery and tooling costs

Although official price lists of industrial AM systems are not easy to obtain, it should be noted that industrial AM systems range from 100K to €2M (or even more). Prices may depend on the machine performance, quality, build volume and production speed of the parts. The more manufacturers will enter this market, the more metal AM systems will be performant and the more prices will decrease.

Although a metal AM system requires a significant investment, several use cases demonstrate that the tooling costs required for this equipment are much lower than the expenses related to injection molding tooling and traditional material removal manufacturing processes.

Indeed, tooling costs can account for approximately 5% of the total production cost of additive manufacturing. In comparison, tooling for injection molding accounts for over 90% of the total cost of a product made by conventional manufacturing systems. The reason of these savings is simple: **the layer-by-layer printing process makes additive manufacturing** equipment extremely flexible and customizable for a wide range of products, whereas subtractive manufacturing equipment must be designed for each product.

Production environment

Metal AM systems best work when the room temperature and air humidity are maintained at the levels recommended by the 3D printer manufacturer. Air conditioners, humidifiers or dehumidifiers are usually required.

Your facility might undergo modifications to enable the appropriate use of a metal AM system. Proper ventilation is also necessary to reduce the risks associated with finely powdered materials.

New gas lines and electrical changes are often required prior to installation of a metal AM system. If you use or store reactive metal powders, such as aluminum or titanium, sprinkler-based fire extinguishing systems must be disabled because metal powders can dangerously react with water.

If the machine is leveraged in a relatively small enclosed space and if argon gas is used, therefore it might be wise to install sensors that will indicate the level of gases, such as oxygen, in the production environment.

These precautions enable to ensure the use of metal AM systems under optimum security conditions.

Accessories and other equipment to consider

Other equipment and accessories are required to ensure the optimal use of your metal AM system. They include: an industrial compressor, a sandblaster (used to clean the powder on the parts produced), a shot-blasting cabinet that enables to improve the surface finish of the parts.

Industrial vacuum cleaners that can be used with reactive powders are also mandatory as well as a screening equipment for powder recycling.

In addition, safety equipment is required to protect the operator from exposure to metal powders. The price varies from a few hundred dollars for gloves and face masks to several thousand dollars for complete suits with integrated air filtration.

Design

One of the most important points that must be taken into account in an acquisition project of a metal AM system is the need to design for additive manufacturing (DfAM). This is basically the first stage every company goes through to translate a product idea into a physical product. It is therefore crucial for companies to master this stage of product development.

Design for AM, on the other hand, refers to a set of design methods or tools leveraged to optimize performance and/or other key product lifecycle considerations such as manufacturability, reliability and cost in order to take full advantage of additive manufacturing technologies capabilities. In other terms, an optimal use of AM requires the use of DfAM technologies. (The «Software» segment of the November 2019 issue of 3D ADEPT Mag addresses "DfAM & DfM").

DfAM: tools and impact

You know that you are designing for AM when you take into account topology optimization, multi-scale structure design (lattice or cellular structures), multi-material design, mass customization or part consolidation.

The list is not exhaustive since – again – the use of these tools depends on the AM technology that you leverage. That being said, the first step for designers is to keep in mind the capabilities of AM: shape complexity, material complexity, functional complexity and hierarchical complexity.

If you do not have in-house workforce, then you will have to consider attending some training courses that are offered by suppliers of additive

manufacturing systems or dedicated CAD institutes.

Furthermore, software license fees are the next factor on the list. Their price depends on the modules of the software you would like to leverage.

Post-processing

The post-production stage consists of a series of additional manufacturing processes such as heat treatment to achieve the desired properties of a part. The removal of excess powder from internal cavities and complex geometries of printed parts is vital in AM-based productions.

Current removal processes fall into three categories: manual processes, liquid immersion and ultrasonic cleaning. (The April 2019 issue of 3D ADEPT MAG provided a key insight into this topic).

Nowadays, the most widely used process remains the manual process, which sometimes requires the use of compressed air to remove cavities. It consists of physically shaking the parts with brushes, pipe cleaners or a plate to remove the powder. Moreover, this stage of the manufacturing process is subject to strict regulations due to the safety requirements of the machine. As a matter of fact, uncontrolled and airborne metal powders increase the risks associated with this process.

As far as liquid immersion is concerned, a research explains that the success of the powder removal process using this technique often varies from one person to another. The equipment used in this case is usually manufactured in-house and usually uses a fluid flow to sweep up the debris.

"Ultrasonic cleaning uses high-frequency, high-intensity sound waves in a liquid to facilitate or enhance the removal of foreign contaminants from surfaces submerged in an ultrasonically activated liquid."

A disadvantage of this process is that after submerging a part in a liquid, the remaining powder is useless, whereas for economic reasons, manufacturers often tend to reuse the removed powder.

The point of view of a manufacturer of metal AM systems

We have asked **SLM Solutions** to share its point of view as a manufacturer of metal AM systems in this topic.

Dr. Simon Merkt-Schippers, Director Business Development Aviation & Aerospace at SLM Solutions Group AG, answered our questions:

Dr. Simon Merkt-Schippers, Director Business Development Aviation & Aerospace at SLM Solutions Group AG

• According to you, what are the features that a company should take into account to invest into a metal additive manufacturing system?

Companies should focus on their specific applications and consider the entire AM process chain to successfully implement SLM® technology. This includes for example the data preparation and topology optimization, the selection of the appropriate material or the post-processing of the components.

At the beginning of the process, users should rethink the design of their metal part to optimal use the advantages of Additive Manufacturing, like the freedom of design and the easy production of inner structures. That also leads to significant material and cost savings and maximizes the customers' return on investment.

Users should also consider which material is best suited for their application. Working with metal powder requires special safety concepts and a safe closed loop powder handling system to avoid direct contact with metal powder.

Additionally, post-processing of 3D printed parts is necessary. SLM Solutions' experts work with customers at each stage of the process to provide support and knowledge-sharing that elevate use of the technology and ensures that they are successful.

• Apart from production quality, what other characteristics should customers of metal AM systems look for?

Productivity is one of the key characteristics in the industry. SLM Solutions offers multi-laser solutions with patented overlap strategy for high productivity. The SLM®500, for example, has a real build rate of up to 171 cm3/h and ensures high machine-uptime, process stability and reliability through innovative features like a permanent filter module and patented gas flow.

Additional characteristics are the build chamber size and the open architecture of the machines. SLM Solutions offers different machine sizes with a build envelope up to 850 mm height and different machine solutions for a quick material change.

• Are there any additional investments to take into account for an optimal use of metal additive manufacturing systems? (Environment, complementary production system, etc.) If yes. Which one(s)?

To optimally use SLM® machines, not only a suitable factory environment is necessary, but also appropriate metal powders are needed to ensure the production of high quality and dense parts. Furthermore, a range of accessories and consumables like sieving station, powder analyzing equipment and sandblasting is required.

Companies should also consider AM facility costs such as air trackers, oxygen, ventilation and floor space. Additional training is required to ensure the correct condition of the machines.

• Which industries are the most demanding for the metal additive manufacturing systems that you provide? For what purpose do they use your systems (prototyping or mass production)?

All of our industries, aviation and aeronautics, automotive, energy, tooling, medical and dental demand specific requirements.

In terms of material specification, documentation, process control and certification aerospace is the most demanding industry. SLM Solutions offers production systems for serial production for nickel-based aero engine parts, structural parts made from TiAl6V4 and hydraulic parts from Al-alloys. Clients from space industry manufacture for example satellite parts made from Al-alloys or rocket engines made from copper-based alloys. Our machines, parameters, powders and services fulfill the requirements from the most relevant industries. One example are our parameters and powders that meet aerospace material specification and enable our customer a fast adaption and qualification of our technology for their specific applications. More than 600 machines installed at customers from different industries worldwide prove this every day.

Conclusion

Several high-performance metal additive manufacturing systems are now available across the world. Since their acquisition costs are very significant, it is crucial to understand the difference between the different metal AM technologies provided on the market, to know and understand the specifications of each equipment, tools and skills required to achieve the desired return-on-investment for a production workflow.

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- Ti-6Al-4V,Ti-6Al-4V ELI
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Markets & Applications
- Additive Manufacturing (AM)
- Metal powder Injection Molding (MIM)
- Hot Isostatic Pressing (HIP)
- Others

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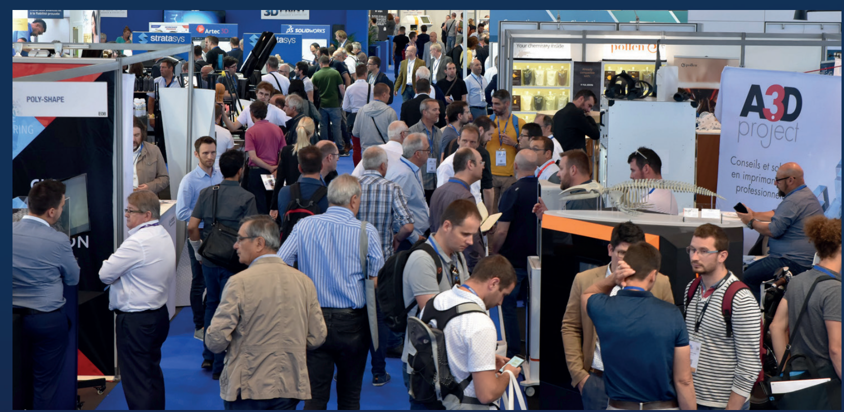

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INSIDE ARCAM EBM CENTER OF EXCELLENCE, A GE ADDITIVE COMPANY

GE Additive run us through Arcam AB's history, working environment & share a look into what's to come

> **GE is incredibly serious about Additive Manufacturing as a business and what it means to be a world-class leader in the industry."**

"GE is incredibly serious about Additive Manufacturing as a business and what it means to be a world-class leader in the industry." From the outset, **Jason Oliver, CEO & Vice-President of GE Additive** quickly set the tone for our tour.

Following such a strong statement, we couldn't help but be more attentive to what we were about to discover, as in the end, one reason that explained our presence at Arcam EBM Center of Excellence on that day, was to appreciate the veracity of this statement for its true worth.

2016, an important milestone for Arcam AB

Founded in 1997, when TIG arc welding of metal powder was a major innovation in the industry, Arcam reached a significant turning point in its history when it was acquired by GE.

At the time, the inventor of electron beam melting machines for metal-based additive manufacturing was based in Mölndal, Sweden. GE's controlling ownership of Arcam stock enabled the multinational conglomerate to influence Arcam and its development.

August 2019: GE Additive announced the opening of its Arcam EBM Center of Excellence in Gothenburg, Sweden. Located at the Mölnlycke Business Park - southeast of Gothenburg – the 16,700 square meter facility triples the floor space of Arcam EBM's previous site in Mölndal.

The previous tenant, a 2D Printing company, completely moved out its last production machines at the end of October 2018.

The facility, therefore, underwent a complete transformation. The new building welcomed the first team members in June 2019 and the production and logistics teams followed over in early December 2019.

"Having a new facility gives you the chance to change and improve efficiency & quality", said Oliver.

In a few words, the new building comprises several areas: the visitor welcoming area, the education centre that includes a dressing room, a convivial space for lunches, breaks, formal and informal meetings, as well as various meeting & conference rooms, the practical training area, the additive test centre, the R&D lab, an open space office environment including private workrooms, meeting rooms, software lab, electronics lab, prototyping room, and a big manufacturing/production area.

Jason Oliver - President & CEO - GE Additive

7,100 m2 of the process areas are currently exploited. The company plans to further improve the working environment of the staff with the creation of other spaces including creative environments.

Throughout the tour, 4 key features stood out as especially noteworthy:

1- Safety

Indeed, safety equipment is required to protect operators from exposure to anything that might dangerously affect their health.

Special precautions have been taken in key areas that we visited, starting from the practical training area. In this area, the company holds theoretical lessons on technology with its customers. However, whenever they have to carry out a specific exercise with the additive manufacturing systems, they have to wear safety equipment.

The production area and the R&D lab are other environments where safety equipment is mandatory. On the walls at the entrance of these zones, one could read the rules of safety and conduct that apply to each space. Furthermore, we identified the safety equipment (shoes, clothes, gloves, etc.) used by operators at specific corners of these zones. Apart from confidentiality reasons, it wasn't possible to enter some rooms because we did not have that required equipment.

As far as technology is concerned, the manufacturing process is subject to strict regulations due to the safety requirements of the machine and the materials.

The hazards of materials, for instance, do not only increase regulatory pressure, but they also lead to a sustainability commitment by manufacturers that must deliver safer AM materials. In that regard, to eliminate the risk of environmental contamination (e.g. groundwater leakage, air pollution) or contamination with more reactive materials, materials must be treated in accordance with strict environmental regulations.

2- Possibilities for cross-cooperation

The quintessence of today's technology advancements leads to new types of cross-cooperation within companies.

At GE Additive Arcam EBM, this cross-cooperation is seen at three levels:

- The working environment
- The type of profile that works for the company
- The cross-border cooperation

The working environment

Open-plan offices prevail at GE Additive Arcam EBM. They are designed to stimulate productivity and collaboration, not to mention that they help with networking.

Interestingly, this new configuration is valid for almost all employees including the management team. This means that not only everyone is on the same level, but employees are easily included in important decisions and projects.

However, the need for quieter spaces and private workrooms is also met for those who perform best when it's quiet or in their own space. For obvious reasons, the staff from the R&D department has their own office.

The type of profile that works for the company

Arcam AB is 23 years old. The company has evolved and still evolves with distinct generations. While this could have led to conflicts, Arcam AB has managed to capitalize on workforce diversity.

"Having all the resources in one technology also passes by young people. As a young entrepreneurial company, technology fascinates us. Our employees can develop and feel they are part of this journey", explained GE Additive Arcam EBM **Karl Lindblom**.

GE Additive Arcam machines at Avio Aero

Annika Ölme *- Vice President of product management at GE Additive Arcam EBM*

« We have been able to transform the way the world sees technology thanks to our multi-faceted team. One thing I realized when I started at Arcam EBM is that there is still a lot be made and our engineers are feeling that. More importantly, to make our vision a reality, each engineer has more than one competence. You will not find an engineer here that only specializes in one core competence »

The cross-border cooperation

In almost every company that strives to build a seat in this industry –, the daily work is increasingly done with people who are across the company borders. Everyday routines might include interactions with customers, suppliers, and even universities across the world.

Taking the example of how the company handles the shipments across the world, **Karl Lindblom** explained that 1/3 of products are shipped towards Europe - mainly in Italy -, 1/3 in Asia and 1/3 in the USA.

3- Growth opportunities

Growth opportunities are not only perceived through the possibilities that employees have within the company, but also in the way the company evolves with its customers.

Let's take the example of a training session for instance: almost every week, a training session is carried out at GE Additive Arcam EBM in Sweden. Such a session does not only enable customers to learn more about Arcam AB's technology, it also enables Arcam EBM's teams to work on specific projects afterwards with their customers or to point out new challenges they have to address.

More importantly, be it at the facility – in the working environment – or within the company itself, there are still new areas that need to be developed. Speaking of the working environment, the company mentioned the need to arrange more creative spaces for the staff.

Regarding technology, automation is the next issue to address – automation in the way AM systems are handled. *"We might expect more output and even turnkey solutions in that regard, in the next couple of years"*, announced **Karl Lindblom**.

Karl Lindblom - General manager - GE Additive Arcam EBM

4- "The wealth factor"

GE has invested $18 million in its Gothenburg-based Centre of Excellence. If everything has been well-thought to enable the whole team to innovate within the company, this new environment is also designed to inspire customers. And that's something that can easily be felt from the entrance.

What it means to be part of GE

Since its acquisition of the Swedish company, GE had announced the site would *"increase machine production capacity and allow for a more collaborative set-up within the company; uniting logistics, research and development, services and operations."* So far these expectations have been met.

"Having an industrial owner is a great chance as they understand us as a company", said **Karl Lindblom,** General Manager GE Additive Arcam EBM. Indeed, an industrial owner will not only understand the needs of an Additive Manufacturing company, as a user, it is also uniquely positioned to push forward the technology. That's why Arcam EBM can deliver a competitive platform and dedicated technology.

More importantly, having an industrial owner also requires that Arcam EBM relies on a strong operating model. After our tour of the company, there is no doubt that GE Additive truly focuses on **Lean Manufacturing** principles.

As stated by the key factors of these principles, GE Additive Arcam EBM is now uniquely positioned to identify the value stream for each product, to make value flow without interruptions, to determine the ROI of customers while enabling them to shift from prototyping to additive manufacturing for serial production, and pursue perfection.

What's next?

From a technology perspective, GE Additive Arcam EBM is ready to meet the needs in existing industries and new industries. In the automotive industry, for instance, the challenges raised by electrification and additive manufacturing are more and more crucial. The GE Additive company is now capturing the business opportunities offered by its customers in that field.

At present, only a limited number of manufacturers specialize in EBM Technology. While others would have been afraid of competition, we have been impressed by a company that welcomes new competitors on this market. If this demonstrates confidence it has in its resources, it will also enable it to keep its leading position in this additive manufacturing segment.

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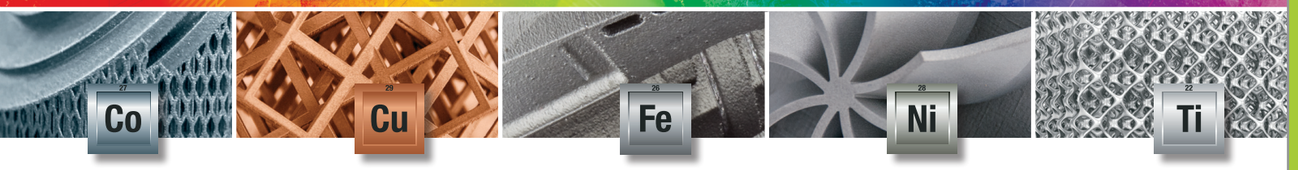

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Ready for the 2020 International Catalogue of Additive Manufacturing Solutions ?

The only catalogue that describes each AM/3D printing technology and post-processing technology while underlining the main players that provide them.

Solukon releases new automated powder removal designed for oversized components

Solukon, a Germany-based company is changing the way we perceive post-processing. Two years after the release of the SFM-AT800S, its smart de-powdering system, the company unveils today a new format for the de-powdering of components produced with LB-PBF technology.

Named **SFM-AT1000**, the system is designed for the powder removal of large components that can reach up to 460 x 460 x 1,000 mm³ and 500 x 280 x 875 mm³.

As a reminder, the manufacturer of AM peripheral systems debuted on the market seven years ago with the SFM-AT800 system. Over time, the company has helped several industrials to understand the vital role of post-processing in a production workflow. Its technology has been acknowledged by key players of the industry including CERN, Siemens, MBFZ toolcraft and Morf3D, to name a few of them, and has positioned the company as a true expert in the field of automated cleaning of additive manufactured metal components.

Key features of the Solukon de-powdering process

Solukon's de-powdering process consists of programmable pivoting of the components including the building platform around two spatial axes. The adjustable frequency enables the desired optimization of the powder flow, not to mention that it enables the cleaning of even the smallest openings and channels, which is of paramount importance for thermal downstream processes.

"Our aim is to give the industry a smart and highly automated and sustainable tool to close the gap between manufacturing and post processing.

The process is fully automated and takes place in a protected and safety-controlled atmosphere, thus avoiding contact with health-endangering fine. Our technology helps to save labor time, ensures the most stringent demands of health and safety are met, and increases significantly the quality process. At the same time, it reclaims the residual powder without contamination and makes it available for further processing and re-use", explains **Andreas Hartmann Co-founder and technical director.**

As far as the SFM-AT1000 is concerned, an inquiry from Starnberg-based AMCM GmbH led to its development. The EOS company provides the industry with various AM services including material development or creation of specific parts for machines, with the goal of meeting the needs that were not met by standardized AM products.

AMCM GmbH has recently introduced the AMCM M4K printers with a component size range of 450 x 450 x 1,000 mm³. Such type of systems opens up new possibilities in demanding industries. They are for instance the ideal candidate for the production of 3D printed rocket engines. In order to enable an optimal production of components of such a size, it was necessary to have a powder-removal system whose size is compatible with the manufactured parts.

Andreas Hartmann Co-founder and technical director

The development of the SFM-AT1000 is based on the SFM-AT800-S system – which delivers a loading volume of 800 x 400 x 550 mm³ and 300 kg component weight.

The main difference between both systems is that the new format has a reinforced slewing system with a novel and particularly compact design.

The new de-powdering system enables industrials to move the higher loads with ease while keeping the chamber volume as small as possible to minimize inert gas consumption. Furthermore, with two smart programmable servo drives, the swivel system makes it easy to move the component not only into any spatial position but also along any imaginable path. This is especially helpful for depowdering complicate internal structures like cooling channels.

Solukon's systems are CE-conform, equipped with UL-conform components and build to meet the requirements of NFPA 79.

From day 1, Solukon made it clear that its goal was to enable companies to have a complete production system by eliminating all risks related to health and safety and increasing efficiency through intelligent automation. Given the crucial role of post-processing, the company is getting there, at a fast pace.

AVIMETAL PM

ISO 9001 ISO 13485:2016

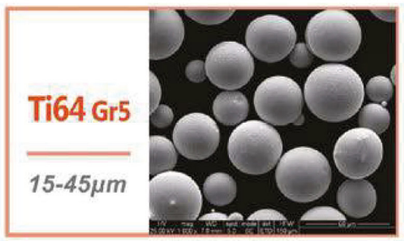
Powder Solutions for Metal AM

Main Powders

Titanium: Ti CP, Ti64 Gr5/Gr23, BT9, BT20, Ti6242, Ti4822, Ti2AlNb, NiTi50
Nickel: IN718, IN625, IN713, Hastelloy X, Hastelloy C276, Waspaloy
Cobalt: CoCrMoW, CoCrMo, CoCrW, HA 188
Stainless Steel: 316L, 17-4PH, 15-5PH
Die Steel: 1.2709(MS1), Corrax, H13, S136
Aluminium: AlSi10Mg, AlSi7Mg
Refractory Metal: W,Mo, Ta, Nb, Cr, Zr

Additional alloys are available upon request

Advanced Atomization System for Metal Powder Production



Powder Characteristics

Controlled chemistry
Spherical shape
High flowability
High apparent density
High purity and applied to aircraft engine

Capacity

Powder 600t/a
Powder Atomization System 30units/a

Particle size range(min/max)

0-20μm
15-45μm
15-53μm
20-63μm
45-106μm
53-150μm

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Pure Copper & Additive Manufacturing

Given the expensive cost of metal additive manufacturing, applications in demanding sectors generally remain the same. They are carried out with materials such as titanium, Inconel, aluminium or steel. Surprisingly, the recent years saw the emergence of Copper 3D Printing/Additive Manufacturing. How? Why now? And for what type of applications? That's what we are going to discuss in this dossier.

This paper aims to present a detailed insight into the use of pure copper in additive manufacturing and how professionals can make the most of it. To explore this topic, we have invited a 3D printer manufacturer, **Farsoon Technologies**, and a material producer, **Elementum 3D**. **Wenyu Guo**, Metal Product Line Manager at Farsoon Technologies will speak on behalf of the company whereas **Jacob Nuechterlein**, President & CEO of Elementum 3D will share the company's expertise in this dossier.

Researches and the latest developments from **Optomec, Fraunhofer Institute for Laser Technology (ILT)** and **The Virtual Foundry** have also been mentioned.

Courtesy: The Virtual Foundry

Pure Copper vs Copper?

Among all metals that exist, copper is one of the rare ones that can be found in nature in a directly usable metallic form. It is described as a soft, malleable, and ductile material that integrates a very high thermal and electrical conductivity.

To test if copper is pure, those who do not have a technical background use what we like to call the "good old grandma recipe": they apply lemon juice over it, then rinse it with water and if it glows like reddish colour, then it is a sign of pure copper.

Otherwise, the density of the metal enables to determine its "purity". The professional just has to weigh the component on electronic weight measurement machine and volume by dimension.

In the manufacturing industry, this metal enables a certain range of industrial applications.

Which manufacturing technique for pure copper?

Interestingly, it should be noted that the use of pure copper in production processes does not start with additive manufacturing.

Prior to be leveraging by additive manufacturing experts, copper can be utilized in various processes: the old traditional process for instance - which is based on roasting, smelting in reverbatory furnaces or electric furnaces for more complex ores. It enables the production of matte and converting for production of blister copper which is further refined to cathode copper.

Furthermore, sometimes the end product and production volume determine the ideal process route to leverage.

For copper tubes for instance, if a company plans a production with high annual output, therefore the production process will include vertical continuous caster, hot forming with extrusion, and subsequent drawing.

For smaller production volumes and thin-walled tubes with small diameters, manufacturers can envision the use of a horizontal continuous caster in the process.

Looking at these explanations, the reasons why one should use a dedicated production process for pure copper makes sense but do they have to be the main criteria measurements?

Using additive manufacturing for pure copper

In additive manufacturing, the need to achieve the technical complexity required for some parts tilts the balance towards this manufacturing process.

When asked the main reasons why pure copper raises interest in manufacturing, **Jacob Nuechterlein**, President & CEO of Elementum 3D replies with a key focus on additive manufacturing:

"Heat exchangers are a primary use in additive manufacturing due to complex designs and internal channeling. Pure copper has one of the highest thermal conductivities of any metal. The extremely high conductivity of over 350 W/mK drives the applications for this material."

In terms of AM technologies, the most-known technique used to process pure copper is metal AM technology, especially Direct Metal Laser Sintering (DMLS).

However, metal AM technology is not the only technique that can process pure copper

It turns out that some material producers have managed to develop a copper-infused filament, that can be processed on an FDM 3D Printer. One interesting example that can illustrate this point is **Filamet™**, a Copper Filament that would contain around 90% metal. With a density of 4.3g/cc, the producer, the **Virtual Foundry**, explained that once fired in a sintering furnace, the printed part becomes 100% metal.

One of the challenges raised by this technique would be the loss of the PLA binder that would lead to a 15-20% shrinkage of the printed component but that's something that can be overcome before the printing process.

Furthermore, as it is not possible to cast two metals at the same time in a foundry, one of the main advantages of such type of filament would be the ability to 3D printing shapes with more than one metal at a time. Lastly, even though it is not pure copper, the printed part obtained with this material achieves the same electrical conductivity as pure copper.

Pure copper processed by a metal additive manufacturing process

As seen with FDM 3D Printing, the manufacturing process raises its share of problems. In metal additive manufacturing, there are still some challenges but at a different level. There are mainly reflectivity and high thermal conductivity.

We will look at the use of pure copper processed by DMLS. As a reminder, DMLS requires the use of a high power-density laser to melt and fuse metallic powders together. The manufacturing process produces stronger and denser parts than investment casted metal parts while enabling complex geometries that are not always possible to achieve with other metal manufacturing methods.

Despite its great advantages, it should be noted that the process requires tools similar to those that are leveraged for a sandblasting system. Also, health safety conditions should be taken into account before leveraging DMLS-based systems.

Courtesy: The Virtual Foundry

Based on their expertise, Farsoon has observed two main challenges regarding the use of pure copper in DMLS:

"Pure copper has a high laser reflectance rate of over 90% with standard Metal Laser Sintering (MLS) systems. It is difficult for the laser to continuously and regularly melt pure copper powder, which leads to issues such as interface failure and internal holes.

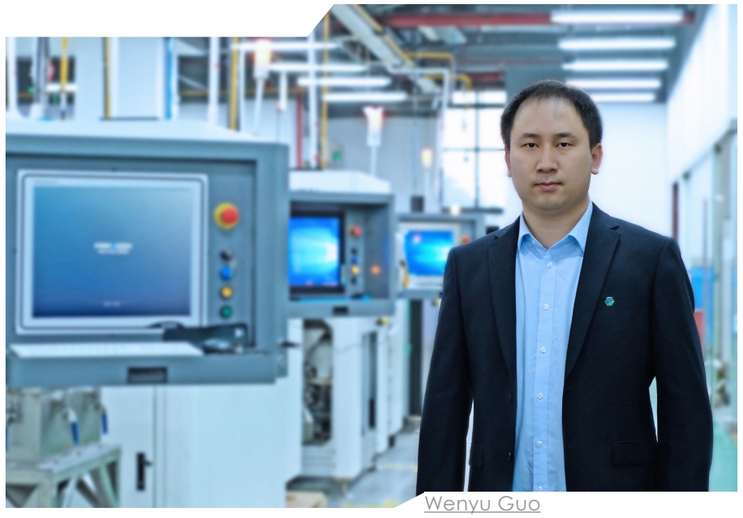
Due to the nature of copper material, pure copper power tends to oxidize in open air, this includes the formation of an oxidized layer of material that prevents further corrosion, but will hinders key properties sought after with pure copper such as electrical conductivity", explained **Wenyu Guo**, Metal Product Line Manager at Farsoon Technologies.

The truth is, pure copper is an interesting choice for end users, given the fact that it is more electrically and thermally conductive than copper alloys. However, due to the obtained surface properties, the material can reflect most of the laser radiation in "traditionally" used wavelengths of 1 micron.

According to a research from the Fraunhofer Institute for Laser Technology (ILT) in Aachen, Germany, the material can only receive a small portion of the laser energy – which is also leveraged for the melting process. Therefore, the reflected radiation can destroy the components of the AM system, not to mention that the receptivity of the material for the infrared light increases as the material transition from a solid to liquid plate. In a nutshell, a complicated situation that leads to unstable remelting process.

Addressing the reflectivity issue

In its open platform system, Farsoon has integrated build parameters, scanning and processing parameters that can reduce this reflectivity issue and achieve the desired performance



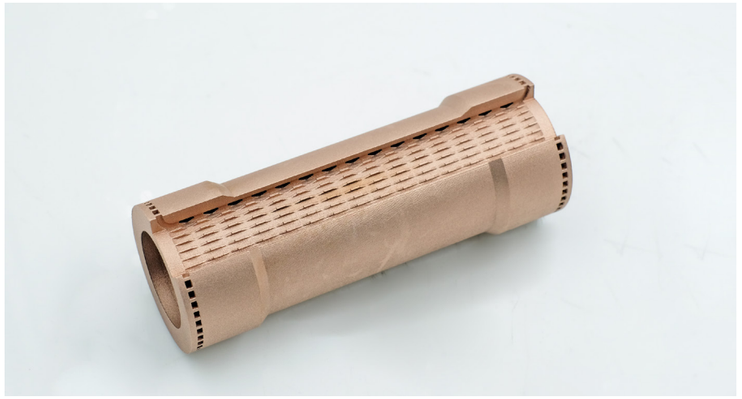
Wenyu Guo

of the application.

The solution has been developed based on a standard fiber laser. According to **Wenyu Guo**, their solution is cost-effective as to process pure copper, the user will not invest in further key optical systems and will be able to expand the capacity of AM applications.

"Copper's thermal stress during printing is less than of other materials. Adjusting parameters of heat treatment process such as temperature, holding time and atmosphere/vacuum conditions can affect the micro structure and give preferred properties including strength and conductivity. The composition of raw material, such as oxygen content and purity of copper, also have a big influence on the conductivity behavior.

During the laser melting process of pure copper, the machine build plate is set to a higher temperature which helps relieving the thermal residual stress. The finished pure copper part will require certain level of processing state according to the application to further releasing the stress and solidify the mechanical/electric performances. Under current development, the build copper parts can achieve a density of over 97%", explains Farsoon's spokesperson.



Heat Exchanger Pure Copper FS271M (Credit: Farsoon)

Another one that addresses this high-reflectance issue is Optomec. The metal AM and electronics 3D printed specialist has developed a pure copper additive manufacturing (AM) process using its LENS directed energy deposition (DED) systems.

'Pure copper is a big challenge for DED systems because of its high reflectance.' said **Tom Cobbs**, product manager for Optomec LENS systems. *'The infrared wavelengths on most standard, laser-based AM systems are not readily absorbed by copper, making it difficult to establish a melt pool as the laser energy is reflected back into the source, causing all kinds of havoc.'*

According to the product manager, the American company's new process protects against this high-reflectance issue. Therefore, the laser can operate at full power on reflective surfaces and includes process parameters to account for thermal conductivity differences and large changes in absorption.

Jacob Nuechterlein, President & CEO of Elementum

What about high thermal conductivity?

Optomec and Farsoon's solutions might be interesting to explore. The only thing is that, they seem to only lay emphasis on one part of the challenge: reflectivity.

"Copper is more difficult to process due to high thermal conductivity of the fused part and high natural reflectivity of copper. Many claims suggest better productivity with green lasers, but that only addresses reflectivity and not the bigger problem of high thermal conductivity", explains the materials producer Elementum 3D.

Indeed, Nuechterlein, strongly believes that reflectivity can be solved by many techniques, but the high thermal conductivity makes this material difficult for most users.

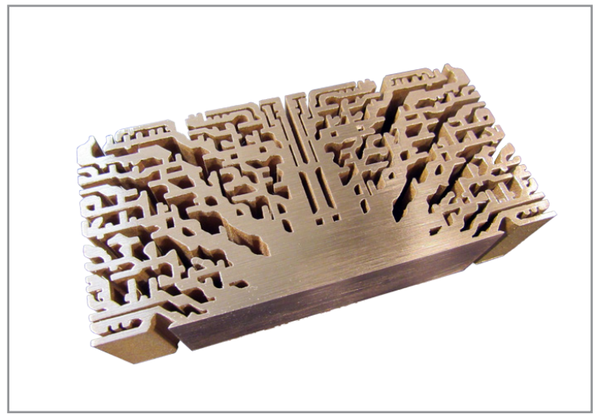
On their side, they have developed a pure copper that is for now, only printable on the AM systems of a manufacturer that develops laser powder bed fusion technology. Moreover, the company declares that their product is designed to be used with off-the-self printers using red or green lasers.

Possible applications with pure copper

Pure copper 3D printed parts are proven to be suitable for heat exchangers in a variety of industrial applications. Induction welders and electronic components are also other examples that can be mentioned.

"The goal of these applications is to achieve production numbers in thousands, or building up second/advanced tier of manufacturing-supply chain", explains **Wenyu Guo**.

Over time, we could envision a broader range of applications. In the area of jewelry design for instance, if the manufacturing process enables a more reproducible process that can fabricate complex geometries, therefore, the use of pure copper in additive manufacturing would enable to produce better products.



Concluding thoughts

There are not many companies that can fabricate pure copper-based products using additive manufacturing. This dossier shows that the manufacturing of pure copper 3D printed parts is still nascent and raises challenges that are not always addressed in their entirety but the first solutions that are undertaken, already enable to achieve viable production. High-volume production is definitely the next point on the list.

Country Focus: Belgium

Atomium

"We can be proud of the Belgian ecosystem. There is a level of companies available that have enough expertise to support companies that want to take a leap into this market, and this is of paramount importance",

Camille MOMMER.

November 2019. "L'Echo", a Belgian financial newspaper, announced that Belgian companies that specialize in technology and biotechnology have raised 491 million euros in the first half of the year. A record compared to previous statistics; not to mention that this time, technology companies have the biggest slice of the cake. While the article highlighted the growth of software companies, we couldn't help but question the importance of additive manufacturing in the Belgian landscape.

This question had already been put on the table in the past – during one or two interviews with a few market players – but always briefly as if in the end, we were not allowed to talk about it. Feedback collected so far gave a certain trend but not the reality. Indeed, an additive manufacturing company might often have a biased view of a single topic, a view that in the end, reflects the reality of its vision, and how it approaches a given market. So, how is the Belgian additive manufacturing (AM) market doing? What are the opportunities for national and international companies? What are the areas for improvement? We have discussed these points with **AGORIA**.

AGORIA

Agoria is the national federation of Belgian technology companies. With more than 1900 Belgian companies in its portfolio, the organization is the largest trade association that contributes to the development of policies at regional, federal and European levels while improving the social and economic climate for companies in the technology industry. An organization that finally requires a certain structure.

Camille Mommer

Camille MOMMER, Business Group Leader Manufacturing, Manufacturing & Innovation Services is Agoria's spokesperson regarding additive manufacturing-related activities. She explains from the outset how the organization is structured and how the subject of «additive manufacturing» came to the table:

"We divide our companies into 2 main sectors: a sector dedicated to manufacturing (manufacturing of machines or parts) and a sector dedicated to digital companies. On May 2018, we realized that we kept receiving questions regarding AM from our members. A quick analysis showed us that AM is the link that enables professionals to move from the digital to the physical product.

My predecessor surveyed to see if there was any interest in the subject. Made in collaboration with PwC, the results of the survey were released last year. They revealed that the market was eager to know more about AM but did not know how and where to start.

So, we gathered around 20 companies that were interested in the project. They constitute a business unit and share knowledge through projects or information sessions."

The 4E approach

On a scale of 1 to 10, what is the level of adoption of 3D printing/additive manufacturing by players on the Belgian market?

"My scientific side is struggling to give you an accurate answer," says Camille. Bio-engineer by training, her background shows that she built up experience in research companies, before being involved in organizations that support companies at the financial level and in their development.

"The hurdles that we identified at the time - two years ago - are still valid", she continues. *"There are still many companies that are not yet aware of the technology potential, and those that decide to take a leap into this market are still confused as they do not know how to evaluate the potential for their business or do not have the qualified workforce."*

That's why the PwC report on the state of the art of AM in Belgium recommends the 4E approach:

« The main challenge to improving processes or creating new products using AM is to identify the first pertinent use case. All companies experience the same virtuous circle: identifying the right AM opportunities raises your position in the learning curve and creates internal know-how. This internal know-how helps (partially) resolve the technology and cost challenges as it helps you identify the next right opportunities. The first step is to start somewhere », explains the report. So, the 4Es approach includes these stages: **Explore, Estimate, Evaluate, Experiment.**

On its side, Agoria has started to put this approach into practice for its members. They launched in November 2019 the "3D Print Challenge" which aims to raise the interest of students and young professionals, in additive manufacturing. By designing and manufacturing a product for the consumer goods industry or an industrial application, participants will be able to "think additively".

While professionals might be able to (further) explore the potential of technology, Camille explains that Agoria's goal is also to encourage students to consider a job in the field as an option.

Collaborating with Belgian companies

The million-dollar question. To work with Belgian companies, you need to understand the context of the country; a country that integrates three main regions - Flanders, Wallonia and Brussels - each of them operating independently.

"3D printing has not evolved in the same way in Wallonia and Flanders. The company profiles are also different. Flanders-based companies mainly specialize in additive manufacturing," explains Agoria's Business Group Leader in Manufacturing.

Associations such as **FLAM3D** whose goal is to promote and support companies in the AM industry have quickly jumped on the bandwagon in the Flemish region and - in the Netherlands.

"Wallonia, on the other hand, hosts industrial companies, major aerospace groups and big names such as Sirris, which has become a key player on the market. Such a company rarely calls for the services of a contract manufacturer or 3D printing services provider. Given the scope of its activities, it usually prefers to invest in technology (to purchase AM systems and/or software licenses)," continues the bioengineer.

What about Brussels? "Beauty" is no longer the land of industrial companies, as per the words of Camille. The city hosts a few companies that have decided to specialize in certain sectors. Spentys, for instance, a start-up that delivers 3D printed prostheses stands out from the crowd.

"In general, medical technology well evolves in the country. Another company that proves it is Materialise. When it comes to healthcare, it's easy to make people understand the value of technology, even if the cost is still thought-provoking", the spokeswoman said.

A profile that should raise the interest of the industry

It seems that companies that may have a strong interest in integrating AM technologies are usually industrial SMEs. According to Camille, such type of companies has to think twice before investing in AM. Indeed, even though they see a potential to leverage, they do not have the same "financial freedom" than Big Fortune have.

Therefore, for these companies, the return on investment must be certain, quantified and accurate.

Are there factors that are slowing down the growth of AM?

First, it should be noted that there are common factors that slow down the development of the market and there are factors that are specific to each market.

The financial aspect is a topic that almost every company, whatever its market is, has to address. As far as Belgium is concerned, our scientist believes that if the business case is clear, the investment will follow.

In Belgium, companies strongly pay attention to market opportunities, and to date, one opportunity that needs to be seized is to help companies understand the value-added of AM for their business.

At the beginning of 2020, the Belgian federation estimated at 20,000 the number of jobs that the technology sector will create by 2024. *"It is, therefore, necessary to intensify activation"*, as CEO Marc Lambotte said, and in this regard, AM companies have a responsibility to share.

In universities and colleges, despite the expertise of lecturers and research units, Camille Mommer notes, that only design colleges have started to integrate AM into their curricula. At the university level, efforts still need to be made.

In a nutshell...?

For a country that mainly exports to Germany, France and the Netherlands, Belgium augurs well with regards to additive manufacturing. As everywhere, there are areas for improvement, and the good news is that professionals know exactly where action needs to be taken.

However, it should be noted that among the giants that are making the market's history, some of them are making the pride of the country.

"We can be proud of the Belgian ecosystem. There is a level of companies available that have enough expertise to support companies that want to take a leap into this market, and this is of paramount importance", concludes **Camille MOMMER**.

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INTERVIEW

BigRep : WHERE IS THE COMPANY HEADED?

Martin Back, Managing Director, takes the floor a few months after ex-ceo Beyer's resignation & loss of Founder **René Gurka**

3D ADEPT MEDIA Martin Back

One company that first comes to everyone's mind when we say "FDM Large Format 3D Printing" is BigRep. The German manufacturer of 3D printers left the industry with a mix of feelings and (un) answered questions at the end of 2019. In less than three months, the company saw the resignation of former CEO Stephan Beyer and lost one of its founders, René Gurka. Yet, at Formnext 2019, the German specialist of large-format 3D printing appeared stronger than ever, and showcased unrivalled applications in the high-tech and automotive industries. What's next now? The new Managing Director, Martin Back shared in this interview how the company envisions the future.

Who is Martin Back, the new Managing Director of BigRep?

Back first came into our radar in June 2019 when the ex-CEO announced that he stepped back from his role. At the time, the responsibilities were shared between Back, Daniel Büning, the CIO, Frank Marangell, CBO, and Stefan Kaufmann, the company's Head of R&D.

Back actually joined BigRep in fall 2018 as Chief Operating Officer, taking in charge the day-to-day operations, global business strategies, new partnerships and the creation of company policies in Berlin, Boston and Singapore.

With 25 years of industry experience in management roles, the economist by training knows the traditional manufacturing industry by heart. With such an outsider view to the AM industry and with innovation as a guiding principle, Back combines the strength BigRep needs to move forward.

What's next then?

As a reminder, Beyer left the company with a workforce of 90 employees. He managed to build up new business opportunities into Boston and Singapore, and partner with the likes of Bosch Rexroth, Etihad Airways and Ford. Such partnerships showed the company's capabilities to unlock the potential of AM for various applications and confirmed its industrial focus along the value chain. A focus that has become a mission, that the Managing Director is also willing to fulfill:

"These are my goals, too. For me, it's really exciting to be at the center of a game-changing industry such as 3D printing, driving the technology forward and making it a key tool for industrial manufacturing while transforming design, production and supply chains.

Ultimately, we dream of a world where every industrial user is enabled to create their own product locally on a large-format BigRep solution", said Back.

In practice, what does it mean?

Achieving this dream means looking at issues that are slowing down the adoption of AM. In the additive manufacturing sector, there are different technologies but each of them addresses specific issues.

When it comes to "Large Format Printing", one of them is Internet of Things (IoT). Surprisingly, for IoT, 3D Printing has become the new way to make and prototype objects. The only thing is that where some saw disruption and opportunity, others saw "security" as an increasing issue.

"In general, in highly interdependent processes, it's impossible to introduce to shop floor applications a stand-alone solution. Therefore, the IoT capabilities of AM systems is a decisive factor of success. And we have come a long way in the past year. We have been one of the pioneers in this area by introducing our BigRep PRO printer in late 2018, which was the first large-format 3D printer offering full IoT connectivity, including G5, thanks to our partnership with Bosch Rexroth, developing the Factory of the Future. We will continue on that path", explains Back.

Moving forward, and speaking about the industry in general, Back only sees development opportunities, if providers are ready to address the demands. For the spokesperson, the current requirements lead to a new and interdependent relationship of integrated applications, optimized processes and specialized materials.

BigRep's current developments with regards to this new form of interdependent relationship of integrated applications, optimized processes and specialized materials

Following the release of the BigRep PRO, the manufacturer of large-format technology has worked on new materials that could fit its entire portfolio, from the **STUDIO and STUDIO G2 to the ONE and the PRO.**

First, as a reminder, the 3D printer PRO developed in collaboration with Bosch Rexroth, can create functional prototypes, as well as composite tooling, end-use parts and small-number serial production using high-performance materials.

At the time, further information had not been given on the materials that were compatible with the technology. BigRep's Martin Back today gives a few examples of compatible materials while highlighting their Metering Extruder Technology (MXT®):

"[Our] Metering Extruder Technology (MXT®) – featured on the BigRep PRO – is a new method of thermoplastic extrusion, combining speed with precision, and perfectly suited for a filament such as BigRep's PA6/66. This is one of the high-performance materials (PLX, PET-CF and BVOH) we have recently introduced. Some of these [materials have been developed] in partnership with BASF.

As we work closely together with our customers, we know what manufacturers really want – they require materials that are highly efficient, can serve multiple purposes or are application-specific. An increasing selection of high-performance, engineering-grade filaments is the result. [Moreover] efficient processes and sustainability are becoming increasingly important as well, so filament recycling is another « must have », creating closed-loop supply chains – an opportunity that isn't readily accessible in metal AM applications."

Meeting the growing demand for flexible AM printing services

To meet the individual needs of the consumer good industry, companies increasingly leverage additive manufacturing that enables flexible manufacturing and production of tailor-made products. Over time, companies in demanding industries have faced the same needs: all parts do not require mass production. To meet this demand, BigRep has opened the BigRep 3D PARTLAB. The U.S-based service aims to support both the company's partners and customers who are over capacity. Furthermore, as per the words of the Managing Director, this "360-degrees digital solutions approach" will also deliver customized ordering services for 3D printed parts including prototypes, tooling, molds as well as end-use parts.

"The industry is urgently looking for solutions that will reduce costs, lead times and create new ways to innovate while reducing our carbon footprint. I truly believe that 3D printing is one of the key technologies of the 21st century", concludes Back. And mastering this industry's challenges requires a full understanding of the entire industrial value chain. As far as BigRep is concerned, the company is not only "in good health" but also well equipped to meet these requirements.

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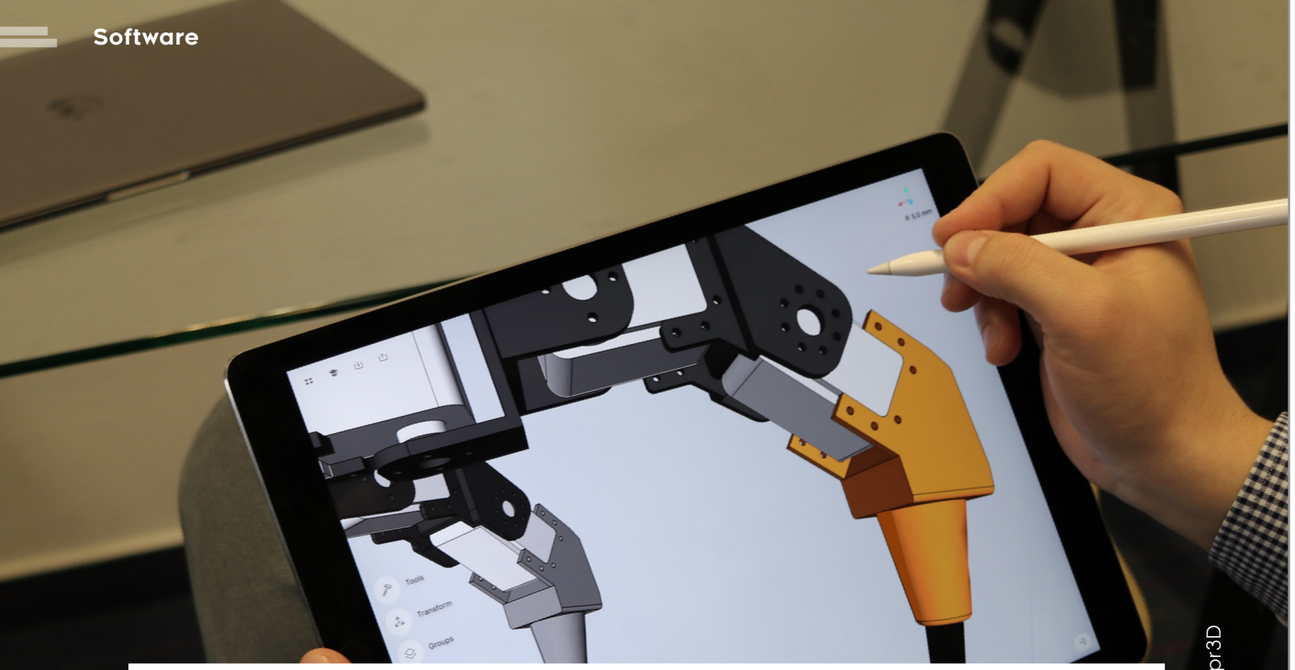


Credit: Shapr3D

CAD ON MOBILE DEVICES: THEIR IMPACT IN MANUFACTURING

Do you remember that feeling you have, when you go out and realize you forgot your phone? Some are willing to go back home/wherever they were, to take their phone. We certainly agree with one thing: mobile devices have changed the way we consume products/information/work, in one word, live. The world has evolved so fast that, almost everything we do today requires the use of mobile devices. Interestingly they have also changed the way, we use technology and design products. What's that impact in manufacturing?

In the past decade, technological improvements have spurred tremendous changes in the way design professionals work. CAD (Computer-aided Design) technologies that were considered an option ten years ago, are now essential today. However, when it comes to manufacturing, it is no secret that modelling a product using a CAD software is the primary step to go through before the manufacturing itself. Do we achieve the same design by working on a mobile device? Is the quality the same?

First, it should be noted that the most common mobile devices that are used nowadays include: smartphones, tablets, laptop computers, smart watches, e-readers and handheld gaming consoles. In the design world, the primary device used for modelling is the laptop. The following lines will discuss the impact in manufacturing when using tablets as part of this exercise.

According to Sophia Georgiou, Chief Designer and Founder of Morphi, 3D modeling and design software, designing in 3D on tablets is more frequent than phone screens.

Together with her team, Georgiou has been making Morphi for four years. The software is used on iPad and by people of all skill levels in more than 125 countries.

What are therefore the advantages of "CAD on mobile devices"?

The first advantage people are looking at, while leveraging CAD on mobile devices is accessibility. This advantage is more obvious for those who leverage full-cloud CAD. Indeed, they can access their work, anytime and anywhere, even on devices they don't own.

At the design level itself, the founder of Morphi talks about the possibility to not be limited by creativity.

"Users can design from anywhere inspiration strikes them, like on the subway or while outside, whereas laptops are often not as portable", she explains. Morphi advocates 3D modelling as an empowering tool. That's why, the company has developed other 2D and 3D drawing tools to improve the user experience through a touch interface.

To illustrate the capabilities of such type of modeling tools, the Chief Designer mentions the 3D printed Named Dress designed by Sylvia Heisel, a wearables specialist. Unveiled last year, the Names Dress is a compostable couture gown that is on display at the Ferragamo Museum in Italy. Heisel utilized Morphi on iPad to write the names of over 300 women in STEAM fields on the touchscreen. She extruded them in 3D in the app and fusing them together to form one continuous piece.

Sophia Georgiou brings out interesting arguments but so far, only gives examples that might give the impression that CAD on mobiles is only useful for artists.

In a more industrial environment, engineers *"need to resolve design issues on the GO & stay on schedule". Imagine an engineer working in a SME. With a myriad of responsibilities, his position might require him to run between different sites (at suppliers and/or customers location) to investigate manufacturing issues.*

Those responsibilities are not limited to reviewing drawings and rotating 3D models. They require active modifications to designs. According to Siemens, "there are other prudent reasons to take immediate action. Given the fact that the amount of time they have at the desk is shrinking, engineers can't afford to let desk-based to-do lists build up while working remotely. Such a backup in design tasks can unnecessarily delay the overall product development process. They need to resolve them immediately, as much as possible, while they are on the go."

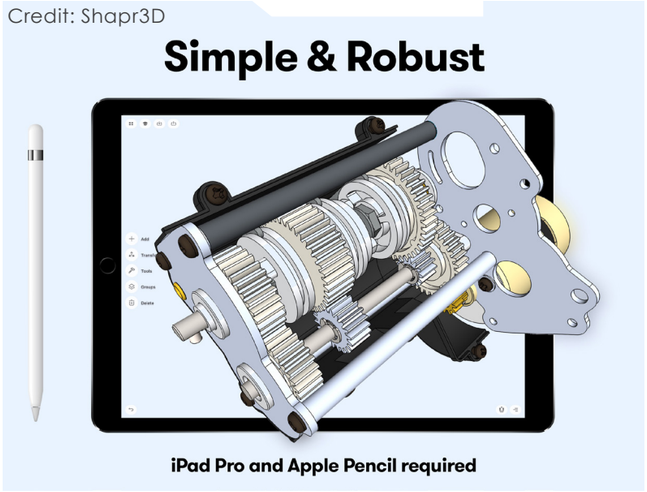
Moreover, as the technology increases, the evolution of CAD on mobile devices has led to the use of AR capabilities that enable a better visualization of 3D models (without 3D printing or manufacturing) and a more immersive experience for users. Georgiou totally agrees with this argument as she relates:

"We started developing our Augmented Reality viewer for Morphi on iPad back in 2016 and released our first feature in 2017 which was a very simple way to open your camera and place your 3D model in your environment. After the release of Apple's ARKit in various stages, we have been able to create more immersive ways for our users to directly 3D model and visualize their designs in a variety of ways in our iPad apps. We also have a new iPhone app, Morphi AR for iPhone, that will be released next week [from February 17th] where you can import 3D models created in any CAD software and place and edit them in AR using an iPhone."

Courtesy: Morphi

This list of benefits shows that CAD on mobile devices enables a certain flexibility in the way a designer works but there is still a big gap with their use on desktop workstations.

Credit: Shapr3D



The other considerations to take into account

To run smoothly, CAD applications need processing power, memory, hard disk space and high graphics performance.

An engineer will quickly depict that 3D models of complex parts (with hundreds of pars) require several computer resources in each of the aforementioned categories. In this case, the ability to produce properly and fast will depend on the performance of the platform leveraged.

Be it on a desktop workstation or a tablet, without the proper compute resources, simple tasks such as loading, modifying or manipulating can lead to time lags or delays.

Given their high capacity and upgradeability for processing power, and other resources, desktop workstations are usually – and will certainly remain – the best match for the largest 3D models designed in CAD software.

Over time, tablets have managed to meet these performance expectations, and to professionals that complain about smaller physical graphics screen, they are given the possibility to stream the display to a larger screen. Is it enough?

"Processors, screen size. device connectivity, getting used to touch screen as opposed to a mouse and a lack of accuracy in 3D modeling tools are sometimes discussed as limitations to 3D modeling on mobile devices. However, we think the biggest limitation is probably mindset. Mobile devices are powerful computers and impactful designs are created on them every day. Users have even told us that designing in 3D on mobile devices enhances their creativity because they associate it with experimentation and can see things in new and interesting ways", said Morphi's founder speaking of limitation of CAD on mobile devices.

Speaking of these differences with desktop workstations, a research carried out by Siemens explains that finger gestures are another consideration to take into account, and even an advantage for productivity for those who leverage CAD on tablets:

"Finger gestures on a touch sensitive screen and other peripheral-less interactions on tablets present an opportunity for productivity improvements. Instead of plugging in a physical keyboard and mouse, which may not be possible in some use cases, users can enter text or interact with models on the touch screen directly. Besides supporting the software with the right computation resources, some software providers have retooled the interface and interaction of their CAD application to leverage multi-touch interfaces".

Productivity vs Freedom: is there a balance?

This article does not question the use of CAD on mobile devices. People do really do CAD on mobile devices. That's an undeniable fact. But who are they? The way CAD is used on mobile devices is not the same from one user to another.

While the use of these tools will strongly influence productivity for enterprises, for individuals, the question will turn around the ability to materialise a 3D model "the way they want".

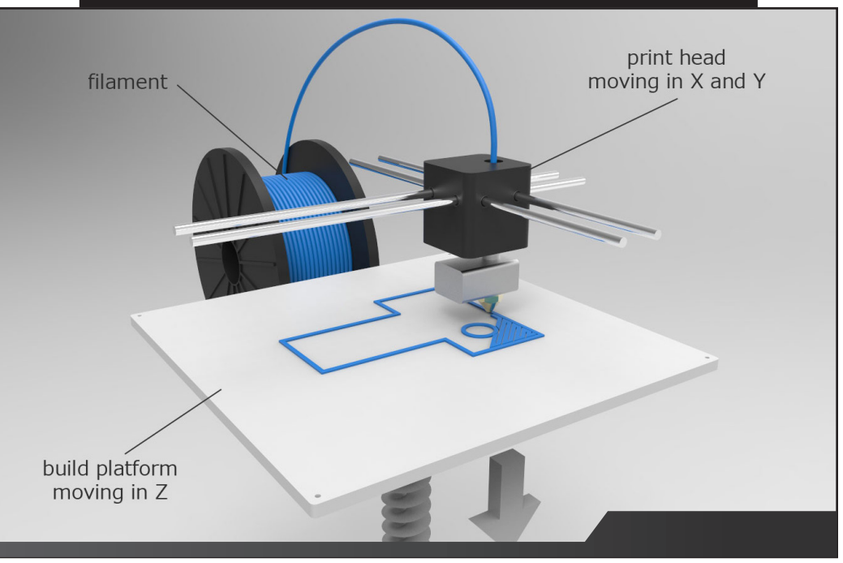
For Morphi's Sophia Georgiou, *"people should use whichever tools they feel will help them better visualize, evolve and share their ideas. It is not about choosing to model in 3D on a desktop versus mobile device - they can do both seamlessly now. It's more about people being empowered to create the things that matter to them and their communities."*

This reflection might not always be the same for organizations. Productivity is the key to release a product on time, be it evolutionary or revolutionary. Finding from Siemens PLM Study (2015) show that on average only 55% of development projects are released on time, a very low score for those who aim to be the "first" on a given market.

Despite the complexity due to the design of some complex parts, CAD on mobile devices aims to resolve issues earlier and to stay on schedule, therefore to improve this percentage. The question is: what is the true reality for these companies?

IS FDM 3D PRINTING (STILL) A GOOD CHOICE FOR PROFESSIONALS?

"Professional users adopting 3D printing are not looking for a new hobby, they're looking for solutions to their most pressing business problems", **Kevin Han.**



Fused Fabrication Filament (FFF), Fused Deposition Modeling (FDM), Fused Laser Manufacturing…the polymer material additive manufacturing technology has been given various names by manufacturers that wanted to distinguish themselves among others of the same range. Even though the most well-known name remains FDM, all of these technologies all share the same principle: the creation of a model using layer-by-layer deposition of a feedstock plastic filament material extruded through a nozzle.

Over time, we saw the emergence of various companies delivering polymer additive manufacturing technology. Scott and Lisa Crump may have invented this technology that has made and still makes the success of Stratasys but the growing segmentation of the market led to the development of the technology across several industries. How has this technology really evolved – at the technical and manufacturing levels, and more importantly, are there any other improvements we can expect? That's the million-dollar question we will discuss in this segment – with contributions from **AON3D** and **INTAMSYS**, FDM 3D Printer manufacturers. **Kevin Han, CEO of AON3D** and **Charles Han, CEO of INTAMSYS** are the spokespersons that will share their expertise in this paper.

The FDM 3D Printing technology is much more than the simple layer-by-layer deposition of a feedstock plastic filament material. Manufacturers that decided to enter this market segment have improved this technology and raised the interest of segments that one did not expect from the beginning. What could be these improvements? This article aims to highlight these advancements in order to help professionals to decide if it's (still) a good choice for them.

First, FDM 3D Printing can be leveraged via a Desktop FDM 3D Printer or in an Industrial 3D Printing system. As a reminder, several features might enable to distinguish a professional 3D printer from an industrial 3D printer. They include part accuracy, (high-performance) materials, typical layer thickness, build envelope as well as production capabilities (temperature, etc.) to name a few of them.

Apart from "materials", all these features can be linked to the machine capabilities.

Charles Han, CEO of INTAMSYS

Improvements made with regards to machine capabilities

It was easier to attribute the use of Desktop 3D Printers to makers and the use of industrial 3D printers to big companies. Actually, SMEs and big companies can leverage both types of 3D Printers in their R&D or production department.

The choice for one or the other might vary from one company to another but their interest in both systems has given another reason to manufacturers to improve the capabilities of their machines.

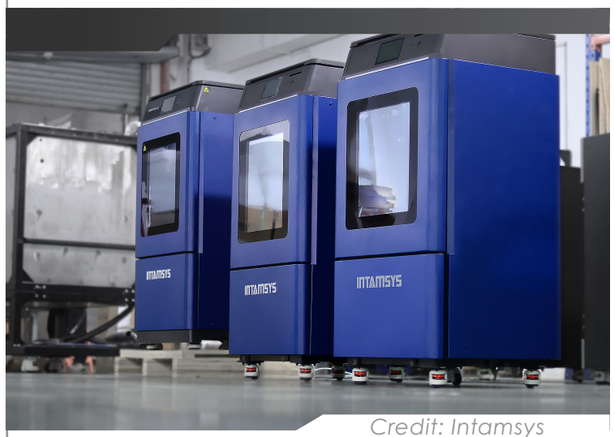
It goes without saying that, the vision of a company and the way it evolves within the market, its objectives, are factors that will always have an influence on the advancements of the technology a company develops.

Going back to the roots, one major feature that enabled a drastic improvement of the field was the improvement of the **filament feeding mechanism and its extruder.**

After sending your file to the 3D Printer – and obviously after loading the filament in the 3D Printer, the print head starts to move but nothing comes out. Beginners sometimes easily think that their 3D printer is broken – especially those who have 3D printers with reels hidden. It turns out that sometimes, the issue might be linked to the nozzle or the filament mechanism.

Several causes might explain this issue: the nozzle is just too close to the bed and you have to adjust it, the user has forgotten a tiny piece of filament in the nozzle when replacing spools in which case he just needs to clean the nozzle with a needle; it might be linked to the parameters that have not well been set up or simply to the feeding filament mechanism and the extruder that have not been well fabricated.

Printing speed and **printing precision** are the next features on the list. They remain key features that can be improved. **INTAMSYS CEO, Charles Han** explains that *"printing speed helps to increase the production volume and thus to reduce cost, while printing precision improvement enables 3D printing applications to expand to more demanding industrial applications."*



Credit: Intamsys

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For AON3D's CEO & Founder **Kevin Han** on the other hand, improvements can go beyond printing speed and printing precision:

"Whatever it takes to improve repeatability, reliability, and process control - and this will be accomplished through a combination of both hardware and software. There's a lot of hubbub right now over factors such as size and speed, but sophisticated users understand that without the foundation of repeatability, reliability, and control in place, the only thing a bigger or faster solution will do is create more scrap faster.

We're approaching this challenge from multiple angles. Preventing variability from occurring in the first place with improved hardware, monitoring the build process with both hardware and software, and enabling continuous improvement to prevent future errors from repeating with data and software."

Credit - AON3D

Improvements with regards to the mechanical properties of the 3D printed part

The more the market advances, the more industrials set the bar high for industrial FDM 3D Printing. The challenge is even more significant as there are now several 3D Printing technologies that claim to achieve the "impossible". Therefore, the new standards imply that the improvements are no longer just about machine capabilities, they also concern the mechanical properties of the parts.

That's why, «3D printer manufacturers - material producers» partnerships have become so crucial to help the industry move forward that they raise one question: how is this expectation going to change the market?

"It's not just having access to high-performance polymers; it's having access to the right high-performance polymers for the job at hand. If you break it down, every manufactured component can be described as a combination of three fundamental elements: Design + Material + Process. By limiting the availability of materials, the types of components that can be built are also limited", comments Kevin Han.

Indeed, industrial FDM 3D Printing requires engineered-grade plastics (ABS, polycarbonate (PC) or Ultem), which are usually fabricated with certain additives that alter their properties so that they fit certain industrial requirements such as high impact strength, thermal stability, chemical resistance and biocompatibility. That's why, some 3D Printed products manufactured with engineered-grade materials deliver material properties that are similar to injection-moulded parts – and are "ready-to-be used".

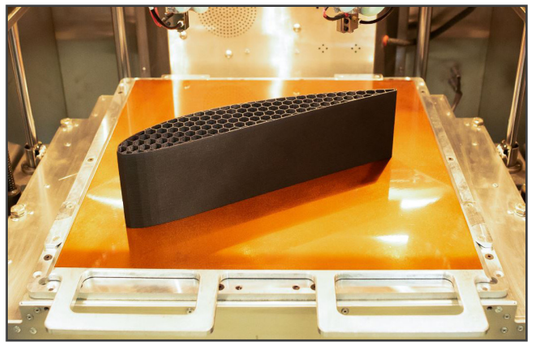
In other terms, it becomes "a must" to look at the combination of several characteristics that play a key role in the printing process and not just machine capabilities.

At the design level, *"users bring the design element to the table, and it's the OEM's job to deliver on the rest. Users want the freedom to choose the right material for the job, at competitive prices, and without the need to undertake additional R&D. From Day 1 we have been committed to the idea of enabling an open material ecosystem through a combination of partnerships with material suppliers, a business model that doesn't financially punish customers as they scale, and a technical service offering that eliminates the challenges associated with developing the process parameters for new materials"*, continues AON3D's CEO.

If Kevin Han confirms the importance of partnerships with material suppliers, Charles Han leys emphasis on a point that also seems crucial: **the importance to improve the overall engineering mindset.** After all, we can have the perfect combination behind a partnership, but in the end, the engineers working behind will constitute the performance indicator of the company's scalability.

"The overall engineering mindset can also be improved, as well as the engineering concepts that can be optimized to adapt to the characteristics of 3D printing. Based on our experience, we also found out that many raw data files generated by traditional engineering methods can deliver unexpected results if printed directly in FDM without any changes made. However, the printing performance can be improved by changing the internal structures of 3D models without any compromise on the quality delivered", **Charles Han** explains.

Nevertheless, improving the mechanical properties of a part is, as per the words of Kevin Han, both the biggest opportunity and challenge the industry faces today. If software constitutes another "Holy Grail" of the manufacturing process – too long to address


Courtesy: AON3D

in this paper -, to maximize part performance, the specialist advises to control the process.

"A block of marble and hammer & chisel in the hands of a master sculptor would yield quite a different result than in the hands of someone with less experience. Similarly, the same material and printer with optimized process parameters will yield a better part than with non-optimized process parameters", completes the CEO of AON3D.

Current expectations regarding Industrial FDM 3D Printing

We have seen in the above lines that printing issues and part performance have enabled developments in FDM technology. Today's market shows that this technology has the required capabilities to help manufacturers achieve several applications.

However, moving forward, the question of scaling up a business using FDM 3D Printing remains important. Fulfilling this dream of FDM additive manufacturing for production might require the use of a fleet of 3D printers or 3D printing farms.

"Depending on the application and the workload, some companies may want to use 3D printers for functional prototyping, in this case, a few 3D printers are enough. Some companies may have a lot of tooling applications in their factory; thus, they may need a larger number of 3D printers. There are also a lot of companies willing to use 3D printing for low volume production. These companies might want to build proper 3D printing factories with a significant number of 3D printers", **Charles Han** concludes.

The approach to additive manufacturing and 3D printer construction is changing and decades after its creation, FDM is today, legitimately positioned to open up new markets for extrusion-based systems.

EVENTS

Key Takeaways from the 3D Dental Printing Session held by Jakajima

On February 4th & 5th, Jakajima organized the 8th edition of its 3D Medical Printing Conference. The first day offered parallel sessions on 3D Dental Printing and 3D Bioprinting whereas the second day focused on 3D printing pharmaceuticals and 3D medtech printing. Participants to the conference on Day 2 also benefited from an extensive plenary session focused on 3D printing in (Non) Academic Hospitals.

The conference gathered around 150 participants during the two days. Pieter Hermans from Jakajima and Kety SINDZE from 3D ADEPT Media ensured the moderation of the sessions on the first day of the conference, whereas on the second day, he was accompanied by Alessandro Ricci from 3Dific in this exercise.

First, it is interesting to note that unlike other conferences/ events organized in the country, this conference was not a Dutch-dedicated event. It actually gathered both international and national speakers as well as a diverse audience that belongs both to the medical and 3D Printing industries.

However, in order to report on the key takeaways that professionals learned from this conference, the following lines will be focused on the main highlights of the 3D Dental Printing Session.

7 professionals with various profiles shared their experiences and the main experiences that are currently shaping the 3D Dental Printing world.

Application of 3D printed patient specific implant in oral and maxillofacial surgery

Based on real patient-cases, Dr. Yi Sun, Head of 3D surgical planning Lab – Oral and maxillofacial surgery at UZ Leuven (in Belgium), demonstrated that the use of 3D Printing for implants in oral and maxillofacial surgery is already a reality in Belgium.

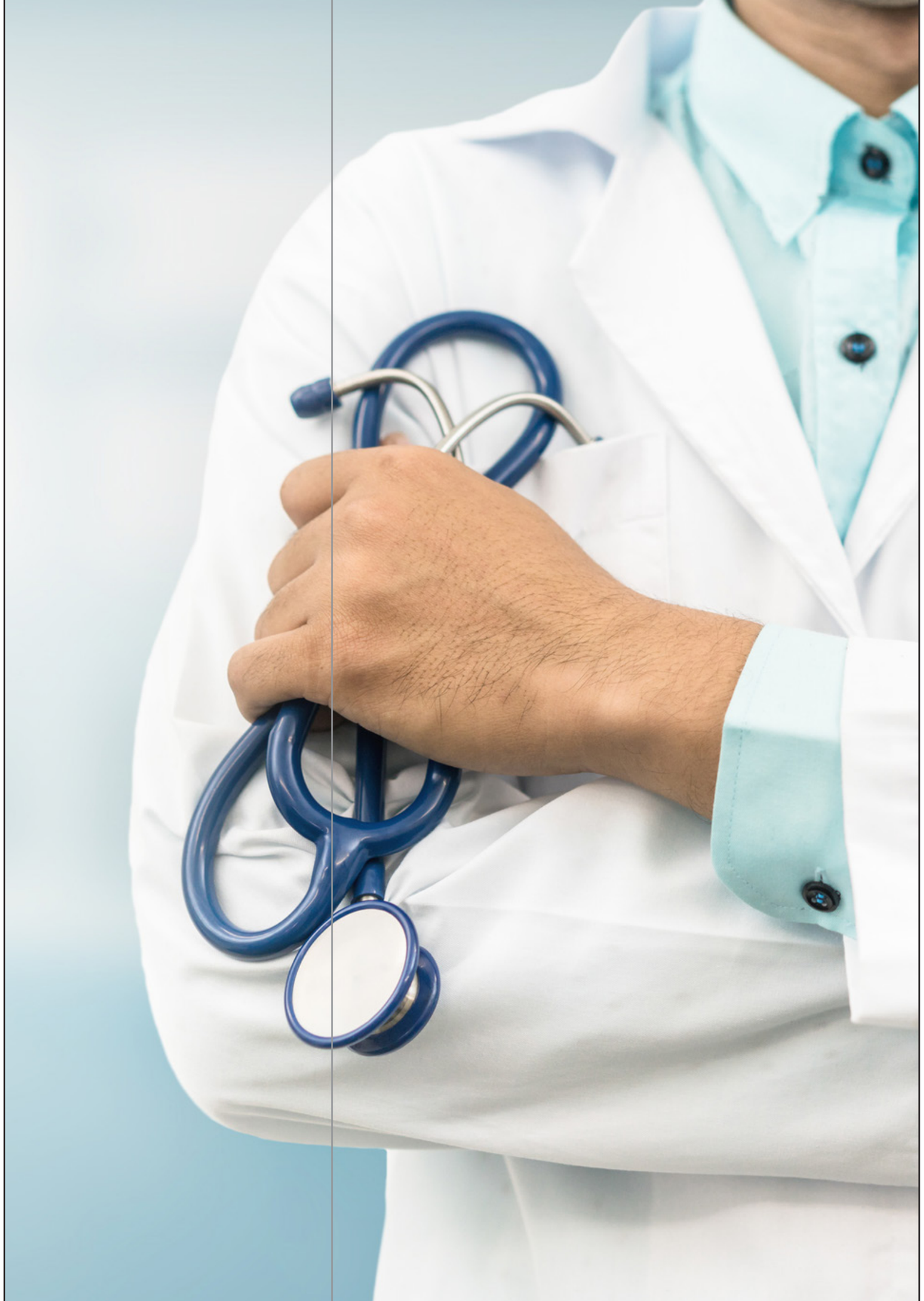
The presentation of the specialist depicted how the fields of dentistry and maxillofacial surgery can take advantage of 3D printing in specific areas such as orthognathic surgery, maxillofacial reconstruction and more.

In addition to the clinical applications of 3D Printed titanium implants, the audience learned more about the design workflow and the clinical and engineering challenges faced by the team.

If each case is unique, Dr. Sun reported that most of the times, given the scope of some projects, most of the researches are carried out on animals to use 3D printed scaffold for bone regeneration.

However, despite the endless possibilities 3D Printing can offer, one big challenge for both the patients and the professional team remain the financial insurance, quality control regarding to medical regulations and how to improve the efficiency of the workflow to design patient specific implant. Thus, we should bring together clinicians, engineers and scientists in all aspects to deliver better healthcare service to our patients.

Edited by 3D ADEPT MEDIA



Orthodontics in the digital world: a 3D approach combining LMF and DLP technology

Emanuele Paoletto & Luca Carnevali discussed the impact of 3D technologies in orthodontics.

Emanuele Paoletto is Orthomodul Lab Manager and Luca Carnevali is Dental / Medical Sales Area Manager at Sisma. Their presentation highlighted the MAPA Protocol, a protocol developed by Maino B. Giuliano, Mura Paola and Emanuele Paoletto, that enables a patient to be treated in one single surgery while leveraging 3D technologies.

While taking the example of a skeletal anchorage, Paoletto explained that throughout the 3D Workflow, a scanning of the patient enables the medical team to plan the surgical strategy and the mini-screw placement. The surgical guides and the metal framework are thereafter designed before being printed on Sisma's 3D Printing technology (a DLP printer for models and guides, or an LMF Printer for metal frameworks). Only after the printing process, the medical team can proceed with the surgery.

Emanuele Paoletto and his team have been acknowledged by various scientific publications around the world. Today, they are ready to collaborate with medical teams that would be interested in leveraging this protocol.

Multi-material 3D Inkjet for 3D Dental Printing

René van der Meer, CTO & co-founder of Lake3D believes in the potential of Multi-material 3D Inkjet for dental applications.

Most multi-material 3D Printers available on the market are utilized for rapid prototyping applications. According to van der Meer, Lake3D aims to change the game by developing a device that will improve key aspects of the production such as time and ready-to-use printed parts.

Furthermore, the project requires the contribution of four companies: NextDent, a company of 3D Systems that specializes in dental applications, Brightlands Materials Center for its expertise in 3D printing materials; TNO, a research organization that brings its experience in SLA technology and Océ. Known for its 2D Printing expertise, Océ will bring the print heads required for the Inkjet technology of the 3D printer.

Together with his team, van der Meer proved the potential of Multi Material 3D inkjet for dental during an EFRO/STIMULUS funded project. His presentation does not only show they are up to something meaningful, it also shows that their solution might deliver solutions that might go beyond the medical field.

Turning your upperjaw into a mouthguard

Entering the 3D printing market by the sports industry is certainly the best way to avoid the regulatory constraints that the technology raised in the medical industry.

This was the gamble taken by Arno Hermans, founder of 3D Mouthguard, a company that improves the way athletes enjoy their favorite sport by using cutting edge technology to produce sports apparel.

According to a report from QYResearch Group, in 2018, the global mouthguard market size was **174.9 M USD**, and it will be **278.6 M USD** in 2025, with a CAGR of 6.9% between 2018 and 2025. Given the key role that a mouthguard plays in various sport disciplines such as hockey and rugby, Hermans seizes the opportunity to develop a custom-made product for each athlete that will protect their mouth during a competition.

According to Hermans, the current mouthguards available on the market are not always comfortable, hygienic, safety and sustainable. Together with his team, they develop a custom-made product for each athlete that does not require weeks of production but just a day after they receive an order. In addition to the multiple stages of manufacturing that have been removed, another key advantage the engineer highlighted is the fact that it is no longer necessary to stop by the dentist.

To test the capabilities of this product, the company carried out several tests including a saliva study and an impact study.

As part of the saliva study, artificial saliva (regular saliva and saliva combined with sport drinks) has been put for 1176 hours in a row in the material used for the product. Hermans explained that the results show there is no effect on the mechanical conditions of the material Arnitel® ID2045, a 3D Printing material developed by **DSM Additive Manufacturing**.

As far as bacteria is concerned, "bacteria stick to the material so it's very important to clean the mouthguard on a regular basis", explained Hermans. The same observation is made with traditional mouthguards.

"Another result is that the 3D printed mouthguard is dishwasher proof. This means the mouthguard can handle high temperatures without losing the strength of the mouthguard. However, you have to be careful with certain food such as tomatoes in the dishwasher, that have an effect on the color of the mouthguard", said the founder.

The impact study on the other hand aims to research the best way to measure realistic impact. In this specific case, the swing happens to be the best method for the company. Based on different speeds and bounce, the team has been able to measure energy consumption and power distribution. This study is still in progress as the next stage consists in analyzing the reaction of materials.

Lastly, the mouthguard is produced using FDM 3D Printing technology. The company is currently exploring other manufacturing technologies to diversify its production workflow.

3D Mouthguard aims to develop a safe product for sports people. The company still has a long road ahead but one thing is certain, they are on the right path.

Numerical Simulation in Additive Manufacturing

Mathieu Perennou, Director of Sales & Business Development EMEA region at Simufact Engineering GmbH introduced the main use of AM simulation in various applications. If most examples shown demonstrated a key potential of numerical simulation for automotive and aerospace applications, the principles of simulation remain the same for medical applications: identifying in advance manufacturing issues and establish countermeasures before the printing process.

Nevertheless, the requirements for leveraging AM Simulation in medical applications remain quite different compared to industrial applications. Although the differences were not presented, it should be noted that simulation can be used at different stages of the AM value chain. Such simulation stages are sometimes very data-intensive and high-performance computing (HPC) facilities may be required. Therefore, the use of simulation requires in-depth expertise in computational mechanics to adapt accordingly.

Nanofiber technologies for improving the biological compatibility of metal implants

In the end, **Marek Pokorny** a Senior researcher from Contipro, a producer of hyaluronic acid for the pharmaceutical and cosmetic industries reported on how nanofiber technologies can improve the biological compatibility of metal implants.

He raised attention on the importance of surface treatment of 3D implants intended for pharmacy. *"A surface layer of a metal implant affects its acceptance by the human body"*, explained Pokorny. In the presentation of the whole process, he showed how the surface treatment can improve metal implant properties such as its biocompatibility, enhance a cell adhesion and proliferation, reduce inflammatory responses, and facilitate integration between the implant and surrounding tissues.

Such improvement is due to the continuous adjustment of the spinning process to achieve uniformity and quality of the surface layer; more importantly to achieve desired geometries and mechanical measurements while evaluating the results of preclinical tests.

"From the results achieved, the use of such coatings is very promising for practical use in orthopedic surgeries", concluded Pokorny.

Gabi Janssen, Business Development Manager Healthcare at DSM Additive Manufacturing shared the company's view on regulations in medical applications. However, she was not able to make a comment on time as part of the publication of this article.

NEWS ROUND-UP :

What happened in the industry during the last two months?

What news you shouldn't have missed since the release of the January/February issue of 3D ADEPT Mag? In this monthly edition of 3D ADEPT Mag's News Round Up, you can find what marked the industry in several areas: Business, 3D Printers, Materials and Adoption of Additive Manufacturing.

Business

The news have not always been good…First, the trade fair business in Asia – especially in China – has been interrupted because of the Coronavirus. For most companies, this period is still the Holiday's season but they will remain close until further notice from the government.

In Europe, the European Powder Metallurgy Association aka EPMA has announced it will close its UK-based office from April 30th.

The announcement follows an exciting 2019 that marked the celebration of its 30th anniversary. In a press release, Lionel Aboussouan, Executive Director and Ralf Carlström, EPMA President explain that this decision aims to improve "improve efficiency through facilitating collaboration and communication as well as enabling a better platform for cost optimization."

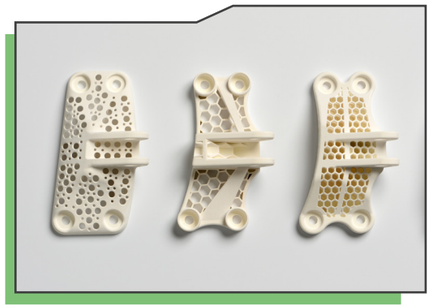
From May 1st, the 2 EPMA offices will be gathered into a common office in France – located at the address 1 Avenue du General de Gaulle – F-60500 Chantilly – France. Remaining employees will work from home. The French office will stand as the main administrative office whereas the EPMA Headquarter will still be based in Brussels.

The press release also explains that the UK-based staff was given the possibility to relocate to France but does not confirm any decision of relocation. However, in the meantime, a part of the team will work until the EuroPM2020 congress to ensure continuity.

EPMA offices in UK

Acquisitions, funding & expansion

BellandTechnology AG, a producer of high-performance thermoplastics, has totally acquired industrial 3D printer manufacturer Xioneer Systems GmbH. The merging of both companies will enable them to expand on the international AM market. So far, both companies mainly operate on their respective market.



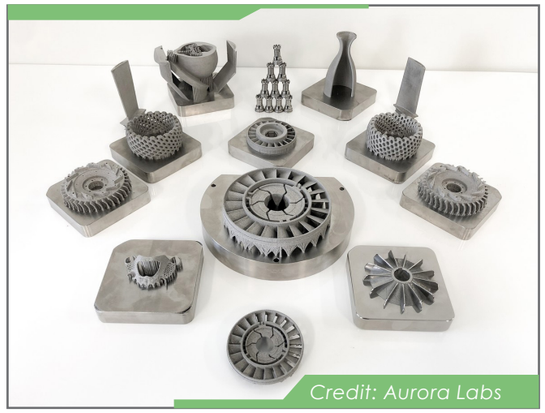
Meanwhile, WAAM3D Ltd., a spin-out company from Cranfield University, has received funding from Accuron Technologies Ltd., an international engineering and technology group based in Singapore. If the amount has not been revealed, the CEO of WAAM3D Ltd, Dr Filomeno Martina announced that they will bring in as many as 20 staff in the coming year to scale up operations.

As far as expansion is concerned, Formatec has added Ceramic 3D Printing services to its offering. The Netherlands-based company manufactures CIM, MIM and 3D printed products, products that have a great fit in the chemical, medical and aesthetical industries.

Partnerships

What would be business in this industry without its partnerships?

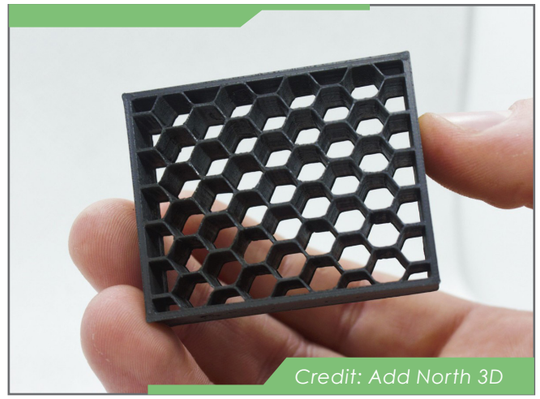
Aurora Labs Limited aka A3D has entered into a Framework Agreement with DNV GL. As part of the agreement, the global quality assurance and risk management company will provide certification services for A3D's unique 3D metal printers. If the conditions of this agreement have not been revealed, let's note that several companies joined this mission to advance the use of additive manufacturing in the Oil, Gas and Maritime industries and Aurora Labs is certainly not the last one we will hear on the topic.



Credit: Aurora Labs

Let's go to Sweden: Additive Composite Uppsala AB & Add North 3D developed together a polymer composite for radiation shielding applications.

The new polymer composite consists of boron carbide within a co-polyamide matrix. Available in the form of a 3D printing filament, the experts explain that the boron carbide enables effective absorption of neutrons such as those produced at major research facilities, in the nuclear industry or other places that use radiation sources.



Credit: Add North 3D

The use of the material in a 3D printing process that can produce complex shapes makes it the ideal candidate to deliver effective shielding of stray radiation and to provide collimated beams.

Named Addbor N25, the new material can therefore replace other materials such as cadmium metal, which is now forbidden on the market, due to its toxicity.

Speaking of materials, Adaptive3D gives the MSOE Rapid Prototyping Consortium priority access to its ETR 90 3D printing material. On the other hand, Sindoh Co., Ltd. will utilize RIZE portfolio of composite materials, RIZIUM.

Lastly, Honeywell Aerospace has added VELO3D to its partners portfolio. The aerospace specialist is qualifying the Sapphire™ Metal 3D Printer of the US-based manufacturer. To make it a reliable manufacturing platform for the production of aircraft parts, the qualification process will first focus on a nickel-based super alloy named INCONEL.

Materials

Speaking of material producers that unveil new materials, we covered Evonik, Markforged and researchers from the University of Toronto.

Available in powder form, Evonik releases a bioresorbable polymer for the 3D printing of implantable medical devices on Selective Laser Sintering (SLS) equipment.

Named RESOMER® PrintPowder, the biomaterials specialist claims to be the first to commercialize such type of material. It has been developed within the Nutrition & Care segment of Evonik, a segment that serves more than 1,000 pharmaceutical, nutraceutical and medical device customers worldwide.

The free-flowing powder would integrate tight specifications and an optimized particle size distribution for efficient processability. It will also allow the supply of ISO 13485-certified formulations for development and commercial use.

Credit: Evonik

Markforged joined the limited number of players that provide pure copper additive manufacturing. The manufacturer of metal 3D Printers introduces pure copper to its Metal X Systems.

Credit: Markforged

"Copper powers our world. It's everywhere. It builds our cars, enables phones, and keeps electrical equipment running," said Greg Mark, Markforged CEO and Founder. "Copper has traditionally been an expensive and challenging material to machine and incompatible for 3D printing in a pure form with other techniques. Now, we've made it easier and cheaper to produce. Markforged 3D printed Copper will be a game-changer for the automotive and electronics industries, and it will open the door to innovation across many more."

While some turn waste cooking oil into soap, others turn it into 3D Printing resin. Researchers at the University of Toronto have found a second life of cooking oil. They have been able to transform cooking oil - from the deep fryers of a local McDonald's – into a high-resolution, biodegradable 3D printing resin.

The team used a straightforward one-step chemical process in the lab, using about one litre of used cooking oil to make 420 millilitres of resin. The resin was then used to print a plastic butterfly that showed features down to 100 micrometres and was structurally and thermally stable, meaning it wouldn't crumble or melt above room temperature. This story is definitely on to watch.

Credit: University of Toronto

3D Printers

In this segment, **Stratasys** and **VSHAPER** announced new releases.

Designed for brilliant design and productivity, Stratasys new 3D Printer, J826™, combines part realism and productivity and will be commercialized to half the price of other J8-series.

Stratasys - J826™

VSHAPER on its side is ready to unveil its 5AX FDM-based 3D printing system. Throughout the development of this system, the engineers of the company focused on the anisotropic nature of printouts, an issue that users still encounter in industrial applications.

Credit: Evonik

Adoption of additive manufacturing

In terms of adoption of AM, two players in the aerospace and automotive industries stand out from the crowd: Pratt & Whitney and Ford.

In order to increase the performance of locking nuts, car manufacturer Ford leverages 3D printing for their production.

Ford Europe collaborated with with EOS to create locking nuts with contours based on the driver's voice.

Like an iris scan or a fingerprint, a person's voice can be used as a unique biometric identification. Engineers record the driver's voice for a minimum of one second, saying something like "I drive a Ford Mustang", and use software to convert that singular soundwave into a physical, printable pattern. This pattern is then turned into a circle and used as the design for the locking nut's indentation and key.

With the geometry in place, the nut and key are designed as one piece, then 3D-printed using acid and corrosion resistant stainless steel. When finished, the nut and key are separated, with a small amount of grinding required to make them ready for use.

The design also includes second level security features that prevent the nut from being cloned or copied. The unevenly spaced ribs inside the nut and indentations that widen the deeper they go prevent a thief from making a wax imprint of the pattern, as the wax breaks when it is pulled from the nut.

Credit: Ford

If not using the driver's voice to create the contours, the nuts could feature designs specific to a vehicle, such as with the Mustang logo, or use the driver's initials. The design could also take inspiration from a driver's interest, for example, by using the outline of a famous racetrack.

Manufactured with ST Engineering, Pratt & Whitney announces production grade additive manufacturing of an aero-engine MRO component. This production marks a milestone for Pratt & Whitney in the ***maintenance, repair and overhaul (MRO)*** of commercial engines.

The 3D-printed aero-engine component was produced in metal 3D Printing via a controlled process operationalized by Pratt & Whitney. This 3D printed part will first be used in a fuel system component on one of Pratt & Whitney's engine models.

Both teams from Pratt & Whitney and ST Engineering worked hard to ensure the processes leveraged in this case are certified to Pratt & Whitney's requirements for aftermarket applications.

Credit: Pratt & Whitney

ADDITIVE MANUFACTURING EVENTS IN 2020

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JEC World (TBC*) - March 03-05th - FRANCE
RapidPro - March 04-05th - The Netherlands
APS Meeting - March 10-11th - FRANCE
Metav 2020 - March 10-13th - GERMANY
4th Additive Manufacturing Forum March 11-12th. - GERMANY
Global Industries March 31st – 03rd Apr - FRANCE
Manufacturing World Nagoya April 15th -17th - JAPAN
3D Printing Value Chain Event April 21-22 - The Netherlands

3D Printing Europe
May 13-14th - GERMANY
3D Printing 2020
May 18-19th - FRANCE
The Advanced Materials Show and Ceramics
July 08-09th - UK
3D Print Lyon
June 16-18th - FRANCE

TCT Show 2020
September 29 – October 1st ,Birmingham, UK
Metal Madrid
September 30th – October 1st - SPAIN
Euro PM2020 Congress & Exhibition -
October 4- 7, Lisbon, Portugal
Formnext
November 10-13th - GERMANY

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