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3D ADEPT MAG

3D PRINTING

AM TECHNOLOGIES - MATERIALS - 3D PRINTERS - INTERVIEWS - NEWS - EVENTS

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3D Adept Mag

ADDITIVE MANUFACTURING/ RAPID PROTOTYPING/ TECHNOLOGICAL INNOVATIONS

Edited by
3DA Solutions
Creative Director
Benell Delano
Editor in chief
Kety Sindze
Graphic Designer
Martial Y., Charles Ernest K.
Editorial team
Laura Depret, Yosra K., Yves Marcial D.
Proofreaders
Jeanne Geraldine N.N., Laura Depret

Cover image - credit LEO Lane

Questions and feedback:
Belgium / Rue Borrens 51 - 1050 Brussels
Phone: +32 (0) 4 89 82 46 19
Email: contact@3dadept.com
Online: www.3da-solutions.com
www.3dadept.com
3D ADEPT SPRL
VAT: BE / 0681.599.796

Editorial

Take a giant leap!

Who was to know that a shy boy, who loved books and music, would become the first person to set foot on the moon on July 20, 1969? For everyone, this milestone, Neil Armstrong achieved was a giant leap for mankind.

After careful consideration, I realized that we rarely talked about the fact that, as a young boy, Neil's recurring dream was to float high above the people, houses and cars. He spent his free time reading stacks of flying magazines, building model airplanes and staring through a homemade telescope. As a teenager, he was so obsessed with the idea of flight that he paid flying lessons at a nearby airport thanks to odd jobs. He earned his student pilot' license on his sixteenth birthday. He certainly did a lot more that I can't remember while writing these lines.

My point is, Neil took that giant leap long time ago when he was young, when he made the decision to invest every single penny, he had to make his dream come true. Very often, the real leap is something people do not see.

In the additive manufacturing industry, I noticed the same principle. There was recently a big media hype around Cytosurge for instance, a Switzerland-based company that announced its 3D printing business unit is now a standalone company. In the midst of this celebration, many forgot to mention that this milestone is the result of applications that resulted from the company's proprietary FluidFM® technology developed ten years ago.

Today, even though companies increasingly leverage AM, we can see that a great number of companies still hesitate to take that giant leap into AM. Reasons and concerns vary from one company to another. We have decided to explore some of them in this issue to help you in your decision-making progress.

In the end, I believe that reading this magazine is another step towards the final one. So, take this giant leap.

Inside

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Additive Manufacturing

With contributions from 3Faktur and ZiggZagg

Industrial AM : Misconceptions & Stereotypes

Like so many other groundbreaking technologies, there is a need to strike a fair balance between what additive manufacturing technology is capable of doing and what is merely impossible. Several challenges in various sectors of the industry still need to be overcome, but one of the most important is to be able to separate the myth from reality. Markus May from 3Faktur and Jo De Groote from ZiggZagg draw on their own industry experience to address the common misconceptions and stereotypes at this current stage of the market.

3Faktur and **ZiggZagg** are two 3D Printing service bureaus. The first one is based in Germany, and the second one is based in Belgium. Both companies mainly rely on HP's MJF technology to provide their clients with additive manufacturing services. Other technologies include Stereolithography machines and some conventional manufacturing systems.

3Faktur delivers its services to clients across a wide range of sectors: automotive, medical, machinery, defence, consumer goods, optical and high-tech. ZiggZagg on the other hand, targets the injection moulding industry, aerospace, design bureaus in addition to consumer goods, automotive and medical.

Markus May is the ***founder and CEO of 3Faktur***, whereas **Jo De Groote** is the ***Sales Manager of ZiggZagg***.

Given their extensive experience in the industry, 3D Printing service bureaus are uniquely positioned to have an objective opinion on this topic.

So, what's the client's mindset?

Two main reasons can explain why misconceptions and stereotypes might hold back the use of industrial additive manufacturing:

- The first one is the **lack of knowledge**. Professionals that are in their way to adopt additive manufacturing may have many ideas regarding the use of technology. Most of these ideas are not true because they come from their imagination rather than real facts and studies.

- The second reason is that potential industrial users sometimes have already experienced 3D Printing at home. In that case, they mentally map their experience with 3D home printing into the more formal additive manufacturing of critical components in a production environment.

Speaking of their clients, Markus May explains that, *"some less experienced clients tend to think that 3D printing is mainly a technology for 'hobbyists. Others, however, believe 3D printing can be used for anything, even printing complex multi-material parts with included electronics."*

For Jo De Groote, having *"a variety of customers who already have an experience in Additive Manufacturing is much easier when providing a 3D printing service. In fact, when the customer does not know anything about additive manufacturing, much work needs to be done to convince him to delve into the technology."*

Jo De Groote - Sales Manager of ZiggZagg

Additive Manufacturing is another type of traditional manufacturing

A significant number of articles have suggested that AM will replace conventional/traditional manufacturing. Those who are familiar with AM see it as complementary to conventional manufacturing, whereas those who are not familiar with it see it as another type of conventional manufacturing.

"Before supplying any service to a client that already leverages conventional manufacturing processes, we first visit their manufacturing facility. Their manufacturing facility will tell you how they think. Our observation so far is they are traditionally mechanically trained. So, every question related to a new approach of manufacturing will only result in an answer based on a conventional way of thinking (e.g. remove powder). It is understandable, but on the other hand, it leads to a misconception in a first attempt to explore industrial additive manufacturing", explains the Sales Manager from ZiggZagg.

The truth?

AM is a distinct and unique manufacturing process. Some parts can only be produced by AM while others are usually only best produced on a three-axis CNC machine. Both types of technologies will still be harnessed in the future. The real challenge for engineers will be to know when to use AM instead of another type of production process to add real value to product development.

AM only requires the push of a button

One of the most commonly-held beliefs about 3D Printing is in the way a 3D printer functions. Most users compare 3D Printing with 2D printing: you just need to press the "print" button and it will take a few minutes to have a part that is ready for use. This analogy is a common belief among new users (hobbyists and professionals).

The truth?

An industrial 3D Printing process requires much time in design preparation and post-processing to ensure that parts come out as desired. Such complexity also explains the increasing number of automated hardware systems launched on the market. Not to mention that companies have also developed software to enhance and streamline AM processes, from design preparation to workflow management.

However, industrial customers might not have this misconception. Markus May states regarding this myth: *"AM generates raw parts, which need to be finished in order to fulfill their intended purpose. In our experience, most customers have a good understanding that this is not the case."*

"AM is the way to go"

That's a common belief Jo De Groote often hears. "Some people think that, in a couple of years, everything will be built via AM," said Jo. As far as this assertion is concerned, the founder of 3Faktur limits the use of AM to a small subset of parts.

For many years and still today, a significant number of people has thought that almost anything can be made by Additive Manufacturing. Companies or media have certainly encouraged this misconception by unveiling use cases of projects that feature complex shapes that can only be made by AM processes.

Such type of use cases has somehow reinforced the idea that AM is the magical solution to everything.

The truth?

3D Printing can do wonders when enhancing design development. The technology certainly opens up new opportunities in manufacturing, but in the end, it remains a tool in the toolbox, with its limitations and appropriate applications.

"AM parts are smaller than conventionally-made parts"

This belief raises the questions of mechanical integrity and quality of AM parts compared to those made traditionally. Moreover, it often appears in metal AM environments.

To ensure the structural integrity of AM parts, there is a need for establishing process-structure-property-performance relationships; mainly where these components and structures are being used in safety-critical applications. All these elements are not analyzed in the same way in a conventional manufacturing process hence the difference between the properties of additively manufactured parts and those produced by conventional manufacturing.

A blatant example is seen at the level of design. As Jo De Groote said, *"the design changes but the part remains the same."* The part needs to be designed for AM in order to enable reduction of materials and weight, which result in improved functionality. Moreover, the total material cost would be lower because less material would be used.

Another logical truth would be to analyze the build volumes of 3D printers. There is a wide range of 3D printing systems available on the market that can print unexpected large parts and small parts. Sciaky's Electron Beam Additive Manufacturing (EBAM) is known for creating giant titanium domes for satellite fuel tanks.

3D Printing only equals to the FDM/FFF technology

3D printing/ additive manufacturing has become a synonym of the most popular additive technology: Fused Deposition Modeling also known as Fused Filament Fabrication (FFF).

The founder and CEO of 3DFaktur explains that: *"There are technical misconceptions as well as varying levels of expectations of less experienced clients. Technologically, less experienced persons tend to believe 3D printing equals the FDM/FFF technology (e.g. they would ask with what infill we print parts). Furthermore, the expectation level tends to be too high in some cases (e.g. injection molding surfaces are expected) or too low (e.g. believe 3D printed parts are very unprofessional and could not be applied for end-use parts)."*

Markus May - founder and CEO of 3Faktur

Markus' explanation unveils other misconceptions less-experienced professionals might have but speaking of 3D Printing in general, it is no secret that it is just an umbrella term that encompasses a wide range of AM processes: SLA; DLP, SLS, SLM, DMLS, WAAM, sheet lamination and many more.

Zero skill manufacturing, less workforce

There is a great number of automated AM processes that run without manual intervention. Some of them have built-in feedback and real-time control, while others require data acquisition to flag off-normal conditions.

The truth?

Most jobs in additive manufacturing processes remain at the level of operation: machine setup, process monitoring, and post-processing.

Support activities such as calibration and maintenance will be just as critical on these machines as with any other manufacturing processes. Moreover, in some cases such as the material environment, the need for human labour is even more essential but those professionals will not require any specific AM skill.

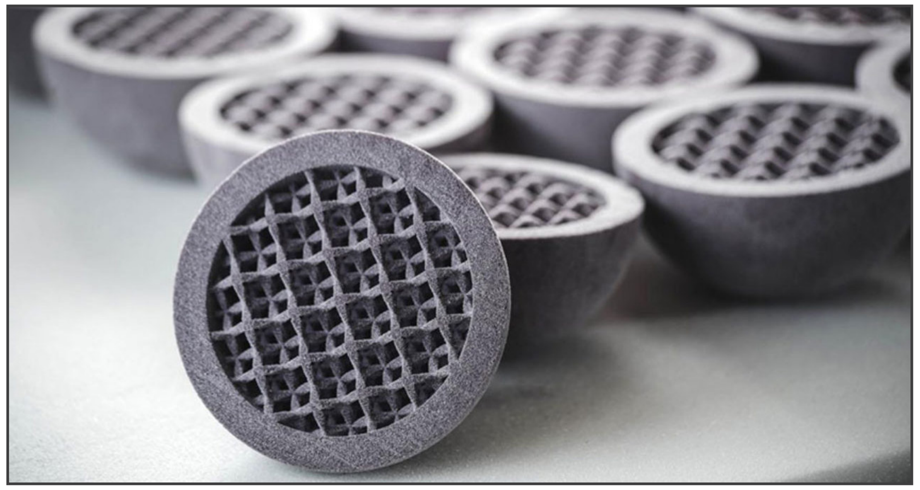
Lastly, many AM machines lock the users out from controlling or even knowing many of the operating parameters due to intellectual property restrictions. In that case, they simply do not allow intervention with many of the settings.

Conclusion

As AM grows in popularity, more resources will be made available to allow a wider acceptance of the technology. Knowing what works and what does not, while separating myths from reality can help decision-makers in their strategy. The true disruption can only occur when every aspect of current manufacturing is examined.

Additive Manufacturing

Comparing the potential & limitations of binder jetting and MIM



The rise of 'Metal Injection Moulding-like' Additive Manufacturing processes seems to be linking to previous technologies that were leveraged way before the fast adoption of metal AM technologies. In the following dossier, Ralf Carlström of Digital Metal, Larry Lyons of Desktop Metal and John Hartner of ExOne review how one technology has led to the success of the other. They also compare the potential and limitations of binder jetting and MIM in manufacturing and explain why metal binder jetting is taking off as a new manufacturing technology.

MIM has come a long way since the early days, and its operators have proven that this technology is capable of reliable high-volume production and strong material properties. On the other hand, with the growing adoption of AM technologies that rely on a sintering process as a final production stage, a key focus is often made on "MIM-like" AM processes.

Several questions led to this investigation: why do we associate MIM to binder jetting? What are the real advantages of MIM? Will binder jetting replace MIM over time? Are applications the same for each technology? Several references have been consulted to confirm the validity of our assertions and the expertise of participating companies has been a key strength to remove uncertainties.

All participating companies specialise in metal additive manufacturing. Some of them shared their experience in both MIM & Metal AM.

Whilst this dossier will give a more detailed overview of these technologies, the article aims at guiding prospective users to identify the technology that best meets their needs.

The evolution of Metal Injection Moulding (MIM)

Thirty years ago, MIM first came onto the manufacturing scene. The technology is seen as a combination of plastic injection moulding and traditional powder metallurgy. Experts of the field even consider the manufacturing technique as a branch of both technologies.

Indeed, one similarity between MIM and plastic injection moulding is observed when the material is fed into a heated barrel, mixed and pushed into a mould cavity where it cools and then hardens to the mould die cavity shape.

As far as traditional powder metallurgy is concerned, the similarity occurs in the way the procedure is implemented. This technique can compact a lubricated powder mix in a rigid die by uniaxial pressure, eject the compact from the die and sinter it.

Furthermore, MIM is also seen as a branch of a broader area, powder injection moulding (PIM); that involves the use of both metallic and non-metallic powders in the fabrication of small-to-medium-complex-shaped parts in large numbers.

Description of the process

Several developments of the MIM process have been observed during the past 30 years. They include MIM with space holders and forming processes to name a few of them.

However, we will keep in mind this explanation of the technology principles from Ralf Carlström, General Manager of Digital Metal:

"The process steps involve combining metal powders with polymers such as wax and polypropylene binders to produce the «feedstock» mix that is injected as a liquid into a mould using plastic injection moulding machines. The moulded or «green part» is cooled and ejected from the mould. Next, a portion of the binder material is removed using solvent, thermal furnaces, catalytic process, or a combination of methods. The resulting, fragile and porous (40 volume per cent «air») part, is in a condition called the «brown» stage. To improve handling often the debinding and sintering are combined into a single process. Sintering heats the powder to temperatures near the melting point in a protective atmosphere furnace to densify the particles using capillary forces in a process called sintering. MIM parts are often sintered at temperatures nearly high enough to induce partial melting in a process termed liquid phase sintering. For example, stainless steel might be heated to 1350 to 1400 degrees Celsius). Diffusion rates are high leading to high shrinkage and densification. If performed in a vacuum, it is common to reach 96–99% solid density. The end-product metal has comparable mechanical and physical properties with annealed parts made using classic metalworking methods. Post sintering heat treatments for MIM are the same as with other fabrication routes, and with high density, the MIM component is compatible with the metal conditioning treatments such as plating, passivating, annealing, carburizing, nitriding, and precipitation hardening."

Ralf Carlström – Digital Metal

In addition to explaining the process, the description announces a few similarities with binder jetting technology, but that's something we will discuss in the lines below. First, let's see **how and why this technology increasingly leads engineers to consider metal 3D printing as a much valuable tool in their toolkit**.

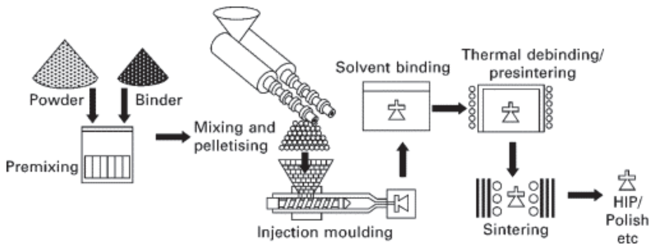


Image: Metal injection moulding (MIM) flow diagram. Credit: Advances in Powder Metallurgy, Woodhead Publishing Series in Metals and Surface Engineering

From what setbacks did MIM suffer?

First of all, components from a wide range of sectors can be created using MIM. A few examples include parts in the medical field, the manufacturing industry, firearms and much more.

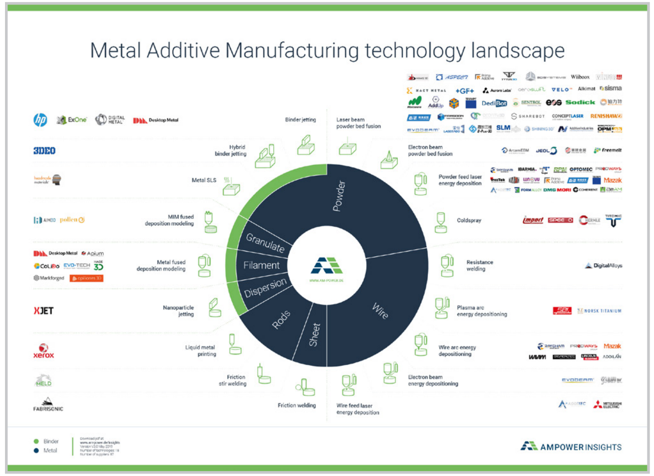
However, the truth is, for many years, at the manufacturing level, part repeatability, voids, fatigue issues and part performance have given operators so many headaches that they have started considering the technology as a production method of last resort, or considering its use when cutting costs was prioritized over part performance.

Reality shows that the technology has known its array of improvements but has not fundamentally changed its principles hence the increasing interest in another manufacturing technology that can bring "diversity" in the production facility. This technology is metal additive manufacturing.

Metal 3D Printing adds another option to the engineer's toolkit

There are at least a dozen metal AM technologies on the market today. Each of these technologies presents its advantages and limitations when it comes to mechanical properties and costs, which does not simplify the decision-making process.

The two well-known types of metal AM technologies are melting processes and sintering processes. However, our focus today will be on sinter-based AM processes, especially binder jetting.



In general, sintering processes require a debinding and sintering step. That's why heat is their primary energy source.

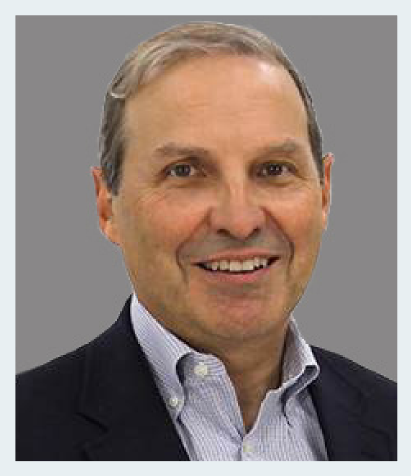
From MIM to binder jetting

Following Ralf Carlström's explanations on MIM, we realized that MIM & binder jetting share some characteristics in their development.

First, *"binder jetting is a metal AM technology that leverages decades of powder metallurgy experience. Thin layers of powder are dispensed, selectively bound, cured, and then sintered to high density. By using the same powders and furnaces as MIM, binder jetting produces parts that meet MPIF Standard 35 for MIM"*, said ExOne CEO **John Hartner**.

"The 3D Printed part is built up from many thin cross-sections of the 3D model. An inkjet print head moves across a bed of powder, selectively depositing a liquid binding material. A thin layer of powder is spread across the completed section and the process is repeated with each layer adhering to the last. When the model is complete, the unbound powder is automatically and/or manually removed in a process called «de-powdering» and maybe reused to some extent. The de-powdered part requires sintering to develop final properties", adds **Digital Metal's Managing Director**.

In other terms, in a binder jetting process, metal powder is moistened for a specific purpose by a liquid binding agent, binding it together. The binder is applied to the powder, before the addition of the next layer. Furthermore, the process requires the use of various types of metal powder to be processed, which typically would need to be processed by Metal Injection Moulding (MIM). In a nutshell, the technique involves one layer of powder and binder and is repeated until the part is entirely produced.



John Hartner ExOne

Desktop Metal on its side explains how they leveraged the potential of MIM to develop their binder jetting technology, and it all starts with the expertise of their founding members in these technologies.

Indeed, one of the co-founders of Desktop Metal, **Professor Ely Sachs** invented binder jet printing in the late 1980s when he was at Massachusetts Institute of Technology (MIT). Sachs' technology allows engineers to create functional parts and end-use products rather than prototypes.

The VP of products also mentioned the expertise of **Dr Animesh Bose**, who has been involved in the area of powder metallurgy and particulate materials (PM) for more than thirty years. As per Larry Lyons' words, Dr Bose's *"experience of working with similar materials in the context of the MIM process has been crucial to developing new capabilities of 3D Printers specifications."*

However, even though the term "3D Printing" was originally coined by MIT in reference to metal binder jetting technology, other researches show that Extrude Hone Corporation, a manufacturing company, obtained an exclusive licence for MIT's technology in 1996. The company, therefore, developed and commercialised metal binder jetting systems, with the 3D printer, ProMetal RTS-300, delivered to Motorola in 1999.

ExOne, which was part of Extrude Hone Corporation, became a stand-alone company in 2005 and remained the only company to offer metal binder jetting services and systems until the early 2010s. At that time, the first MIT patents for the technology began to expire, allowing new companies into the market.

From **Desktop Metal's Larry Lyons** statement, MIM has somehow inspired the development of the company's metal additive manufacturing systems:

"Desktop Metal aims to deliver affordable 3D metal printing, in the same way, low cost plastic 3D Printers are accessible on the market today. So, when the company was founded, a wide range of researches on different technologies was carried out to figure out the best way to do this.

The initial technology that was leveraged during these researches for our systems – the Studio System especially– was primarily based on Metal Injection Moulding chemistry where we would take "MIM-like" materials and process them on a 3D printer.

We then created our own user-friendly system to obtain a process that would produce solid metal parts.

However, over time, a key focus was made on another range of the spectrum: large industrial systems such as our «Production System», that are much faster at making parts.

Working on this system, we realized that we couldn't make a 3D printer based on the science of MIM. Indeed, if the knowledge of materials resulting from the MIM process is useful, the MIM technique remains utterly different from binder jetting.

Only the experience in the field of materials has been useful to leverage AM capabilities. »

Larry Lyons – Desktop Metal

Applications & Engineering: MIM vs Binder Jetting Technology

Applications

Let's explore the applications that both technologies enable. We have mentioned above that MIM enables the production of firearms, parts in the medical field and the manufacturing industry.

The three experts agree with the fact that these applications are almost the same when using binder jetting:

"Applications for MIM and binder jetting are very similar. Since binder jetting uses the same powders as MIM and the same furnaces, binder jetting produces similar quality parts. Automotive and firearms are the biggest applications for metal binder jet parts currently", said ExOne's CEO.

"MIM components are used where there is a need for small intricate parts like in medical & dental, Industrial, automotive, aerospace and luxury applications. This is also relevant for metal binder jetting as mechanical properties are in general similar as for MIM", completes Digital Metal's Managing Director.

Apart from the manufacturing processes that involve a few differences, at first glance, two key factors that will be taken into account in the decision-making process are the design of the part and the quantity to produce.

Indeed, from an economic perspective - the holy grail in a manufacturing process -, if manufacturers do not intend to change the design of a given part for the next 5 to 10 years, and if they plan a production of thousands to millions of this part, then, an investment in MIM tooling makes sense.

However, from the end-user perspective, the Binder Jetting technique currently offers an even wider choice: the one to explore several forms of the same product within a limited period of time, the one to mass produce or to produce small volumes of a given part – even if this part is a prototype that is meant to be built with MIM.

With that being said, it is also interesting to mention that the AM supply chain is currently experiencing some change with the increasing adoption of binder jetting. Indeed, metal powder suppliers now supply mass markets such as automotive that increasingly leverage binder jetting technology.

Engineering

As far as engineering is concerned, key factors that have been compared **include design & size of the manufactured part, surface quality, post-processing & cost.**

Speaking of design, it is no secret that additive manufacturing technologies enable to obtain superior design possibilities compared to conventional manufacturing techniques. However, experts also say that residual stresses and the need for support structures sometimes add restrictions to this freedom of design.

"Binder jet parts range in size from smaller than a golf ball to larger than a basketball. Similar to MIM, small parts work very well with the binder jet process because shrinkage is minimized. The relatively low binder content in binder jet parts enables binder jetting to produce larger parts than [the ones that] can be made with MIM", explained ExOne's **John Hartner**.

Ralf Carlström, on the other hand, compares MIM & binder jetting in general: *«binder jetting facilitates the forming stage for making large parts compared to MIM, but challenges during the sintering operation are similar for both processes for making large parts. [As far as surface finish is concerned, MIM brings a significant advantage due to the interaction with the mould during the forming step.]»*

Larry Lyons lays emphasis on the technical aspect when giving his point of view on the points mentioned above:

"Binder jetting can do any parts made by MIM. MIM does tend to produce small parts whereas binder jetting provides a wider range of geometries and can produce parts of different sizes, both small and large.

As far as surface quality is concerned, you should know that injection moulding consists of a high-pressure injection of the raw material into a mould. Such high-pressure creates a smooth and repeatable surface that comes out of the mould. In binder jetting, there is no mould to provide that very smooth exterior surface so, we tend to have a rougher surface on binder jetting because you are at the mercy of the powder particles.

However, the postprocessing between the two manufacturing techniques is slightly different.

One of the final steps in a MIM process is debinding, which consists in removing a major portion of proprietary binder. Depending on the binder, some debinding processes can also be done in a furnace. After this step, the "brown" part is created.

In the binder jetting technology, instead of going into a sort of debinding in the next step out of the printer, you go into basically just depowering before going straight to the furnace. Thereafter comes the postprocessing step that depends on the part geometry and what the operator tries to achieve."

In other terms, following the part infiltration, at the end of the binder jetting process, a finishing step such as polishing can be applied in order to obtain aesthetically pleasing surface finishes.

To sum up

This dossier aimed at comparing the potential & limitations of MIM & Binder jetting. The development of materials in the MIM process has somehow facilitated the use of these materials in a binder jetting process. In a nutshell, our findings can be summarized in the table below:

MIM	Binder Jetting Technology
Interesting for the production of more than 20000 parts per year	Interesting for the production of fewer than 20 000 parts per year
Limited part geometry	Freedom of design
Makes sense if part design won't change for the next decade	Makes sense if part design is frequently subject to change
The use of moulds is mandatory and can become quickly costly	No moulds required
Single part per mould	New or updated parts without investing more money

Today, the success of metal binder jetting lies in its compatibility with relatively MIM powders. Desktop Metal, Digital Metal and ExOne are not the only players in the metal binder jetting arena. Several companies are aware of the breakthrough potential of this technology and are now doing their best to seize the opportunities it presents.

Moving forward, these companies might evolve the technology even further. No matter what happens, healthy competition can only help both technologies to carve out a valuable share in the manufacturing sector.

A few notes on the participating companies

ExOne

ExOne is one of the first players that started the commercialization of metal binder jetting systems. Over time, the company has launched five metal binder jetting systems, with each being an evolution on the previous one.

Its latest released system is the S–MAX Pro™, an industrial 3D sand printer, a technology that can print up to 135 l/h (18 s/layer) and 3D Print two full 1,800 x 1,000 x 700 (mm) job boxes, each with a volume of 1,260 L, in just 24 hours.

In regards to this topic (MIM vs Binder jetting technology), ExOne introduced last year the Innovent+. Although the system is said to be slower than the company's M-Flex 3D printer, it offers an Ultrasonic recoater and the possibility to process standard MIM powders.

According to the company, the new recoater improves powder flowability and simplifies material change-over. Furthermore, with the new feature that enables to process MIM powders, ExOne enables the users of its systems to benefit from cost savings and greater material flexibility.

ExOne - S–MAX Pro™

Digital Metal

Founded in 2012, Digital Metal is a subsidiary of a well-known metal powder producer Höganäs Group. The company started supplying its metal binder-jetting in 2013.

Two years ago, the Swedish manufacturer officially launched its DM P2500 3D printer, designed for the series production of small and intricate parts at a resolution of 35 microns – hence its baseline "Small is the new BIG in Additive Manufacturing".

In February, Digital Metal has received notice of completion of product testing and authorization to apply the UL Mark (Underwriters Laboratories) to its metal binder jetting system.

As far as the AM system is concerned, it spreads a layer of metal powder that is 0.042-mm thick. The binder is thereafter jetted according to the part's geometry. According to the company, the process is accurate and repeatable, not to mention that it delivers an average surface roughness of Ra 6.0 micron, fine enough for many end-use parts and features such as internal channels.

Last year, the company made a giant leap forward with its binder jetting system by launching a no-hand production concept. While embracing automation, therefore, reducing human intervention, the robot would remove all manual work to increase productivity. Technically speaking, the printer will be filled with build boxes; they will thereafter be moved for post-treatment in a CNC-operated de-powdering system to which a pick-and-place robot has been fixed.

Digital Metal
DM P2500 3D printer

Credit: Desktop Metal - Studio System

Desktop Metal

Boston-based start-up is only 4 years old and has already convinced more than one in this industry. The metal 3D Printing Specialist is now the highest ever funded company of the industry, with a total of $438 Million, all funding rounds combined.

The technology behind Desktop Metal's systems is what they call Single Pass Jetting (SPJ), a faster version of the typical binder jetting process.

The company develops the Studio System, a desktop metal 3D printing system designed for offices and the Production System intended for industrial manufacturing.

The Production System is one of the first binder jet systems to be equipped with an inert industrial environment that integrates gas recycling and solvent recovery for the safe printing of reactive metals. Such environment enables to process a broader range of metals, including aluminium.

In regards to this topic, it should be noted that Desktop Metal has added substantial speed improvement to its Production System. Indeed, with a build volume of 750 x 330 x 250 mm, this bi-directional system enables high-resolution printing at up to 12,000 cm3/hr. In other words, this implies the production of over 60 kg of metal parts per hour.

The commercialization of the Production System has only been recently announced, so the whole industry will need to be patient to see if its production speed claims are proven. However, if they are effectively proven, the Production System will become the fastest binder jetting 3D printer available on the market today.

Credit: Desktop Metal – Production System

Interview

Circular Economy Concept in Additive Manufacturing

Prima Additive shares an overview of the Circular Economy Approach in Additive Manufacturing.

***Paolo Calefati**, Vice President additive manufacturing business development at Prima Industrie S.p.A.*

Prima Industrie Group specializes in the development, fabrication and commercialization of laser systems for industrial applications, sheet metal processing machinery, laser sources and additive manufacturing solutions.

To date, with over 40 years of experience in the industry, the Group has managed the installation of more than 13 000 machines in 80 countries across the world. Next to its divisions Prima Power and Prima Electro, Prima Industrie S.p.A has recently launched Prima Additive, a division that takes advantage of its longstanding experience in metal and lasers to provide industrials with additive manufacturing solutions.

For Paolo Calefati, Vice President additive manufacturing business development at Prima Industrie S.p.A., their market entry in the AM industry seems to be a logical step for the company, given the fact that AM is currently evolving in the same field where they have built trust and expertise: laser technology and sources, laser machines for cutting and welding, CNC's and dedicated industrial electronics.

"Today, our vision of Additive Manufacturing is very similar: a highly promising technology rapidly passing from experimental use to industrial application up to its evolution into high productivity tools", said the Vice President.

With a key focus on Powder Bed Fusion and Laser Metal Deposition technologies, Prima Additive has launched its own AM system Print Sharp 250. Surprisingly, the company seems to lay emphasis on a circular economy-based approach.

Paolo Calefati tells us the reason why a circular economy-based approach matters to the company.

The circular economy concept

Generally speaking, in theory, the circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. This way, the life cycle of products is extended.

In practice, this model implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby creating further value.

In the manufacturing industry, producers have raised a major concern about sustainability. Indeed, this industry is a big consumer of energy and raw materials, which results in an increasing production of gas emissions and waste. Luckily, applying the concept of circular economy into AM aims to avoid further waste, especially at the materials stage.

As far as Prima Additive is concerned, Paolo Calefati explains: "In a circular economy, the value of products and materials is maintained as long as possible. The resources used and the waste are reduced to a minimum, and when a product reaches the end of its life cycle, it is modified to be used again, creating new value. This can bring great economic benefits.

Practical cases are the repairing of high added-value components with our direct energy deposition products, as it is done with our Direct Energy Deposition machine installed at ENEL.

Another example is the possibility to add features to already existing parts or recoating used parts to restore functionality."

Print Sharp 250

The Circular Economy Concept in AM has been discussed during a conference of EPMA: "the goal of the study was to apply the concept of circular economy into AM, by recovering process side-streams back to the feedstock material for Selective Laser Melting. The objective was to prepare powder from 100 % scrap feedstock following two routes: 1) mechanical milling of agglomerated residue powder, and 2) gas atomization of solid scrap without extra alloying to compensate possible alloy losses. The powder properties were analysed and test specimens for the determination of mechanical properties were made from the prepared powders and commercial reference powder. Conducted test series show that with recycled powders properties fully comparable to reference can be achieved."

What makes then the Print Sharp 250 outstanding?

We already know the metal 3D printing system integrates a Direct Energy Deposition technology. Prima Additive Vice President also lays emphasis on the price-quality ratio, a significant factor in today's industry given the fact that metal AM remains an expensive technology for most industrials.

"[Our Print Sharp 250] is highly competitive, boasting the best price/performance ratio on the market. It is particularly designed for customers who wish to explore Additive Manufacturing starting with an inexpensive investment. Other [main advantages include its] surface quality and its user-friendliness, with simple use and maintenance procedures. But I would say that the biggest reason why [Prima Additive machines stand out from the crowd is because we focus on] our customers. We build a true partnership with our customers, offering an all-round support, from the design phase to prototyping, up to manufacturing optimization.

Further to the Powder Bed Fusion technology, covered by the Print Sharp product family, Prima Additive offers solutions for Laser Metal Deposition, covered with systems based on our well proven Laserdyne platform", adds Paolo Calefati.

The next step for the company

In order to move closer to high productivity, Prima Additive is working on innovative models to complete their production portfolio. The company intends to build its next generation of products while keeping in mind the price-quality ratio. As per Paolo Calefati's words, their goal is to "lower the barriers to entry for this new technology, which at the moment is mainly the prerogative of large companies, and allow smaller companies to explore the potential of these systems."

In the meantime, Prima Additive's experts can reply to any questions professionals might have during the next conferences and exhibitions (RM Forum in Arese (Italy) and Formnext (Frankfurt)) where they will showcase their products, online or on site at their application centre in Turin (Italy).

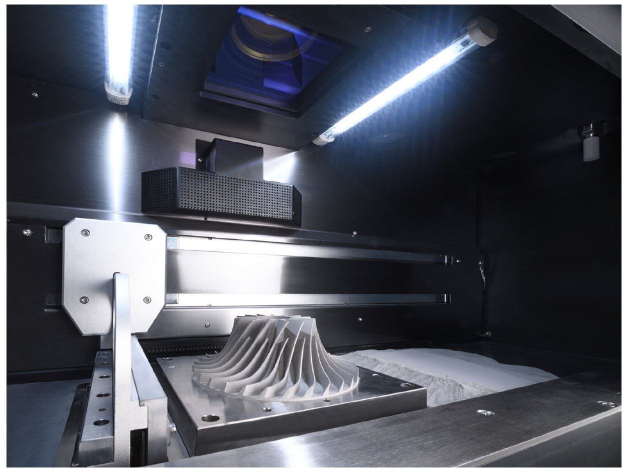
In a nutshell

With the help of Prima Additive, we tried to provide a quick overview of the circular economy concept in additive manufacturing. The topic is broad and can't be discussed in-depth in a single Opinion of the Week.

Among all manufacturing techniques that can be exploited in the industry, early studies show that additive manufacturing holds substantial promise for sustainability and the creation of a circular economy (CE) but there is no guarantee yet that it will be effective for all AM technologies.

The truth is CE principles were embedded into the new manufacturing system before the adoption of AM reaches a critical inflection point in which negative practices become entrenched.

So, maybe the next strategy consists in analyzing a key point: while the current trajectory of AM adoption creates more circular material flows, what enablers and barriers do they really raise in the integration of CE by additive manufacturing?



Interior Print Sharp 250

EVENTS : Formnext 2019

How does Formnext intend to keep its position as the "place to be" in the AM industry?

The annual gathering of the global additive manufacturing (AM) and 3D printing sectors will take place in Frankfurt am Main from November 19th to 22th, 2019. Companies, entrepreneurs, makers, project owners will have four days to discuss the past, the present and the future of the manufacturing industry. In the meantime, let's take a few minutes to recall what happened last year and underline what's currently being planned for the next edition.

- **Throwback to the highlights & records of Formnext 2018**
- **What's new in the upcoming edition?**

For those who are not aware of this annual meeting of the additive manufacturing industry, the Formnext event showcases the hard-to-define and multifaceted world of additive manufacturing across several branches: materials as well as every process step required in a manufacturing environment (pre-production, actual production and post-production).

The event itself supports and integrates established events including the Start-up Challenge, the "purmundus challenge", the AM4U platform with a wealth of career opportunities, and the BE-AM Symposium, but that's something we will have time to discuss later.

The first edition of Formnext was held on November 2015. Going forward, it is interesting to recall the pivotal moments of the past edition and the milestones achieved by both Mesago and the industry. After all, the Formnext event has become a reference for both the organizer and the exhibitors.

In this vein, **Christoph Stüker**, Communication Manager at Mesago during an interview with 3D ADEPT Media explains: *"from the very beginning, the show started highlighting the big AM suppliers. From that point, we also learned that AM is not only its machines but a whole process from design software to 3D Printers, not to mention the crucial importance of materials, post-processing and metrology. Our goal, therefore, was to share the whole AM value chain instead of just showcasing 3D printers. I think that, at the end of the day, that's also important for the visitors. They might certainly need a 3D printer but more importantly, they will also need to understand the whole learning process of product development from start to finish to have a tangible, functional part."*

We believe that those who were not present in the halls of Messe Frankfurt last year in November, have been able to catch up news here and there from various media of the industry.

In that sense, you have undoubtedly read that the event saw a 25% increase in visitors throughout the four-day event compared to the previous year's figures. Furthermore, a total of 632 exhibitors from thirty-two countries showcased their solutions for Additive Manufacturing to 26,919 individuals.

And it was supposed to be more than these figures! The floor space for the 2018 edition was in fact sold out over 10 weeks before the start of the show, with a waiting list of over 20 companies looking to fill any late cancellations; most were quite disappointed to attend the show as visitors.

Connecting bright minds

Speaking of highlights, countless numbers of conversations at Formnext, both on and off the record pointed two things: the need to create more collaborative roads to upgrading additive manufacturing, and the need to develop holistic AM solutions.

As far as the first need is concerned, we have been able to witness a lot of announcements in that sense since the beginning of this year. If you regularly follow the news of the industry on 3D ADEPT Media, you know that I am right! Today, some companies that we can't mention now, have already promised to reveal exciting announcements in the development of their activities at Formnext 2019.

As for holistic AM solutions, it all depends on your needs (which probably involve but not necessarily your level of understanding of the technology, the type of technology you require and how you need it). Moreover, in this range of holistic solutions, it is fair to add that since 2017, "discover3DPrinting" the seminar series for Additive Manufacturing novices, is gaining momentum.

So, through this book of "souvenirs", our aim was just to give you a lot to think about so that you can better prepare yourself for this year's edition.

Looking ahead to the upcoming edition

The first thing Mesago announced last year at the end of Formnext 2018 was the introduction of a partner country for the 2019 edition. This country is the USA which makes sense because there is an opportunity to seize.

Credit : Mesago – Thomas Masuch

Six years ago, according to a report from the U.S Department of Commerce, there was a general concern that the U.S. manufacturing industry had lost competitiveness with other nations. Over the years, additive manufacturing has provided an important opportunity for advancing U.S. manufacturing while maintaining and advancing U.S. innovation.

Today, while looking at the global landscape of the industry, the global additive manufacturing market is expected to grow to US$ 36.61 billion by 2027 from US$ 8.44 billion in 2018. (Report 2019 on ***"Additive Manufacturing Market to 2027 - Global Analysis and Forecasts by Material; Technology; and End-User"*** from the Report Buyer, Research firm).

Therefore, promoting the USA as a partner country underlines the contribution of its players in this landscape. This year, there will be special highlights for American guests. A diverse program awaits Formnext's visitors on the partner country stage of the U.S. pavilion, including a discussion panel of renowned speakers. Moreover, the organizer will renew the "AM Standards Forum", launched in cooperation with the U.S. Commercial Service.

So far, over 650 have already secured their place for this year's edition. The new exhibitors include international groups such as 3M Advanced Materials, Bosch Rexroth, Covestro, Evonik, Mitsubishi, and thyssenkrupp Materials. Both young companies & SMEs such as Peter Lehmann and August Rüggeberg, as well as industrial clusters such as Bayern Innovativ and Leichtbau BW, will be represented this year.

Interestingly, a key area that has evolved this year is the post-processing stage. *"Here, many companies from traditional industrial sectors have seized market opportunities and developed very exciting products and technologies,"* says **Sascha F. Wenzler**, Vice President for Formnext, Mesago Messe Frankfurt GmbH. *"In addition to growth in other sectors, Formnext can also further expand the process chain and explore the different areas in more depth." Formnext reflects the development that sees additive manufacturing in industry often integrated into a multi-stage manufacturing process, in which several manufacturing processes are linked and combined. "We demonstrate various manufacturing processes, at the heart of which is additive manufacturing,"* comments Wenzler.

"Another key area that visitors will discover during the 2019 edition is the BE-AM Built Environment – Additive Manufacturing Symposium 2019. For the first time, we will support another event dedicated to the integration of AM in the construction industry. The event is organized by the Technical University of Darmstadt in Germany. We are supplying a platform that will bring these experts together and develop what they need.", said **Christoph Stüker**.

Moreover, last year many complained about the logistical hurdle of navigating three sets of elevators between meetings or press conferences. Luckily, this year, thanks to the huge growth, the exhibition will take place in Halls 11& 12 for the first time. According to the organizer, these halls are the *"most modern part of the Frankfurt exhibition grounds"*. In a few words, it's a part that offers high-quality and elegant architecture combined with the modern and spacious entrance building Portalhaus.

In November, a lot of issues will still be addressed: standardization, polymer and metallic materials – a pivotal part of the business equation -, production (real, serial, increased or distributed), qualified AM technologies and the indisputable role of software solutions. Companies are working on this right now. Will they be ready? Come to Frankfurt with your projects to find out. It's the place where ideas take shape.

Additive Manufacturing Interoperability

As manufacturers more and more recognize additive manufacturing (AM) as a viable production alternative, they find themselves facing new challenges in informatics or systems integration. Every day, operators answer and raise several questions related to platforms interoperability. Today, we seize the opportunity to complement existing efforts in current digital solutions. Experts from ***Authentise, AMendate*** *and* ***Volume Graphics*** *share their expertise in this topic.*

Interoperability refers to the ability of computer systems or software to exchange and make use of information. In other terms, different manufacturers can connect their devices in order to leverage specific data for a given process. In a manufacturing process, designers need to master several things to design the part in the right way. In additive manufacturing especially, the design process is quite different from other manufacturing methods. That's why we first need to understand, what additive manufacturing interoperability is; at least at what level, one can talk about interoperability in an additive manufacturing process.

Philip Sperling, Product manager Additive Manufacturing at Volume Graphics defines interoperability in AM as "the connection between different hardware and software components of the AM process chain." "If you are looking at the complete AM process chain, e.g., for the powder bed fusion technologies, you will find a lot of equipment and software necessary to get to the finished part", adds Philip Sterling.

Credit: AMendate-optimized upright vertical

In this vein, issues related to platform interoperability can be observed from and between design, manufacture, and post-process. An assertion that **Dr Thomas Reiher**, CEO and Co-Founder of AMendate GmbH confirms:

"Additive Manufacturing (AM) enables a digital process chain and thus fosters smart manufacturing. To be successful, the interoperability of AM is a fundamental factor. Consequently, the digital creation process has to be combined with actual manufacturing. There has to be an integrated process from and between design, manufacture, and post-processing."

For **Andre Wegner**, Founder & CEO at Authentise, we speak most frequently about interoperability of data. For example, interoperability of design files, interoperability of machine data, etc. However, as we have seen in the literal definition, he laid emphasis on the fact that the term goes beyond the software level and can be studied in other fields.

Interoperability at the software level: Dependencies and related standards

Andre Wegner said that we mostly speak about interoperability of data. Several cases can describe dependencies that might explain the need for an interoperability process in a manufacturing environment.

The use of new features in software

Data interoperability between CAD systems remains a significant hurdle in information integration and exchange in a collaborative engineering environment. The use of CAD data exchange standards causes the loss of design intent such as construction history, features, parameters and constraints.

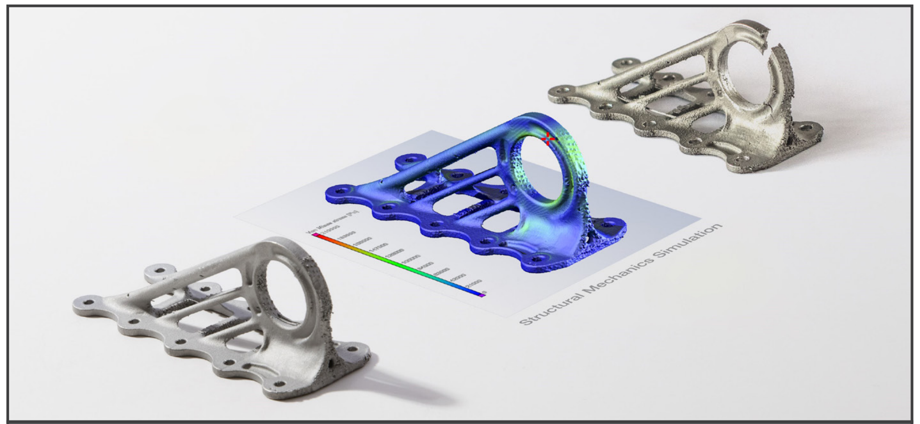
Such hurdle often results from the migration of some functions generally found in AM specific software to CAD software. Those functions might be *«part placement in the build environment, design of support structures, or setting a build orientation.»*

These functions are still a part of the AM process, but eventually will become a CAD design function. So, CAD software companies now develop those capabilities or integrate existing AM software into their software. *"There is a need to capture the information associated with those functions in a [single] file for interoperability and long-term archiving and retrieval."*

The use of several tools/ software during the design process

While the first dependency laid emphasis on the confusion created by the migration of specific features into a given software, another dependency might occur during the design process of complex parts. This dependency occurs when the design of a part requires the use of different software solutions.

"For highly complex parts, you have to make a lot of considerations when designing your part regarding the function and how to make it «printable». During this process, you have to use different software solutions that cover single design steps, e.g., the topology optimization, the lattice design, positioning of support structures, force and build simulation, as well as build preparation. These different solutions may not integrate properly to convey original design intent", explains Volume Graphics Product Manager Additive Manufacturing.



***Credit: Volume Graphics** – Caption :*

additively manufactured aircraft cabin bracket (miniaturized, without surface finishing, and with the typical appearance of a 3D-printed part) with deliberately inserted discontinuities. (Middle) Volume Graphics software generates a color-coded display (finite element analysis) of the locations of the weak points directly on the scan of the real component. (Right) Part after destructive test shows component failure in the exact spot predicted by the software. Part courtesy of Airbus Emerging Technologies & Concepts; software images courtesy of Volume Graphics; part manufactured by Concept Laser.

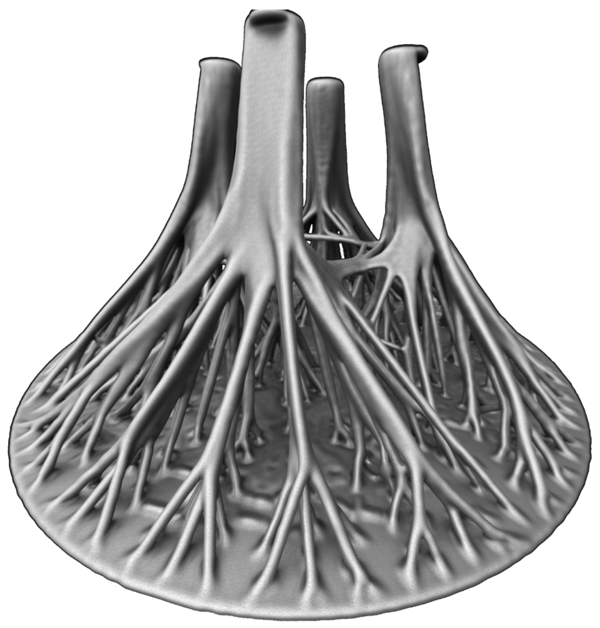
The integration of AM has certainly the potential to reduce time and cost during the production process. However, *"it's currently still too cumbersome to move a part from idea through design, through manufacturing preparation and production. Multiple tools are involved [and] interoperability allows us to reduce the number of tools, the number of steps and effort required"*, adds the founder & CEO of **Authentise**.

In this specific case though, manufacturers still have a long way to go before reaching stable compatibility between all processes. For AMendate GmbH's CEO, the understanding of the issue seems clear in theory but, in practice, *"continuous and thorough integration is usually more difficult than expected to implement and many small details cause major problems. However, compatibility [between solutions] is only really interesting and seamless if we also embrace the physical level of production and post-processing. On the one hand, data must arrive at the machine entirely and correctly and [must] be processed. On the other hand, though, it is also important to ensure that findings from production flow back into the software. When we have a constant flow of information back here and [when we will] continuously adapt and align the software [for] production, we will have stable compatibility in the future.*

Nowadays, compatibility is more important than ever. Intensive cooperation takes place at various levels. Data, processes and products must be exchanged efficiently to carry out this cooperation effectively and quickly. Compatibility is the lubricant of a well-functioning system. [A few years ago, the improvements were not as significant as expected on the compatibility of different machines, software and companies]. Nowadays, in terms of Industry 4.0 and smart factory, this is a significant advancement. Companies such as Hexagon are working on a broad basis for interoperability of software and machines and thus guide the engineers in their daily business."

The ideal way to have interoperable manufacturing

Today, we do not question the importance of interoperable manufacturing anymore. Its importance seems justified, especially in a manufacturing environment that is increasingly digitalized, and that frequently requires new tools to achieve complex tasks.



We question its real feasibility because so far, operators still seem to face a range of challenges that seem difficult to explain when delving into technical aspects of the manufacturing process.

In the range of possible solutions that we can explore, experts share their opinion on the idea:

From our analysis, Authentise and Volume Graphics would obtain the "same result" at the end of a given manufacturing process using "almost different approaches":

While Authentise' **Andre Wegner** uses the words "Open Standards" to talk about the ideal way to reach interoperable manufacturing, Philip Sterling, on the other hand, talks about *"a standardized, scalable file format for AM that enables interoperability through all the different process steps—design, printing, post processing, and inspection."*

Andre Wegner first explains his point:

"In the absence of open standards for machine data (or, rather, standards still being established), Authentise is working on interoperability by providing a connector to different machine data types. Currently, Authentise already integrates data from HP, EOS, SLM, Carbon, Stratasys, 3D Systems and many others.

In addition, Authentise's open, modular infrastructure allows integration into existing IT systems as well as the integration of 3rd party modules, such as mesh healing and support algorithms. This means that users no longer have to interface with different systems, but can manage the pre-production processing for various machines in one, seamless interface.

Andre Wegner, Founder & CEO of Authentise

Finally, the integrations Authentise has built into other 3rd party systems enable further interoperability. One example is the integration with Autodesk Netfabb, which allows users to switch seamlessly between CAD and production planning. Another example is our integration with Microsoft Flows, which enables additive interoperability between hundreds of different online services to empower operators to create their workflows."

Philip Sterling clarifies his assertion:

"Since users have to work with different programs, they also have to work with different file formats and interfaces with many constraints between them – not to mention the added challenges of varying interfaces and workflows, and even interpretation of data and results.

As we are offering [a] software solution [that analyzes] industrial CT data sets, we get a lot of requests from the Additive Manufacturing industry. Sometimes we encounter some of the consequences of missing interoperability as users send us different files for the nominal-actual comparison with CT data. We then receive single files for the part, the lattice design and the support structures—all of which makes our process for completing the analysis more complicated.

We try to make our customers' lives easier by supporting a lot of data formats to import and export in our software solution."

Dr Thomas Reiher

Dr Thomas Reiher, on the other hand, still lays emphasis on the "compatibility" argument:

"The lack of compatibility was one of the triggers for the foundation of our company. When optimizing components, the conventional process is characterized by the fact that different software solutions are necessary to achieve a result with a lot of manual work. Data exchange between these programs, however, led to information losses due to data conversions, [which] degraded data situation.

With AMendate these conversions are no longer necessary. The software integrates all relevant steps in one software and automates them. The result is a fully integrated, automated optimization process in which compatibility for previous and subsequent operations plays a crucial role.

This considerably simplifies the work process. In the next step, we are working on integrating Simufact' s production simulation into our design process. Once this is implemented, AMendate will foster the integration with other MSC products to enable a consistent data workflow with down- and upstream applications such as MSC Adams (multibody simulation), MSC Nastran (high detail FEM-Simulation) and CNC-machining.

In the end, our solution can be optimally leveraged directly on the selected machine, without any significant intermediate steps in a single, continuous digital chain."

In a nutshell?

AM interoperability focuses on simplifying the additive process and enabling an interoperable workflow. Its vision is to create a collective experience through a secure, intuitive tool that reduces design iterations and speeds up the time to print a good part, according to the design intent.

AM interoperability can happen in different situations: while using new software that integrate several tools, or while using several tools to achieve the design of a ready-to-print part. Furthermore, AM interoperability can be observed at different levels of the production process.

However, whatever the situation is, when we look at the experts' points of view, we can see that even though the "final goal is the same", roads that lead to it vary from one company to another.

A few words on the participating companies:

Founded by Andre Wegner, Authentise provides the additive manufacturing industry with process automation software. Its tool automatically monitors active prints and identifies Key Performance Indicators in the production environment.

AMendate aims to create a better way for optimizing parts. Founded by Thomas Reiher, Steffen Vogelsang, Anne Düchting & Gereon Deppe, the company has recently been acquired by Hexagon. AMendate's strength relies on its ability to decrease time-to-print for Additive Manufacturing significantly.

Volume Graphics develops software for the analysis and visualization of industrial computed tomography (CT) data. The software company ensures quality control in AM using industrial computed tomography.

Materials

Elastomers used in additive manufacturing

Elastomers are materials that are part of the big family of polymers. Generally speaking, they refer to rubbers, i.e. macromolecular, natural or synthetic substances that integrate the elasticity of rubber.

They are found in almost all daily objects. Elastomers are widely used across a wide range of industries, including the automotive, aeronautics, transport, electrical industries- and medicine. All these sectors leverage additive manufacturing, hence our interest in tackling this topic.

Filaments – Elastomers
Credit: Innofil3D

Elastomers are strengthened by the addition of other materials such as metals, textiles, and some plastics. A part manufactured with the elastomeric material of company A will not necessarily deliver the exact same rendering as a part manufactured with the elastomeric material of company B. Moreover, due to intellectual property, some producers do not disclose the chemical composition of their materials.

General characteristics of elastomers

Elastomers are unique; their features are different from plastics or plastomers, other materials of the polymers' family.

Elastomeric materials that are mechanically recognized as a rubber are:

• Flexible: they integrate low stiffness;

• Soft: parts made of this material can withstand extensive deformations without breaking or reaching «breaking» elongations;

• Elastic. The parts regain their initial shape when they are no longer requested. Also, the harnessed energy to deform the part is then redistributed quantitatively in the middle of the part.

In the additive manufacturing industry in general, there is currently a limited range of elastomers compatible with 3D printers. Indeed, due to the mechanical constraints of 3D printers (melt index viscosity, etc.), many materials integrate formulations that best suit traditional manufacturing processes.

Elastomers that are suitable for additive manufacturing

When it comes to elastomers, four materials stand out from the crowd: **TPU, flexible PLA** and **flexible PE for thermoplastics, and acrylic-type photo-elastomers.**

When asked what the widely used elastomer is, market players' answer is not the same. **Albert de Boer**, additive manufacturing engineer at Innofil3D and **Franco Cevolini**, VP & CTO of CRP Technology, share their company's expertise in this article.

For those who may not know, Innofil3D is a producer of filaments designed for FDM/FFF technologies – The company has recently been acquired by BASF. Based in the Netherlands, Innofil3D supplies its filaments throughout Europe.

CRP Technology, on the other hand, belongs to CRP Group, an industrial group that specializes in **additive manufacturing, Rapid Prototyping** and **high precision machining services**. The company mainly supplies its services to the motorsport sector. By creating CRP Technology, the group is opening up to rapid prototyping and additive manufacturing solutions to serve these sectors of activity better.

For **Albert de Boer**: *"an elastomer is far more flexible than the more regularly used rigid thermoplastic polymers such as PLA for example. The main elastomeric polymers I think, which are used in AM, are TPU materials with different shore grades. TPU stands for Thermoplastic polyurethanes. Consisting of hard and soft segments to control the shore hardness."*

Franco Cevolini states that *"the main elastomers used in the AM market belong to TPE and TPU. TPE stands for Thermoplastic elastomers, TPU stands for thermoplastic polyurethane. CRP Technology's elastomer is Windform® RL, and it is part of the TPE family."*

TPUs and TPEs are the most widely used elastomers in the additive manufacturing market.

Credit – CRP Technology – Part of a seat

Which elastomer for which AM technology ?

Elastomers are generally used with FDM or FFF technologies. According to Innofil3D, FDM technologies are the AM technologies that best process these materials.

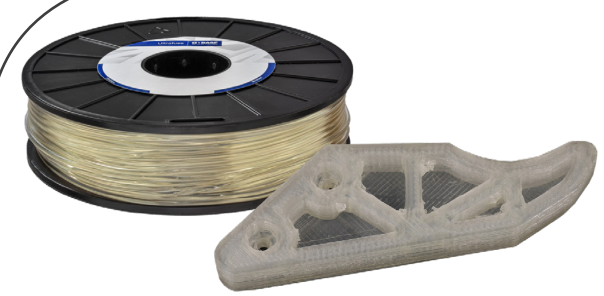
CRP Technology, on the other hand, advocates that they can also be used with other AM technologies, including SLS technology. Even though most operators increasingly use less expensive technologies (e.g. FDM) for prototyping applications, CRP Technology leverages SLS technology and elastomers to produce parts.

However, it should be noted that some AM suppliers have developed materials that can be used to produce functional parts.

Stratasys, for instance, has recently brought to market advanced elastomers and enhanced materials for its leading FDM and PolyJet machines. The FDM elastomer solution delivers new levels of elasticity, durability with true soluble support – while advanced colors for PolyJet drive enhanced realism to transform legacy design and prototyping processes.

Offered across the F123 3D Printer platform, the Stratasys TPU 92A Elastomer is designed to meet the needs of manufacturers requiring high part elongation, superior toughness, and full design freedom.

"Creating elastomer parts using traditional silicone or CNC molds are extremely costly and time-consuming – while it is our view that other additive techniques just cannot deliver parts with the size and complexity of our elastomer approach," **Zehavit Reisin**, Vice President and Head of Solutions and Materials Business, Stratasys. *"Manufacturers demand 3D printing solutions that can be put to work in real prototyping and extreme production environments. With reliable and highly resilient parts, our solutions are designed to enable customers to do just that."*



Technical specifications and application of elastomers in AM

Technical datasheets from Innofil3D and CRP Technology show that the chemical formulation of each TPU material varies from one manufacturer to another.

Speaking of Innofil3D's **Ultrafuse TPU 85A**, the TPU material is highly resilient, available in its natural white colour and has excellent wear performance. Furthermore, it has good flexibility at low temperatures and good damping behaviour.

Franco Cevolini, on the other side, presents Windform® RL («RL» stands for rubber-like), the first thermoplastic elastomer material within Windform® TOP-LINE family of high-performance composite materials.

"Just like all Windform® TOP-LINE materials, it is designed for laser sintering technology. Windform® RL shows excellent durability and stability. If elastomers lose their properties overtime; it should be noted that it doesn't happen to Windform® RL. The material accommodates chemicals and heat resistance and combines superior tear resistance with burst strength. Windform® RL withstands repeated bending and deformation. It is also UV resistant. Being a TPE material and thanks to its main properties, it assures high-performance sealing power. Since it is a TPE material and thanks to its main properties, Windform® RL is meant to assure high performance sealing power."

Some of the mechanical properties of Windform® RL are: "tensile strength: 5,2 Mpa (sintered value) 5,0 Mpa (Value after Windform® RL Seal infiltration). Tensile Modulus: 20,0 Mpa (sintered value) 20,3 Mpa (Value after Windform® RL Seal infiltration). Elongation at break: 397,1 % (sintered value) 383,6 % (Value after Windform® RL Seal infiltration). Shore A Hardness: 84,8 (sintered value) 83,0 (Value after Windform® RL Seal infiltration)."

CRP Technology produced Energica's motorcycles seat using 3D printing and Windform® materials. At the end of the manufacturing process, the company unveiled a 3D printed front air inlet made with Windform® high-performance materials.


Credit: CRP Technology – 3D Printed seat

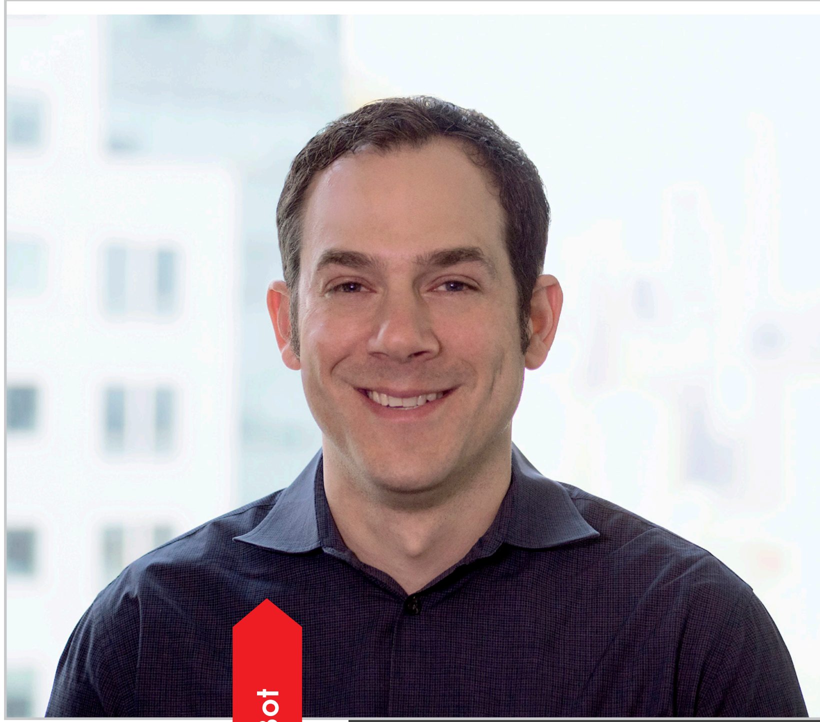
Market expectations

To sum up, *"due to their low production cost, their flexibility and their ability to be leveraged by several thermoplastic processing techniques, operators increasingly harness thermoplastic elastomers (TPEs). These advantages over conventional rubbers make them very competitive in all applications that do not require high elasticity or high heat resistance,"* explain 2 researchers from Paris-Sorbonne and the Ecole supérieure de l'industrie du caoutchouc.

In additive manufacturing especially, a similar situation with other polymer materials can be observed: the lack of qualified materials that can be used on different AM technologies. Stratasys and CRP Technology are part of the few specialists that have unveiled different applications of AM with elastomer materials. If other applications have been achieved with other technologies, they are not yet sufficiently popularized.

Lastly, one thing is certain: as long as elastomers guarantee high performance, the more the market expands, the more applications for mass production will be explored.

3D Printers



Dave Veisz, Vice President of Engineering, MakerBot

Pilot production with 3D Printing

Generally speaking, the term "pilot" is meant to be the testing ground to gauge a new product. In the TV world for instance, it is a standalone episode of a television series that is used to sell the show to a television network. In the industry, a production line is set up usually during engineering or manufacturing development, to test new methods, processes, and systems. We wanted to discover more about it in the additive manufacturing industry, and we asked MakerBot a few questions.

We are almost sure that MakerBot is a company that does not require further introduction but let's follow the rules and introduce the manufacturer.

MakerBot is an American desktop 3D Printer manufacturer. The adventure officially started ten years ago, in January 2009 with Bre Pettis, Adam Mayer, and Zach "Hoeken" Smith. Six years ago, the company became a Stratasys company. Over time, the company has built a unique positioning in bringing 3D Printing to students.

We have witnessed a sort of "quiet period" in the company's activities, but with Nadav Goshen as CEO, the company has opened a new chapter of its history. A chapter in which we have witnessed the launch of new FDM 3D Printers including Method & Method X, 2 FDM 3D Printers that integrate industrial 3D Printing features.

In this article, Dave Veisz, Vice President of Engineering, MakerBot has shared the company's insights into FDM technology. This article aims to present an overview of what happened before the official launch of a product, a 3D printer especially. More importantly, it will question the importance of FDM technology in a pilot program of a given product.

Pilot program of a 3D Printing system

Every year, several 3D Printers are unveiled in the 3D Printing community. Each of them aims to be the gamechanger for makers, engineers and companies. In such a competitive market, the consumer is lost and does not know who to turn to.

Furthermore, only a few numbers of manufacturers are willing to share some insights into the process they follow to launch their product. Such a process might enable to evaluate the efforts invested in delivering a premium product and helping the user in his decision-making process.

As explained earlier, a pilot program is an experimental trial that helps a company to evaluate how a large-scale project might work in practice. Even though we do not question the advantages of such a trial, it should be noted that running a pilot program varies from one company to another. So far, we haven't yet seen a defined guide applied by manufacturers of 3D Printing systems.

METHOD

FDM 3D PRINTING AND THE LAUNCH OF NEW PRODUCTS

Two years ago, Impossible Objects, a manufacturer that develops a composite-based additive manufacturing method (CBAM) launched its AM System Model One. A pilot program has been launched with a few beta customers whose names were not unveiled.

We have seen that the development of a desktop 3D Printer was slightly different:

"In the development of the MakerBot METHOD 3D Printer, for example, there were several milestones build and test cycles leading up to the start of serial production and shipping. The initial builds are using primarily prototype (3D printed plastics, machined metals, quick turn electronics), but as the design matures, the builds become more production representative and consist of a mix of tooled parts and rapid prototyped parts, and the numbers of units increase so that more thorough testing can be performed.

For a new platform like METHOD, a «pilot run» for MakerBot is generally at least 100 full assemblies so that we have enough units to perform statistically relevant testing for reliability and performance as well as the manufacturing process and in-line quality control. One unit may be adequate for proving out early stage proof of concept, but for a Pilot run, the quantity needs to be enough to sufficiently test the variability in part quality and the manufacturing process", explains **Dave Veisz**.

This procedure has been applied to MakerBot METHOD 3D Printer. Other manufacturers certainly adopted a similar path but we can't confirm it right now.

Now, before the launch of a consumer product, are processes exactly the same?

FDM 3D Printing is, without any doubt, the most widely used technology in the additive manufacturing industry. Nowadays, it is a technology of choice for both makers and enthusiasts that wish to discover 3D printing and for companies that wish to take their first steps into the technology.

"FDM printers are used in primary schools to introduce students to design thinking and other STEAM topics, but are also used to produce end-use aerospace and defense parts that have extremely demanding requirements. Therefore, FDM printers cover a very wide range of use cases. FDM printing is a great introduction to 3D printing because it is an accessible and safe 3D printing process that does not require hazardous chemicals, or secondary processes to create a usable part quickly" said MakerBot Vice President of Engineering.

As far as companies are concerned, market testing and pilot production remain one of the most expensive parts of launching a new product. Indeed, with conventional manufacturing processes, small run tooling can quickly become costly, especially if the part design regularly changes. And obviously, not trying every single idea/design can result in investing in a product that will not perform well in the market.

Pilot production with 3D Printing offers an alternative to this issue. Indeed, using 3D Printers, manufacturers can produce one prototype, small to mid-volume production runs of a product without any of the tooling cost. Furthermore, in most cases, these 3D printers remain FDM 3D Printers. For MakerBot's Dave Veisz, several reasons can justify the choice for FDM, but as volume goes up, the need to consider tooling will become more obvious:

"Many companies are doing this in addition to using FDM 3D printers for the production of serial production parts. The main criteria are the requirements of the part (material properties, mechanical loading, etc.) to determine if FDM is the right technology in terms of capabilities, and the second consideration is economics. FDM is easy to justify for high mix, low volume production as there are no large expenditures or lead times for tooling in FDM parts in comparison to molded or other near net shape processes.

However, as volume goes up, dedicated tooling becomes more justifiable over FDM due to generally lower piece prices over the life of the product. Another point to make here is that there are part geometries that are possible to create in FDM that are not possible to create by traditional manufacturing methods. This includes designs with internal voids or variable cross-sections and dynamic «print-in-place» assemblies. Thus, high-tech industries like medical, aerospace, and advanced manufacturing are designing production parts that take advantage of the freedom of 3D printing and reducing part counts, improving strength to weight ratios, and achieving other advantages that justify the use of FDM in manufacturing production parts."

FDM 3D Printing is therefore an interesting alternative that allows startups and design firms to do market testing affordably and quickly; not to mention that its affordability makes it possible to do more tests then normal.

The next question that crosses our mind then is to know the characteristics of ideal FDM 3D Printers for pilot production.

Key features to consider when choosing FDM 3D Printers for pilot production

When it comes to FDM technology, the user will mostly pay attention to the **printer parameters, warping, layer adhesion, support structure, infill & shell thickness, materials and post-processing stage.**

As far as printer parameters are concerned, from a designer's perspective, build size and layer height are essential.

Warping is a common defect in FDM. When the extruded material cools during solidification, its dimensions decrease. However, here again, the operator can reduce this probability by choosing a 3D printer with large flat areas or by choosing different materials.

Moreover, if infill and shell thickness affect the strength of a component, the material used, on the other hand, may affect the mechanical properties and accuracy of the printed part. And the thing is that there is a wide range of materials available for FDM. They range from commodity thermoplastics (such as PLA and ABS) to engineering materials (such as PA, TPU, and PETG) and high-performance thermoplastics (such as PEEK and PEI).

Lastly, an array of post-processing techniques exists. Some of them include sanding and polishing, priming and painting, cold welding, vapour smoothing, epoxy coating and metal plating.

In a nutshell, nothing is black or all white when it comes to 3D Printing. Every single feature plays a crucial role in the user experience and will determine if he will renew his experience with the 3D Printer. Unfortunately, the issue encountered while using a specific 3D printer is not necessarily the same with the FDM technology of another manufacturer.

That's certainly the reason why **Dave Veisz** lays emphasis on the rendering of the 3D printed part:

"The ideal characteristics of FDM printers are the incorporation of controls and features that enable the user to print accurately, repeatedly, and reliably. You need to be able to trust that the 3D printed part is an accurate representation of the design and that the part will have the same properties each time it is printed. In manufacturing, variability is the enemy, so you want a printer that has enclosed, sealed material bays to keep material dry and an enclosed, temperature-controlled chamber so there is consistency in the quality of the print regardless of the environment. Material capabilities per printer platform vary, so that will be consideration.

The other consideration is whether support material is required and the type of support (breakaway vs. soluble). With soluble support, it is possible to print geometry with voids and small support inclusions whereas certain geometries are not capable with breakaway support. There is a wide variety of cost options and the claims that manufacturers are making can be confusing. There is a difference between being able to print a material, and being able to print a material accurately and repeatedly. Accuracy and repeatability really do require the "industrial" feature set regarding controlled printer and material environments and soluble support in order to reduce process variability and allow geometric freedom."

INTERVIEW RUTH HOUBERTZ

Co-founder & CEO of Multiphoton Optics

"We are bridging the gap between micro/nano technology, 3D Printing and injection moulding"

Physicist by training, Ruth Houbertz has dedicated her life to building equipment. She is part of the EPIC (European Photonics Industry Consortium) and is certainly one of the 4 female CEOs that everybody who is looking for a career in photonics needs to know. A few minutes with her will enable you to discover a brilliant woman that knows how to make complex concepts easy to understand for everyone.

One key element of this interview is photonics. This technology generates and harnesses light and other forms of radiant energy whose quantum unit is the photon.

What led to the creation of Multiphoton Optics?

"I wanted to revolutionize optical data transfer. On the other hand, we identified many different applications and markets in optics and photonics."

The whole experience has started by late 2000. Ruth was working at Fraunhofer ISC in materials and technology development. The beginnings of the technology were done with LZH. In the course of her works, she aimed at building equipment that would revolutionize the photonics industry and would enable a wide range of new applications. Finding the right person to help her build the desired equipment was not an easy task. That's how she turned to 3D printing and explored the possibilities offered by this technology.

Supported by various partners around the world, her fascination for 3D Printing led her to explore the technology's principle with other fields of activities such as semiconductor and optical interconnects. From one experience to another, she then came up with 3D lithography which is now High Precision 3D printing, a technology that enables to create photonics and optical interconnects.

"Simply put, several things led to the creation of Multiphoton Optics: the fascination for 3D Printing and its ability to print any design, my collaborations with semiconductor companies, photonics institutes and optical interconnects specialists. One specific reason that explained the confidence I have in this industry is this simple analysis from another sector: when we looked at telecommunications, it became very clear to me, that the increasing amount of data transferred via internet, would lead to a crucial challenge: energy consumption. It then became obvious to me that we needed much data transfer possibilities in order to lower energy consumption and to protect our environment. In this specific case, we are talking about optical data transfer. Today, with the technological advancements, we can actually reduce the energy consumption for transfer builds. Another reason is that using photonics for production enables to obtain a powerful tool that will serve various industries."

After several researches and after overcoming various challenges, Multiphoton Optics (MPO) GmbH was officially founded in 2013. As Houbertz stated, speaking of the company's services: "We sell equipment, but most of the job remains license. We focus on applications & services. We have a real industry 4.0. approach."

What are the sectors of activity where high precision 3D Printing can be applied?

"We target any industry that uses photonics components which can be produced with our machine", said the Founder and CEO. In other terms, the possibilities are endless since photonics involve the use of lasers, optics, fiber-optics, and electro-optical devices in a wide range of technical fields including manufacturing, healthcare, telecommunications, environmental monitoring, homeland security, aerospace, solid state lighting, and many more.

Furthermore, "we are currently living in a total accessible market that is worth 2 hundred billion dollars and we can expect further expansion", explained **R. Houbertz.**

There is a growing number of companies that start specializing in High Precision 3D Printing. How do you perceive it?

"The more advanced the technology is, the more we will see competitors in the industry. This growing number of competitors just confirmed my idea that we are on the right track. Besides, I strongly believe that competitors enable us to push our limits in order to provide the market with the best technology and with the most sophisticated solutions. I have already had a few exchanges with some competitors and sometimes, it's really healthy."

LithoProf3D® provides a platform that integrates both, an additive fabrication mode and a subtractive fabrication mode. How is it possible? Is it possible to use both processes at the same time?

First, it should be noted that High Precision 3D Printing on a sub-micrometer scale enables the creation of structures in an additive process using materials such as photosensitive polymers and hybrid polymers. In a subtractive way, special glasses and metals can be used.

The type of materials used will determine the type of manufacturing process in which the machine will operate: be it additive manufacturing, subtractive manufacturing or another process.

"Both processes cannot operate at the same time because there is only one light source. In order to use both processes at the same time, we would need to integrate another light source", adds Houbertz.

How do you explain the gap between 3D printing, micro/nano technology and classical fabrication of optics?

"There is still a gap but we will close it. We will do even better. We are basically bridging the gap between micro/nano technology, 3D Printing and injection moulding, because Multiphoton Optics' technology enables to overcome obstacles in design and manufacture of components. Its name is the program."

You recently closed a Series B Financing round. Could you share further details about what's next?

"We have recently achieved a milestone in our activities. Multiphoton Optics has improved the fabrication speed of 3D structures by implementing massive parallel fabrication. Together with 12 partners in 5 different countries, our main goal was to bring 2D and 3D printing to a new level. To achieve this objective, Multiphoton Optics has demonstrated – using a specially designed optics from IMT Atlantique – that its newest model of the LithoProf3D®-GSII series, the LithoProf3D®-GSIIP, is capable of 3D printing 121 structures of 4 µm x 4 µm x 12 µm in just 70 seconds with high quality. Compared to serial fabrication, one would need 2.5 hours for the same amount of structures in this special setup."

Any last words to add?

"High Precision 3D Printing will rock the world."

www.multiphoton.net

EURO PM2019 Congress & Exhibition

Marches on to Maastricht

The annual Euro PM Congress & Exhibition, organised and sponsored by the European Powder Metallurgy Association (EPMA), is taking place in the centrally located city of Maastricht, The Netherlands.

In line with recent Euro PM Congresses, 2019 has again recorded a high number of abstracts from across the Powder Metallurgy community, has resulted in a positive number of technical sessions. This will make for an active 3-days of presentations, discussions and networking opportunities at this year's event. 2019 will again be an all topic event, representing all areas of powder metallurgy – Additive Manufacturing, Functional Materials, Hard Materials and Diamond Tools, Hot Isostatic Pressing, Metal Injection Moulding, New Materials Processes and Applications and conventional Press & Sinter.

The event will take place for the first time in Maastricht at the Maastricht Exhibition Congress Centre (MECC) a modern facility within easy reach of the city. From Roman origins and the largest city in the province of Limburg, Maastricht is a thriving place to meet and discuss new business opportunities.

MECC will be the hosting all the Technical Sessions, Exhibitions and EPMA Sectoral Group Meetings during the 4-days of the annual event. Delegates will be able to choose from 7 parallel strands all covering the powder metallurgy aspects, technologies and sectors. The opening session will provide an 'Overview of the Graphite Industry from the PM Perspective' presented by Asbury Graphite & Carbons, as well as, a presentation on 'Powder based Laser Processes in the Context of Digital Photonic Production and Industry 4.0' by Prof Johannes Schleifenbaum Chair of Digital Additive Production, RWTH Aachen, Germany. After the opening sessions there will be a special panel session called '60 Years of EPMA: From 30 Years Ago to the Next 30 Years', that will represent all the different PM sectors, facilitated by Dr Cesar Molins, AMES SA, Spain, as part of EPMA's 30th Anniversary celebrations.

Additional to the 3-days of technical sessions there will be 8 Special Interest Seminars (SIS) within the programme focussing on a specific industry topic for deeper understanding. The SIS's cover the following sectors –

• Additive Manufacturing - The 30 Years of EPMA – Looking Back and into the Future of AM

• Additive Manufacturing - Industrialisation of AM

• Additive Manufacturing & Hot Isostatic Pressing - Optimising the Properties of AM Parts Using Hot Isostatic Pressing

• Functional Materials - Porosity from Past to Future: A Defect to Avoid Becomes an Added Value

• Functional Materials - Porosity from Past to Future: Applications and Case Studies

• Hard Materials & Diamond Tooling - Nano, Near-Nano and Ultrafine Hardmetals Part 1 & 2

• Hot Isostatic Pressing - The Future of HIP

• Metal Injection Moulding & Additive Manufacturing - MIM and AM

Within the programme there will be ample opportunity to network with PM industry colleagues and discuss pertinent issues arising from the technical sessions during the scheduled coffee breaks. New for 2019 will be the ability to join/lead a Campfire Meeting, a relaxed meeting time to discuss a relevant topic for up to 30-minutes. These Campfire Meetings will be steered by a facilitator to get the most from the discussion topics and will take place during the Tuesday lunch break.

On Wednesday evening, all participants are invited to enjoy a special 30th Anniversary Closing Drinks Reception at the MECC, prior to the annual Congress Dinner, to raise a toast to the Association and its achievements. The Congress Dinner will take place at Château St. Gerlach where attendees will be able to network during a seated dinner in the newly build Pavilion building.

Registering before the 4th September 2019 allows participants to take advantage of the Advanced Registration Rate. The Euro PM2019 Congress & Exhibition Technical Programme PDF provides all the details and costs associated with this year's Euro PM2019 Congress & Exhibition event and can be downloaded at www.europm2019.com or alternatively download the Euro PM2019 Congress & Exhibition App via Apple/Google stores, to have the content of the technical programme in the palm of your hand!

Euro PM2019 Congress & Exhibition, will help celebrate the associations 30th Anniversary with additional sessions and social events surrounding this landmark.

Andrew Almond
EPMA's Marketing Manager
aja@epma.com

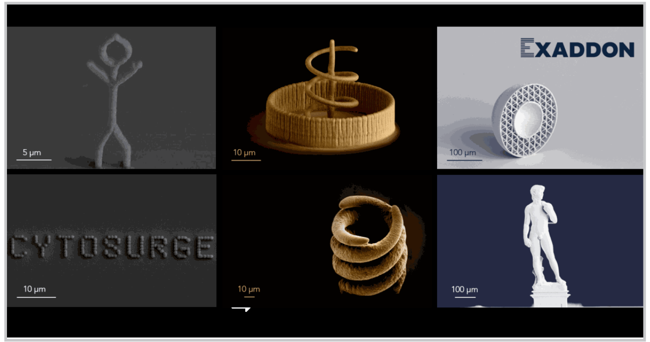
News Round Up

This is an industry that never sleeps. The summer period did not prevent companies from unveiling exciting projects in the additive manufacturing industry. Discover below the hot news you shouldn't have missed during this summer!

Business

- Physna, short for "Physical DNA", secures $6.9 million in series A funding to create the "Google of 3D Models". Physna has developed a search technology that enables anyone to search 3D models in seconds. The next step for Physna is to increase the database of 3D models by adding models that are increasingly used in a wide range of sectors including manufacturing, aerospace, automotive, defense, consumer goods, electronics, and energy. The company has now all the tools in-house to become the standard for "3D Search". Can we believe in this dream?

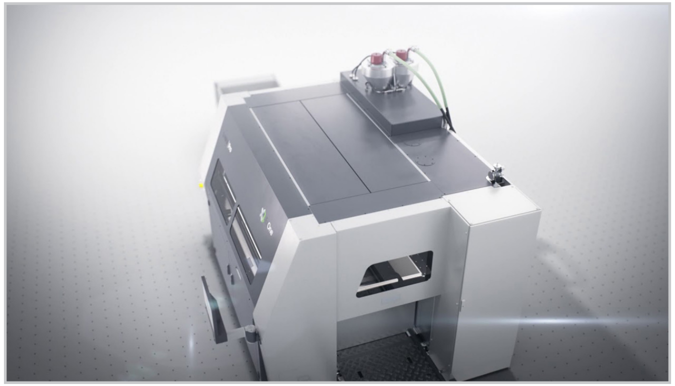
- Meanwhile in Switzerland, Exaddon AG officially debuts as a standalone company in the AM industry. The former 3D printing business unit delivers something unique: "CERES", a metal 3D printing system that can print with nanometer resolution tiny objects in sizes from 1 μm to up to 1000 μm.



3D Printers

Several companies unveil new 3D printers during the past two months:

- **ExOne** unveiled an Industrial 3D Sand Printer named **S-MAX Pro™.**



- In the FDM Segment, MakerBot adds Method X to its portfolio, less expensive and with more features than its predecessor Method.

- **Airwolf 3D** followed with **EVO R**, its second FDM 3D Printer.

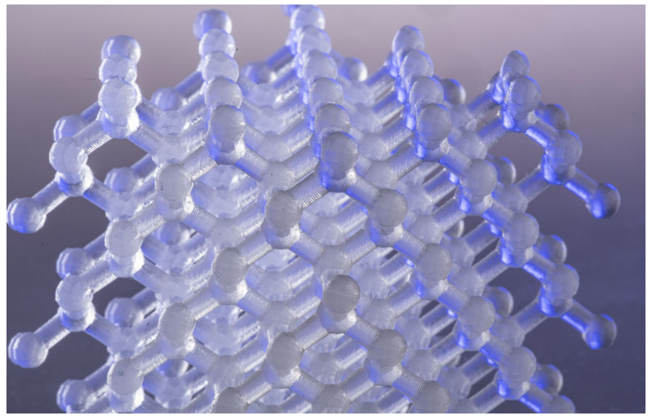
- Lamp manufacturer Gantri also launched its FDM 3D printer but this one is not meant for commercialization. The company wants to harness its 3D printers to continue the production of its various products.

- **Kumovis** closes the FDM chapter with a 3D printer designed for the medical industry. A clean room integration makes the 3D printer outstanding.

Lastly, in 3D Printed electronics, Nano Dimension launched Lights-Out Digital Manufacturing. The company claims a faster printing of electronic circuitry and a wide range of opportunities for short-run, small volume manufacturing of printed electronics.

Materials

- Huntsman takes its first steps into the AM market with the IROPRINT® line, a line that comprises resins, powders and filaments designed for the AM industry.



- BASF left everyone speechless with the launch of Ultrafuse 316L, a metal- polymer composite designed for Fused Filament Fabrication (FFF). The material aims to deliver cost-efficient production of fully metal parts.

- Other well-known companies include 3DGence that revealed the Flexfill 98A. The flexible filament can also be 3D printed using the company's recent released soluble material – ESM 10.

- Lastly, Zortrax unveiled castable jewelry resins.

3D Scanners

- Faro added Cobalt Design to its portfolio. The 3D scanning solution would be ideal for prototype design, packaging design, digital cataloguing, jewellery and fashion design. It is also said to be ideal for scanning complex surfaces.

- Moreover, with the Galaxy Note 10 model, Samsung follows the move of other manufacturers of phone by integrating instant 3D scanning capabilities.

Software

- Exciting milestone for Sigma Labs who entered into collaboration with Airbus. The aerospace specialist will test and evaluate Sigma Labs' new PrintRite3D® version 5.0 software.

Applications

It was hard to decide but let's go or sustainability. BigRep has manufactured 3D-printed urban green habitat installation.

ADDITIVE MANUFACTURING EVENT IN 2019

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

GLOBAL INDUSTRIE CONFERENCES- 05- 08 March
Lyon, France

RapidPro 2019 - 13- 14 March
Veldhoven, The Netherlands

Additive Manufacturing Forum - 14-15 March
Berlin, Germany

APS MEETINGS - 19-20 March
Lyon , France

ADDITIVE WORLD 'Industrial 3D printing conference'
20-21 March, Eindhoven, The Netherlands

3D PRINTING EUROPE- 10 -11 April
Berlin, Germany

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

ADVANCED ENGINEERING 22 - 23 May
Ghent, Belgium

3D PRINT Exhibition 2019 / 4 - 6 June
Lyon, France

ROSMOULD 2019 -15-18 June
Moscou, Russia

Emo Hannover - 16 – 21 September 2019,
Hannover, Germany

TCT Show 2019 - 24 – 26 September
Birmingham, UK

Euro PM2019 Congress & Exhibition - 13 - 16 October
Maastricht, Netherlands

IN(3D)USTRY 2019 - 29- 31 October
Barcelona, Spain

FORMNEXT 2019 - 19 -22 November
Frankfurt, Germany

Metal Madrid 2019 - 27-28 November
Madrid, Spain

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