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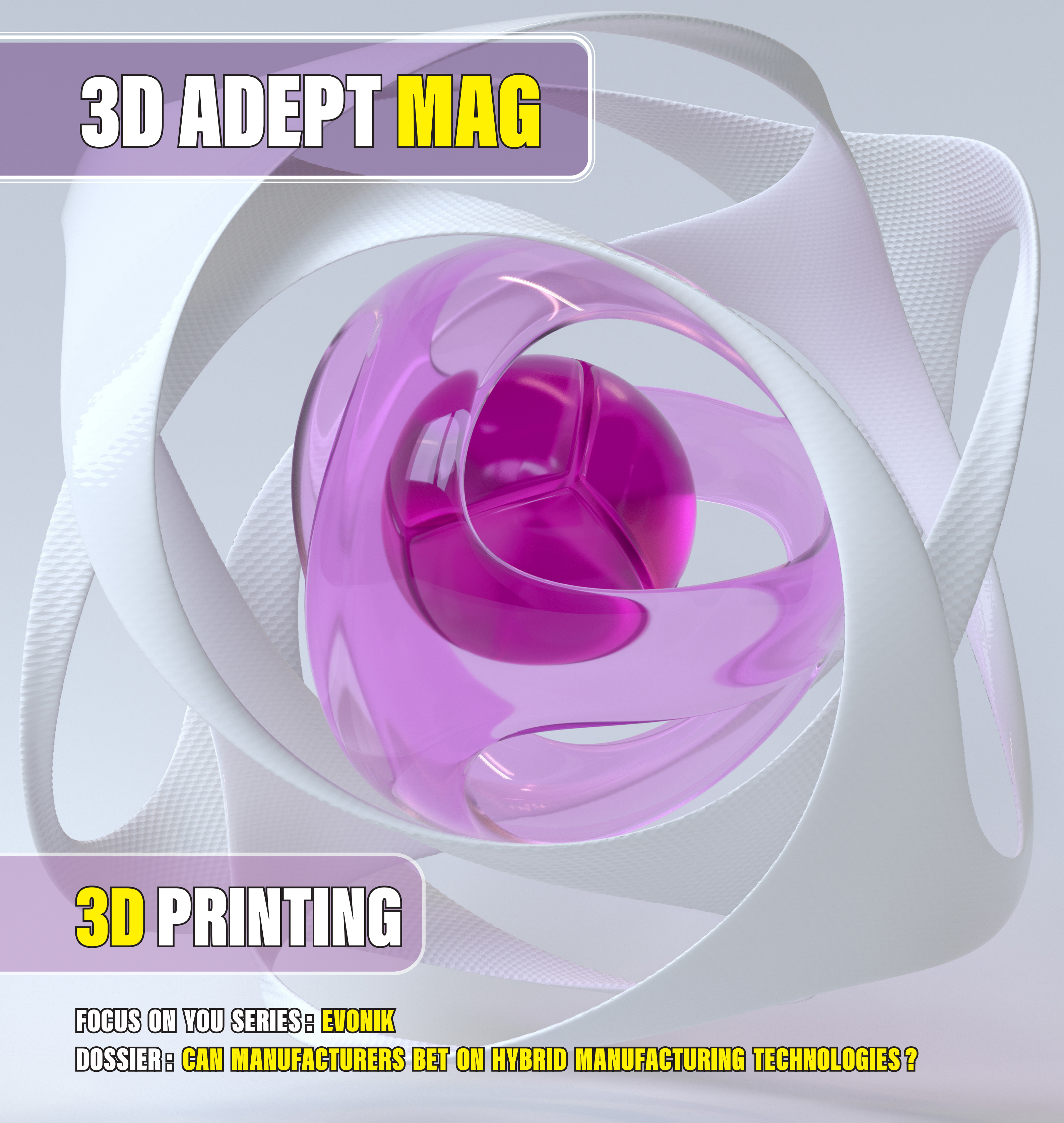
3D ADEPT MAG



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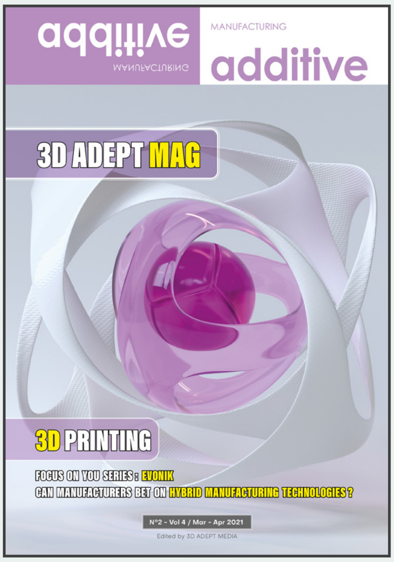

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SCAN ME

3D ADEPT MEDIA
All about Additive Manufacturing

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Hello & Welcome

How do you look at manufacturing?

On December 1913, when Henry Ford started operating the first manufacturing assembly line, the concept changed worldwide manufacturing operations by making volume manufacturing feasible and cost competitiveness attainable for the general public. Today, manufacturing has evolved so much that the term is now almost always used in «pairs» with another word: "additive manufacturing", "hybrid manufacturing", or even "advanced manufacturing" which is the term that encompasses all of the developments in the manufacturing field over the last 60-plus years including high-tech products, lean, green and flexible manufacturing.

In this March-April issue of 3D ADEPT Mag, we've had a look at some of these developments and we've realized that unlike most scenarios where we used to highlight the advantages of additive manufacturing over conventional manufacturing processes, sometimes, operators do not necessarily want to choose between the two manufacturing processes. Sometimes, they want both and even more. They want more automation, they want faster, smarter and more reliable processes, they want sustainable materials but they also know they cannot have all of that, without qualification, certification and standardization.

This issue captures the essence of hybridity from the manufacturer's point of view but also from the user's point of view (understand the key verticals like automotive). It sheds light on those ingredients that make us talk about manufacturing using a compound word; ingredients that include the link with IoT, post-processing, and even an underappreciated component: materials. Most importantly, it highlights the differences between qualification and certifications and the next challenges for AM companies to overcome.

As it provides several answers to different manufacturing concerns regarding the aforementioned developments, it will leave you with one question that you will be uniquely positioned to answer: **How do you look at manufacturing?**

Kety SINDZE
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Editorial

CAN MANUFACTURERS BET ON HYBRID MANUFACTURING TECHNOLOGIES ?

As its name suggests, the purpose of "Hybrid Manufacturing" is relatively easy to understand: taking the advantages of both additive and subtractive technologies within the same machine. The concept is relatively new as first hybrid manufacturing (HM) machines were launched in the 2000s. And like any new technology, there is a set of challenges, there is a learning curve and there are several concerns it raises within industries.

Unlike most scenarios where we used to highlight the advantages of additive manufacturing over conventional manufacturing processes, this article will look at the way they complement each other within the same platform. The concept becomes intriguing when one knows that additive processes start from the ground up while subtractive processes start from the top down – or when AM processes consist in adding raw materials, layer-by-layer to form a product while subtractive manufacturing consists in removing raw materials until the desired dimensions are met. Given the variety of additive and subtractive technologies that exist, **what type of technologies can be combined to form a hybrid technology? What can we expect from a manufacturing process that involves the use of a hybrid manufacturing system? And what are the investments and implementation costs?**

As we saw with AM, the potential benefits of HM have convinced some early adopters on the market. As a matter of fact, in the exhaustive list of companies that developed HM processes, one counts DMG MORI, ELB-Schliff, Matsuura, Mazak, Mitsui Seiki, Okuma, Meltio, 3D-Hybrid Solutions Inc., Hermle, Siemens, Sodick, Diversified Machine Systems, Fabrisonic, Optomec, Thermwood, Weber Additive, Sulzer, and Hybrid Manufacturing Technologies, Imperial Machine & Tool Co. to name a few.

However, to tackle this topic, we have invited **Hybrid Manufacturing Technologies**' Co-founder and CEO **Dr. Jason Jones** as well as **Hans Weber Maschinenfabrik GmbH**'s Commercial Director Additive Manufacturing **Manuel Kolb** to share the manufacturer's perspective. CGTECH's Product Manager, **Gene Granata** will touch on the software aspect of this topic.

The combination of additive and subtractive processes

As you may know, the AM portfolio covers various types of technology processes, which can be divided into three main categories: AM technologies that process **powders, liquid** and **solid** – each of them requiring a wide range of materials.

Traditional subtractive manufacturing on the other hand, is first intended for metals. Over time, this portfolio has included other processes that are compatible with a wider range of materials. They include **electric discharge machining, CNC machining, water jet cutting, electrochemical machining** and **laser cutting**.

Directed Energy Deposition (DED)* is often mentioned as the main AM process that can be hybridized but it turns out it is not the only one.

"Any type of additive process that uses a nozzle for deposition can be combined with milling, grinding, or even laser cutting/ablation. The most common combination is Directed Energy Deposition (DED) with CNC milling of metal parts. Material Extrusion (ME) with CNC milling for polymer composites is also a growing adoption path, particularly for making fixtures and tooling", **Jason Jones** from Hybrid Manufacturing Technologies states.

The truth is, while in the end, one only talks about hybrid manufacturing, it should be noted that manufacturers can either develop off-the-shelf hybrid machines or modify existing additive or conventional manufacturing machines to form a HM process. In this vein, in addition to DED, AM processes like **sheet lamination** and **powder-bed fusion** can be used in various forms with **CNC machining**. For instance, Beam-directed technologies, such as **laser cladding** can be integrated with computer numerically controlled (CNC) milling machines by mounting the cladding head to the z-axis of the milling machine.

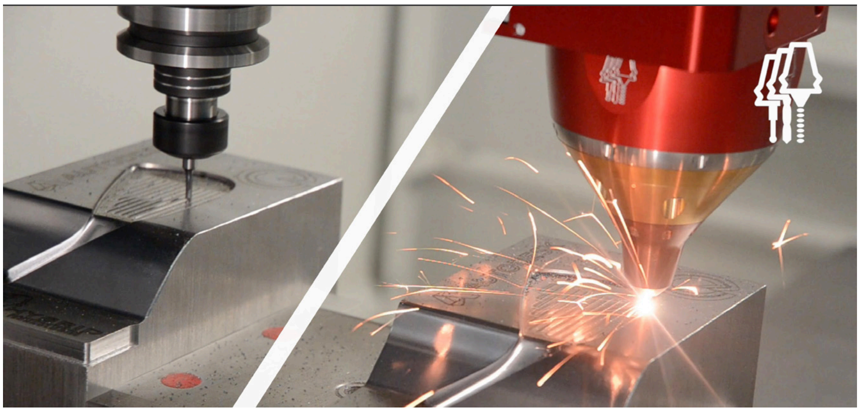
Jason Jones, CEO of Hybrid Manufacturing Technologies

Speaking of hybrid machines his company develops and commercializes, Jones explains:

"The part shape and material(s) determine the processes required and the required accuracy for the machine. We choose the best combination of machine and processing heads/tools for our customers. We integrate the modules into existing machines or supply new turnkey systems.

When budgets are tight, often customers will opt for field integration into machines that they already own. However, additional capabilities come with one of our fully optimized turnkey solutions. We have solutions running on CNC machines (verticals, universals, mill-turns, etc.), gantries, grinders, robots, and parallel kinematic machines (hexapods, etc.)."

In the quest for the ideal system that will disrupt advanced manufacturing technologies, manufacturers have explored the combination of **Wire-Arc Additive Manufacturing* with milling.** Due to the deposition rate of WAAM that can reach up to 50–130 g/min with almost no limitations of the build volume, compared to 2–10 g/min in laser- or electron beam-based processes, the combination with milling is acknowledged for delivering high productivity, low cost, high material utilization, and high energy efficiency.



Credit: Hybrid Manufacturing Technologies – Legend: Tool steel forging die enhanced and finished in a single setup using a hybrid CNC featuring the AMBIT™ ONE LMD system

Furthermore, researchers have also found out that new capabilities can be reached in a newly developed hybrid form of manufacture: **Ultrasonic Additive Manufacturing** (UAM), or **Ultrasonic Consolidation** . Designed for metal components, the manufacturing process - which is classified in the category of sheet lamination - would raise the interest of those who are looking to produce multi-material structures with embedded componentry.

Also, **cold spray processes** that keep the metal powders in a solid state instead of melting them as seen in thermal processes have been explored in hybrid processes due to the deficiency in ductility/plasticity of cold spray additive manufacturing materials which limit the applications with this process. – An exclusive feature has been dedicated to "Cold Spray" in the January-February Issue of 3D ADEPT Mag.

Another example of hybrid manufacturing technology can be seen with the **extrusion of plastic pellets**. "*We can combine fused granular fabrication with 5-axis milling to fabricate large, complex parts, with high surface quality and minimum material use. The additive process is a planar layer-by-layer melt deposition process, as known from fused filament fabrication. The milling process follows the same CNC machining concept Reichenbacher Hamuel is implementing in their classical subtractive machining centers. The two processes can be carried out sequentially: first the mentioned additive process, then the conventional milling process*" **Hans Weber Maschinenfabrik GmbH's Manuek Kolb** explains.

The manufacturing process of hybrid machines

Given the wide range of possibilities that exist in the HM portfolio, it won't be possible to have a closer look at each process developed by market players. With examples provided by Hybrid Manufacturing Technologies, Weber Additive and CGTech, we will have a look at what to expect from the manufacturing process at the **software**, and **post-processing** levels.

The software perspective

If AM processes require engineers to apply DfAM methods, it turns out that engineers who leverage HM should design for HM in a certain way. As a matter of fact, design software advances are pivotal to capitalize on the advantages of a hybrid manufacturing platform.

"Dedicated CAD/CAM and verification software is HIGHLY recommended to facilitate efficient and SAFE hybrid manufacturing. Every aspect of hybrid part manufacturing is more challenging, more expensive, and often unfamiliar to many companies breaking into this exploding field. Software dedicated to hybrid manufacturing helps by optimizing part designs for Additive Manufacturing (AM), offering unique operations not available in "subtractive-only" CAM software, and by verifying that the entire hybrid manufacturing process (sometimes involving multiple CNC setups and machines) will work as expected to produce the designed part.

Some manufacturers avoided investing in dedicated hybrid manufacturing software, and instead opted to use less efficient combinations of traditional subtractive CAD/CAM design and toolpath technology. They even resorted to manual editing/merging NC programs to create programs for hybrid CNC manufacturing. However, this approach is extremely inefficient and error prone, and sometimes led to expensive incidents in the shop with costly downtimes that followed", CGTECH's **Gene Granata** points out.

While Hans Weber, Maschinenfabrik GmbH's commercial director of AM, believes in the importance of design software advances, he lays emphasis on **three important aspects**: the necessity to **have an excellent 3D model quality or resolution, the calculation of the necessary printing offset of the contours** as well as the **thermally induced intrinsic bulk stress**. Taking the example of a HM process based on plastic pellets and milling, he states:

"One important aspect is the 3D model quality or resolution. It is highly recommended to avoid meshed formats like .stl, because the precise milling process can make these artefacts visible. If it cannot be avoided, then a proper mesh resolution is important.

Another aspect is the calculation of the necessary printing offset of the contours, so that the milling process has enough material to remove and guarantee a homogeneous and void free surface finish. The offsetting can be very individual depending on the exact geometric requirements.

The third aspect is the thermally induced intrinsic bulk stress in the printed material. During the milling process and removal of eventual support structures, the part can be deformed by the bulk stress and the release of fine structures by material removal. This must be respected during the planning of the milling process, to avoid excessive material removal at respective surfaces."

In a hybrid DED+CNC machine on the other hand, Hybrid Manufacturing Technologies' CEO observes that *"the deposition paths and the machining tool paths both need preparation. Fortunately, the digital workflow for both of these processes is nearly identical. In fact, both can be generated from the same computer model and often in the same CADCAM software."*

Several software providers currently offer solutions to do this in the same user environment. However, as part of this topic, we have asked CGTech's specific questions to understand the compatibility of their software with hybrid manufacturing.

CGTech first appeared on our radar after a collaboration with Thermwood, but the company has been active in the AM industry since the mid-2000's. Three years ago, the software provider introduced to the market **VERICUT 8.1**, a simulation software designed for additive and hybrid-AM processes including direct metal laser sintering (DMLS), wire-arc additive manufacturing (WAAM), and big area/large-scale composites additive manufacturing (BAAM/LSAM) methods.

First, *"an important and valuable aspect of hybrid manufacturing is optimizing the subtractive machining paths. With VERICUT Force optimization, this can be done while verifying NC programs, ensuring the final NC programs are not only free from errors, but the overall process is efficient as possible."*

"As we do with all of VERICUT's digital twin CNC machine simulations, we worked closely with the folks at Thermwood to simulate their LSAM machines, including the NC machine codes that control the additive functions: dispensing and monitoring of material, roller tangential following that presses the composites material onto the layer beneath it, and ensuring each layer builds on top of previously deposited material or some other build surface.

A simulation that runs in minutes can inform users when conditions are not suitable for additive deposition on their LSAM machine, detect when expensive collisions could occur with work holding fixtures or the part being built, optimize machining, and check that the final hybrid manufactured part matches the intended design", Granata notes.

For engineers, combining hybrid manufacturing solutions, new topology optimization and generative design software facilitates the redesign of assemblies as single parts, eliminates the need to create interfaces between components and allows for the lightweight and parts reduction strategies that are very demanded in product development lifecycle.

Gene Granata

Taking the example of VERICUT, Granata sheds light on software specifications related to AM, subtractive processes and hybrid technologies:

"Users can add then cut, or cut then add in any order. On hybrid CNC machines, the choices about the order in which additive versus subtractive process are applied to produce the part are controlled by the order of NC programs, and the specific NC codes and parameter values they contain. By processing NC programs in the same order as they will be used on the hybrid CNC machine users see exactly how the part will be built, and machined, to achieve the final shape. Multiple operations that are performed on different CNC machines can also be simulated via multiple "setups" in VERICUT. For example, consider a turbine impeller type of part that is created by first turning the shaft/hub on a CNC lathe, then is moved to a hybrid 5-axis machine to deposit the blades on the hub, and perform the 5-axis blade and finish machining. VERICUT users verify the entire manufacturing process end to end, so they know it will work as expected to make the finished part."

Manufacturing and post-processing

As far as manufacturing is concerned, it is worth noting that some processes for **producing metal parts** are not usually that different from processes that are used to **produce polymer parts**.

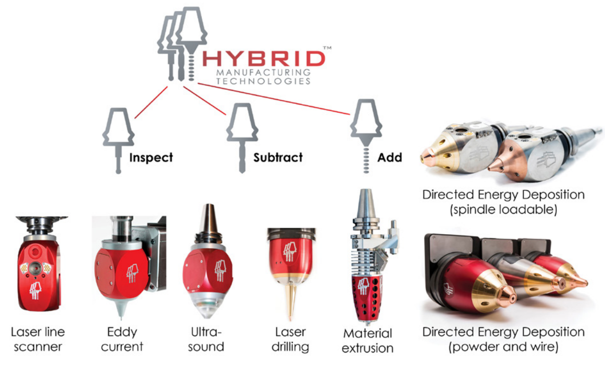
Imagine a machine that adds some material through a type of deposition process and then requires a tool change. Rather than using a deposition head, the operator will bring in a CNC milling tool that will remove some of the material. If desired, the operator can change the tool to use the additive process. While the two processes can be used interchangeably depending on the production needs, the difference is that for polymers everything happens at much lower temperatures.

But that's just one machine. We invite you to look at the specifications of manufacturing processes developed by other players. In this dossier, we have given a closer look at Hybrid Manufacturing Technologies' process as well as Hans Weber Maschinenfabrik GmbH's HM process.

The company provides *"a wide variety of additive (DED, ME, Jetting, Direct Write, etc.), subtractive, and inspection (probing, laser scanning, eddy current, and ultrasound) technologies integrated together". "Our AMBIT™ processing heads are automatically interchangeable so a customer can choose the combination of processes that best addresses their application needs. These technologies are controlled using edge computing and closed loop feedback to enable robust, optimized, and traceable performance"* **Jones** points out.

Interestingly, while the **AMBIT platform** is acknowledged for surface inspection, the manufacturer develops a tool head that can verify quality post-deposition, detect cracks and void beneath the surface of the part.

Not only does this enable CNC users to get quality assurance with their 3D printed part, but it also allows for an all-in-one manufacturing process in which an object is produced, finished and inspected in a single step.



Credit: Hybrid Manufacturing Technologies – Legend: AMBIT™ processing heads: interchangeable suite of heads for AM and inspection on CNCs and robots

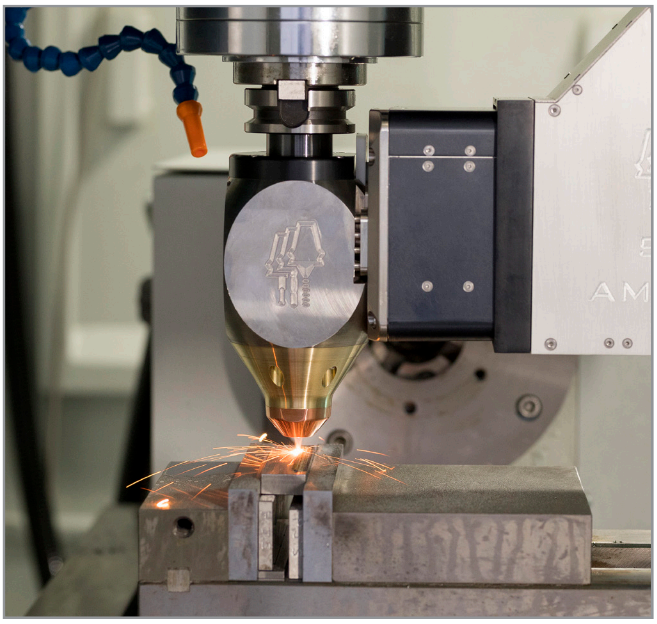
That's certainly the reason why, when he was asked the main stages operators should perform after the manufacturing process, he enthuses: *"The beauty of hybrid manufacturing is that often the post-processing can be fully automated. For metal parts, this routinely reduces the total cost of AM part production by 25-30% or more."*

Manuel Kolb

On the flip side, a look at the combination of fused granular fabrication and 5-axis milling from Hans Weber Maschinenfabrik GmbH reveals that it provides engineers with increased geometric design freedom as well as various extended component functions. Moreover, one item that can raise the interest in this process is the **uniqueness of materials and their optimization**.

While hybrid metal systems can process dissimilar metals to the same part – for instance, cladding with Inconel –, hybrid polymer systems can use injection moulding pellets and composite reinforced polymers. Multiple materials and new hybrid materials can be created and used to achieve an overmolding effect.

Speaking of Hans Weber Maschinenfabrik GmbH's HM process, Kolb outlines that hybrid materials *"consider the synergy effects of the know-how in the field of mechanical engineering (machine construction) and extrusion technology of the two companies Reichenbacher Hamuel GmbH and Weber Additive. These support the emergence of a variety of options for machine configurations and of the production of a wide range of component sizes."*



Credit: Hybrid Manufacturing Technologies. Legend: AMBIT™ FLEX 20 LMD head held in a CNC spindle depositing onto part in vice

For the Commercial Director Additive Manufacturing, the hybrid solution is an ideal production candidate for operators who are looking to achieve better accuracy and ideal properties of the given part, and to reduce post-processing stages in the manufacturing.

"We can extremely reduce the time to print large parts by printing fast with high material output and consequently with rough tolerances with high layer thicknesses. To achieve better geometric tolerances and a high-quality surface finish, the milling process is necessary to be carried out on the cooled down part. Therefore, applications for large parts will be much more economical in contrast to only additive technologies, where the build time would be extremely high. The thermally induced geometrical deformation gets worse with bigger parts. Whereas only AM processes will suffer from high deviations from the original geometry, the milling process solves this issue in a very straightforward way. Additionally, the automated removal of support structures can be also directly implemented in the milling process and saves valuable time for the part manufacturer", Kolb continues.

That being said, it should be noted that printed parts produced with Hans Weber's solution deliver properties similar to milled plastic parts. *"If these properties are not fulfilling the technical requirements, appropriate further post processing steps can be carried out. In some cases, the removal of support structures, a brim can take place first after the part was taken off from the build plate"*, Kolb adds.

Image: Hans Weber Maschinenfabrik – Legend: part manufactured with Weber Additive's machine.

Applications & Costs

Applications. All this literature would not be interesting if there was no proof of concept, right? Experts and researches we carried out reveal that hybrid manufacturing enables applications in **aerospace and automotive industries, repair and maintenance operations as well as mold and dye.** Even though, real use cases have not been shared yet, professionals also believe in the potential of the technology for medical parts, given the fact that 3D printing and machining are already widely used separately within this segment.

Compared to additive manufacturing technologies, three benefits we would keep from Hybrid Manufacturing Technologies' CEO are:

*"Hybrid machines bring three compelling capabilities. First, **in-process finishing** can create smooth surfaces on parts. This encourages faster deposition rates since the stair-step effect can quickly and easily be removed using machining. Second, **in-process inspection** enables assurance that the part produced is good inside and out before it leaves the machine. Lastly, **interchangeable AMBIT™ brand heads** mean that the most optimized tool or head can be used for each feature. This is a practical step that optimizes feedstock usage and cycle times."*

Image: Hybrid Manufacturing Technologies. Legend: Multi-metal brackets benefiting from the heat dissipation and lubricity of bronze with the strength of stainless steel, printed and finished in a hybrid CNC featuring the AMBIT™ FLEX system.

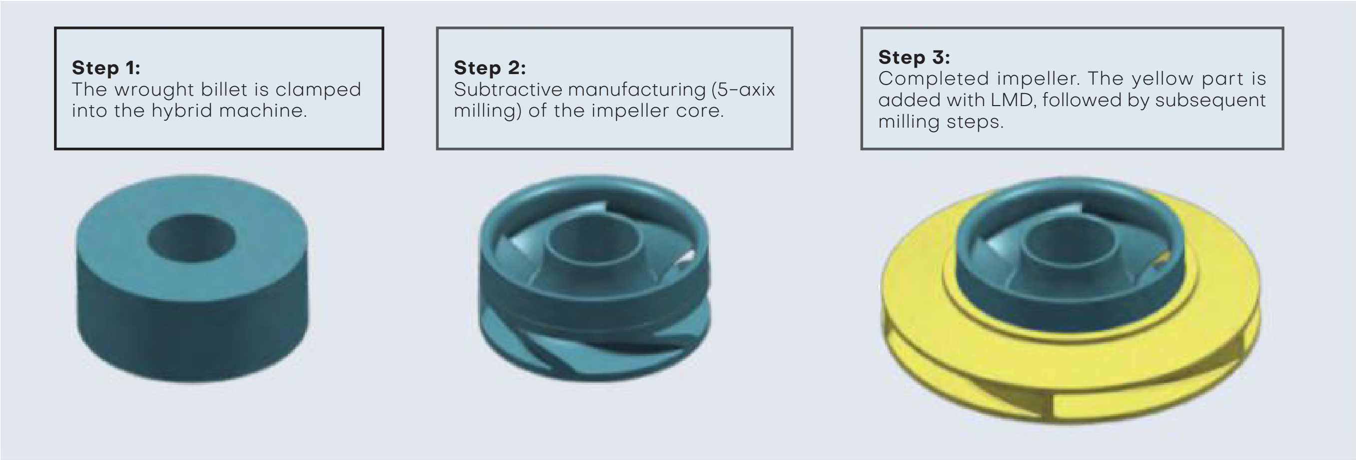
Although, very little information is spread on use cases that required the use of HM, we would like to mention the hybrid manufacturing of **impellers** by Sulzer, as a tangible example of this technology's capabilities.

Operators often opt for casting technologies to produce **closed pump impellers**.

The company explained that the high wrapping angle and twist of the blades often lead to high performance when pumping common fluids like water or oil. This optimized geometry does not allow the internals of an impeller to be machined from a forged material. Furthermore, this restricted accessibility for the tools does not enable the use of subtractive manufacturing technologies like milling or electric discharge machining (EDM) without compromising the original impeller geometry.

The team at Sulzer therefore used a hybrid manufacturing process that combines a **laser metal deposition and a 5-axis milling.**

"With a hybrid process, the amount of additive build-up can be limited. This helps to keep costs of the process reasonable. Additive build-ups quite often need support structures – but with hybrid manufacturing, these structures are often not necessary due to the variable build direction. Thanks to the final 5-axis milling, the material surface quality complies with the accepted industry standards. Because of the high geometrical precision, these hybrid-manufactured parts require less post-processing efforts", the company explains.

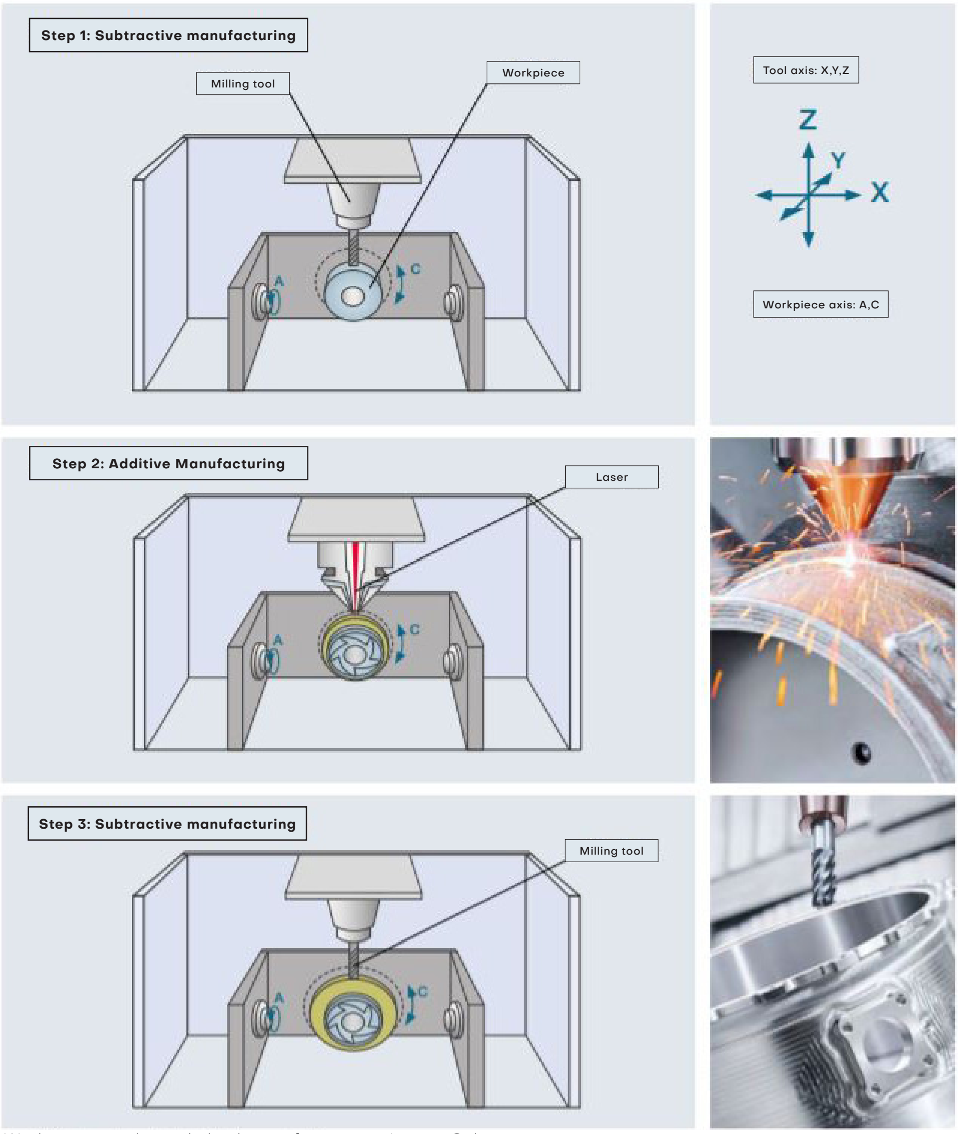


The main manufacturing steps of a closed impeller with hybrid manufacturing - Image: Sulzer

Thereafter comes the **question of costs.** Investments and implementation costs are often a challenge associated with each new manufacturing equipment. Currently, all companies cannot afford the costs of getting in-house AM capabilities. But, the decreasing costs of laser makes HM another alternative for companies that would like to transform their CNC machines into HM platforms. Furthermore, the flexibility and the ease of access are other arguments that work in favour of HM.

Companies that do not see the necessity to acquire a system, can always turn to service bureaus:

"Our in-house service bureau (hybridam.com) lets people use this technology without needing to invest in their own equipment. Next, AM can be added to their existing CNC and robotic equipment. This reduces implementation costs and allows for easy operator training and adoption. Also, hybrid machines generally reduce the amount of capital equipment needed to do AM by as much as 45%. This decisively contributes to the lowest total cost for each kilogram (or pound) of printed and finished material" Jones concludes.



Working steps during hybrid manufacturing - Image: Sulzer

At **Hans Weber Maschinenfabrik GmbH, leasing** or solutions such as **instalment purchase** can be envisioned when it comes to acquisition. The company is open to alternative financial solutions to support investment decisions and give customers the possibility to explore how relevant and efficient their solution is during a trial use phase.

Image: part manufactured with Weber Additive's machine

Advantages and areas for improvement of hybrid manufacturing platforms

The table below summarizes the main advantages and areas for improvement of HM platforms:

Advantages	Areas for improvement
Achieve higher accuracy or better surface finish	
Less need to focus on placement of support structures – as it is the case with AM	Important work to be done when it comes to optimizing the part to add materials or to mill away
Allow for different materials in a single process, which means that parts that require different material combinations can easily be designed	The number of parts produced via hybrid manufacturing may be relatively small
Less or no post-processing work: in-process finishing, in-process inspection & interchangeable heads	

About the contributors

CGTech *has been developing additive technology since the mid-2000's, beginning with advanced fiber placement and wide tape composites applications. With all the other CNC-controlled methods that were already simulated in VERICUT (e.g. milling/turning, grinding/dressing, waterjet and ultrasonic knife cutting), AM and hybrid manufacturing were just the next logical addition that the company knew its customers would come to expect, and need.*

Hybrid Manufacturing Technologies *is one of the first companies that brought hybrid manufacturing into the market. The company develops specialty tool heads that make it possible to transform any CNC machine into a hybrid AM system. [The driving factor of the company's success is its team. They are committed] to integrity and an open architecture approach. This lets [them] bring multiple types of AM technologies together with in-process finishing and inspection. Crucially, [Their] patented integrated solutions provide the lowest total cost of ownership and maximum operational flexibility for many applications.*

Hans Weber Maschinenfabrik GmbH *is a German machine manufacturer that develops and commercialises extruder technology, sanding and grinding technology, robotics and automation solutions, stock & used machines as well as AM systems. The company debuted in the AM industry three years ago and launched a unit dedicated to this segment: Weber Additive. It has recently invested in Colossus Printers and ambitions to establish direct extrusion as a standard manufacturing process.*

Short description of the main processes mentioned in this dossier

· In **a DED process**, a focused energy source, such as a plasma arc, laser or electron beam melts a material, which is simultaneously deposited by a nozzle.

· A **wire-arc additive manufacturing** combines automated metal inert gas (MIG) welding or laser hot wire welding with direct deposition 3D printing.

· **Sheet lamination** is one of the seven recognized AM methods. In this process, sheets of metal are bonded to form an object. UAM is an example process in this category.

· **Powder bed fusion** (PBF) methods use either a laser or electron beam to melt and fuse material powder together.

THE LINK BETWEEN IOT AND ADDITIVE MANUFACTURING

The term Internet of Things, short for IoT, has become so pervasive in industrial communication that manufacturers have (un)consciously acknowledge its pivotal importance for manufacturing without truly assessing and understanding its uses, benefits and how it actually impacts manufacturing. We have decided to shed light on this grey area in regard to the current additive manufacturing industry.

Is "the combination of IoT and Additive Manufacturing in the same sentence" only meant to create a buzz? Does IoT truly have the potential to disrupt AM? Or is it the reverse? The term that was coined in the 1990s for the first time, seems easy to understand and refers to a system of interrelated, internet-connected objects that can collect and transfer data over a wireless network without human intervention.

At the beginning, the term first embodied the concept of home automation, which includes but is not limited to lighting, heating and air conditioning, media, security systems as well as camera systems. The first goal at the time was to save energy by automatically ensuring lights and electronics are turned off or by making users aware of usage.

Over time, with the digital transformation of manufacturing, manufacturers outline this system of interrelated points as a core component of industrial transformation efforts hence the term Industrial IoT (IIoT).

The term has generated so much media hype that manufacturers often describe it interchangeably both as a module or an application. We have asked Gravity Systems, Nano Dimension and Twikit to clarify this grey area for us, and we came to realize that depending on the final purpose, IoT can be seen as a module and as an application.

Martijn Joris, founder & CEO at Twikit states from the outset : "The relation between IoT and AM goes in both directions. IoT can be used to industrialize AM processes, just like AM can be used to prototype and produce IoT devices."

"*We believe that IoT is rather a module than an application. Depending on the utility of the IoT device, its purpose is mainly 'data collection' in our case. Therefore, we use IoT more intelligently than a simple hardware 'add-on'. Data collected from a single device is usually part of a larger transaction where multiple devices and potentially additional business logic are needed to complete a transaction. We implement that consistency right in the edge*", outlines **Huba Horompoly**, Founder & Managing Partner at Gravity Pull Systems, Inc..

"*For Nano Dimension, it's an application. For us, IoT is something that needs to communicate. The recent advancements of additive manufacturing are currently enhancing product development processes and the way engineers design for several vertical markets. When we look at what we call "Additively Manufactured Electronics" (AME), there is a big potential for IoT devices*", states Valentin Storz, VP Marketing & General Manager EMEA at Nano Dimension.

That being said, the lines below will look at IoT as a module and IoT as key vertical.

How is "IoT" utilized as a component of AM production?

IoT solutions encompass everything designers, software developers and product manufacturers need to develop and implement ideas. They can include hardware IP and software platforms. Put it this way, IoT solutions look like everything and nothing at the same time.

From a technical perspective, IoT systems provide a reliable logic structure that can bring autonomous systems together, communicate and interpret data at a level unfathomable by human intelligence.

IoT solutions would therefore be a great advantage for sectors that are looking for digitizing their manufacturing processes, and introducing control as well as monitoring systems along the shop floor. For several industrials, Internet functionalities and data-based services aim to strengthen a production based on the Industry 4.0 paradigm, hence the terms advanced manufacturing, digital factory or industrial Internet of Things generally associated with IoT.

In the additive manufacturing industry, one company that has developed a dedicated IoT solution for the industry is Gravity Pull Systems, Inc. The Swiss software company has developed a software platform named Synoptik that reduces complexity in AM by enabling holistic process planning. Unlike other software systems of the same range that integrate individual single-point functions, Synoptik's approach enables best-practice applications for industrialised AM processes, from order entry, initial planning to production completion, including post-processing.

"Our IoT solution does not require specific tasks", Horompoly explains. There are several in-situ process monitoring applications available on the market. We excel in integrating the information generated by those solutions with our production logistics IoT apps, so we get a holistic picture immediately with analysed co-relations instead of a set of 'raw data' only. We do not simply collect raw data with our IoT apps and self-developed sensors but put them into the right context; this enables Synoptik to give recommendations on possible actions, to react on IoT generated

Huba Horompoly, Founder & Managing Partner at Gravity Pull Systems, Inc.

events in real time. Since our software links every event with costs, we recommend the optimal course of next actions not merely on the logistics level, but also based on financial insights that our optimizer detects based on pre-defined cost accounting principles."

As far as hardware is concerned, a company that has recently introduced IoT solutions dedicated to the post-processing stage of manufacturing is Solukon Maschinenbau GmbH. Their "Digital Factory Tool" encompasses production control, maintenance management, integration of automation and process validation / quality management.

We would like to draw attention to the production control where the machine manufacturer has integrated an OPC-UA interface* into its SFM-AT800 to allow for central controlling and monitoring. For those who do not know, OPC-UA stands for Open Platform Communications United Architecture. It is a platform that provides the necessary infrastructure for interoperability across the enterprise, from machine-to-machine, machine-to-enterprise and everything in-between. At Dresden-based Fraunhofer Institute for Machine Tools and Forming Technology (IWU), there is a Solukon SFM-AT800 that integrates this OPC UA interface within a modular robot cell.

Operators of this Solukon system explain that the robot cell is an example for downstream processing. Apart from powder removal, the robot cell includes a system for optical analytics of the geometry and a system for support removal, not to mention that it can also perform part loading and other jobs related to metal cutting. As pointed out by the concept of OPC-UA, each of these stations communicates with each other.

A scenario where IoT solutions are well integrated in a smart manufacturing environment is ideal for any industry, but its share of challenges often slows down its proper integration.

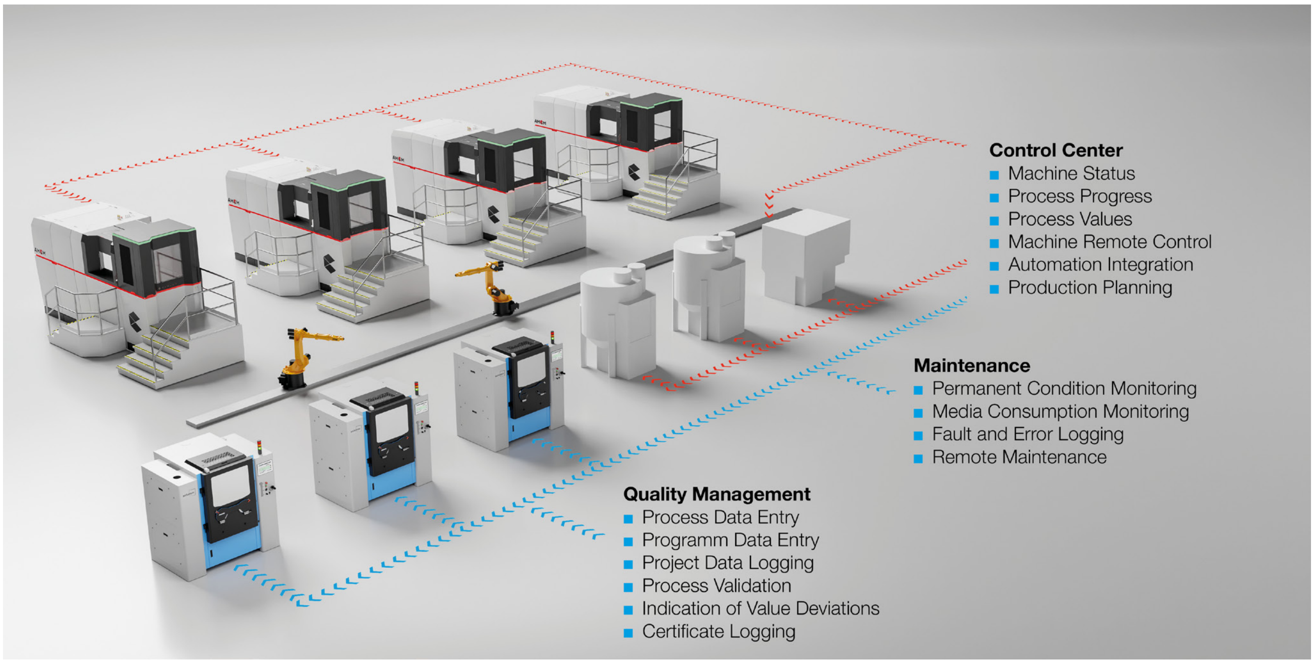


Image: Solukon – Legend: overview Solukon Digital Factory Tool

These challenges include for instance:

- Vulnerable components. Given the interconnection with a number of security disciplines, it is important to look at the convergence between IT security, OT security and physical safety and the shift from closed to connected cyber-physical systems.

- Supply chain complexity. This is a "pain point" for manufacturers of products who often rely on third parties' components for certain productions. This might result in an extremely complex supply chain with a large number of people and organisations involved that need to be managed. According to the team of security experts at Secure Thingz Ltd., not being able to track every component to its source means not being able to ensure product security, which is only as secure as its weakest link.

- Another challenge comes with the fact that industries need to secure product lifecycle – *"device security should be a subject of consideration through the product's entire lifecycle, even end-of-life/ end-of-support of the machine."*

Other challenges might include the "safety aspect", the "human factor", the security updates, and the challenge of handling all that data.

When asked how their solution addresses this security issue as part of an AM production environment, the Managing Partner at Gravity Pull Systems, Inc. declares:

"We developed a solution where any machine (or manually) generated data is validated by a private/public key pair, the validator being installed on a NFC Chip. Before being saved in a database or a blockchain, all data go through this process. We ensure end-to-end data transparency by the application of this infrastructure."

Despite its great promise, the truth is Industrial IoT is still nascent. The main use cases that have already demonstrated the potential for smart manufacturing include quality assurance and machine monitoring.

So far, no current communication standards have been developed for IIoT devices, which means that to get machines to communicate with IoT devices, and with each other, it's up to each organization to create its own interpreter software or to rely on third parties software providers like Gravity Pull Systems, Inc.

A look at IoT as a key vertical

Exploring IoT as a key vertical implies the use of AM technologies to enable IoT applications or to fabricate IoT devices.

Interestingly, a recent report from Market and Markets estimates that the smart manufacturing market would be worth $384.8 billion (€356.1 billion) within the next four years. A significant portion of that growth is 3D printing and its implications in the evolvement of IoT applications. Before diving into examples of applications, a quick look at AM technologies shows that 3D printed electronics is one of the key enablers for such applications.

While engineers can easily move from large wet-process factories to small labs and office spaces, according to Nano Dimension's Valentin Storz, *"there is a wide range of advantages when leveraging AME for IoT applications. 3D printing electronics allows engineers to produce and test a single IoT device in a day to assess its performance, not to mention that it enables lower material costs and lower waste. Furthermore, in sensor design, conductive elements can be printed directly on the board without using an etching and plating process."*

We learned thereafter, that this latter advantage becomes very interesting for the development of capacitive touch sensors, strain sensors, or chem-resistive environmental sensors.

The General Manager EMEA at Nano Dimension explains that with 3D printed electronics, engineers usually benefit from agile workflows.

It should be noted that, to achieve full interconnectivity between a wide range of objects for IoT, engineers must rely on both a transmitter and receiver (transceiver) to create the communication and connection between two objects.

Valentin Storz, VP Marketing & General Manager EMEA at Nano Dimension.

Speaking of IoT devices and the way they are produced, Storz states:

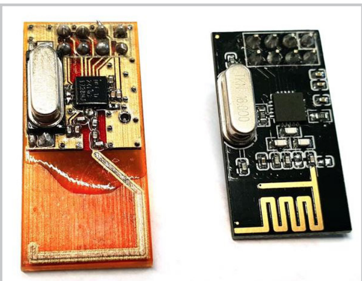
"IoT devices are smarter and more connected. Due to their use of both analog and digital signals, designers need to follow certain guidelines in the design phase. There are devices that need to communicate, that's why engineers will need to integrate wireless communication capabilities in their PCB. One way to do that is to embed an antenna and transceiver in the board."

Another method will consist in designing a printed antenna for the board manually. Since with 3D printed electronics, one can print directly on the substrate, engineers can thereafter easily adapt the board to antenna designs for IoT devices.

Low pass filter (LPF) devices are another interesting application that is worth noting. According to Storz, most common use of LPF devices is between RF transmission amplifier and the antenna. Therefore, it encounters widespread use in application such RF IoT devices and other RF communication devices.

Compared to conventional manufacturing processes, Storz notes that all the manufacturing stages of producing IoT devices can be done in one step with 3D printed electronics.

"We did some tests to assess the performance and quality of 3D printed IoT devices we produce using our technology. We realized that 3D printed electronics provides exceptional results as the devices were 10% higher



Comparison of a 3D printed Transceiver with a Traditional Transceiver – Image: Nano Dimension

Martijn Joris, founder & CEO at Twikit

than devices produced with other technologies and this performance was especially related to data transmission and quality. We learned that antennas that require a ground plane should be printed on multilayer boards, and that RF communications circuits/devices are one of the applications that will benefit the most from 3D printed IoT devices", Storz concludes.

Lastly, the advantages of using AME for the manufacturing include light material, low outgazing, and low price for unique applications.

In addition to prototyping new devices, and micro-manufacturing smart sensors, AM remains a good production candidate for IoT home devices.

In the upcoming years, it will probably be complicated to list all the specific devices and sensors AM can help to produce.

However, for an "applications" dedicated- company like Twikit, AM technologies make IoT applications at *a higher flexibility than before. You can produce your unique board instantly instead of waiting a long time before receiving your copy.*

"As always, we will first look at the added value of the application before deciding on which technologies to use. Projects have passed where casing of IoT devices were produced with AM, as well as a project where IoT was used for part identification in the AM process", Joris concludes.

ABOUT THE CONTRIBUTORS

***Solukon Maschinenbau GmbH** is a manufacturer of automated powder removal processes for additive manufacturing. With the goal of enhancing automation, and accelerating the path to quality assurance and certification, the company has recently developed IoT solutions that were worth mentioning as example as part of this article.*

***Twikit** provides the combination of software development, product design and engineering for digital manufacturing. The company is acknowledged for delivering applications that help companies step into customization with seamless end-to-end solutions. The Twikit approach to applications, business models and the ecosystem creates new value for both the brands and their customers.*

***Nano Dimension** (Nasdaq, TASE: NNDM) is a provider of intelligent machines for the fabrication of Additively Manufactured Electronics (AME). The company was the first to introduce a functional 3D printed IoT communication device, opening new possibilities for smart homes and products. Using its 3D printer dedicated to AME, the print, assembly and testing of a working transceiver prototype was completed in just one day, dramatically accelerating development by up to 90%, for a process that often takes two weeks or more. The remote-control type IoT device, smaller than a silver dollar coin (16 x 33 x 1.6mm), is currently in its qualification phase and Nano Dimension anticipates that it can easily and efficiently be developed into a two-way communication device (transmitter and receiver) such as a router. The company provides NaNoS – 3D Fabrication as a service – for anyone who wants to explore the future of AME fabrication in developing complex, multilayered high-performance electronic devices (Hi-PEDs™).*

***Gravity Pull Systems, Inc.** is the enabler of industrialization in additive manufacturing (AM). Located in Switzerland, the technology solutions provider for manufacturing companies has developed Synoptik, a software solution to optimise Additive Manufacturing for the aerospace, automotive, automation and medical industries. The integration of the Scheduling Optimizer function with a Manufacturing Execution System (MES) enables dynamic adjustment of changing process parameters in real-time with flexible adjustment of production times. Continuous monitoring via Track & Trace ensures continuous transparency and traceability across the entire manufacturing process, and meets industry-specific compliance requirements. At the same time, the dynamic adjustment achieves increased profitability, reduces manufacturing costs and has a lasting effect on environmental protection through lower material consumption.*

©Evonik-PEEK-Filament-for-Implants

EVONIK AND ITS WORLD OF "INFINITE 3D PRINTING APPLICATIONS"

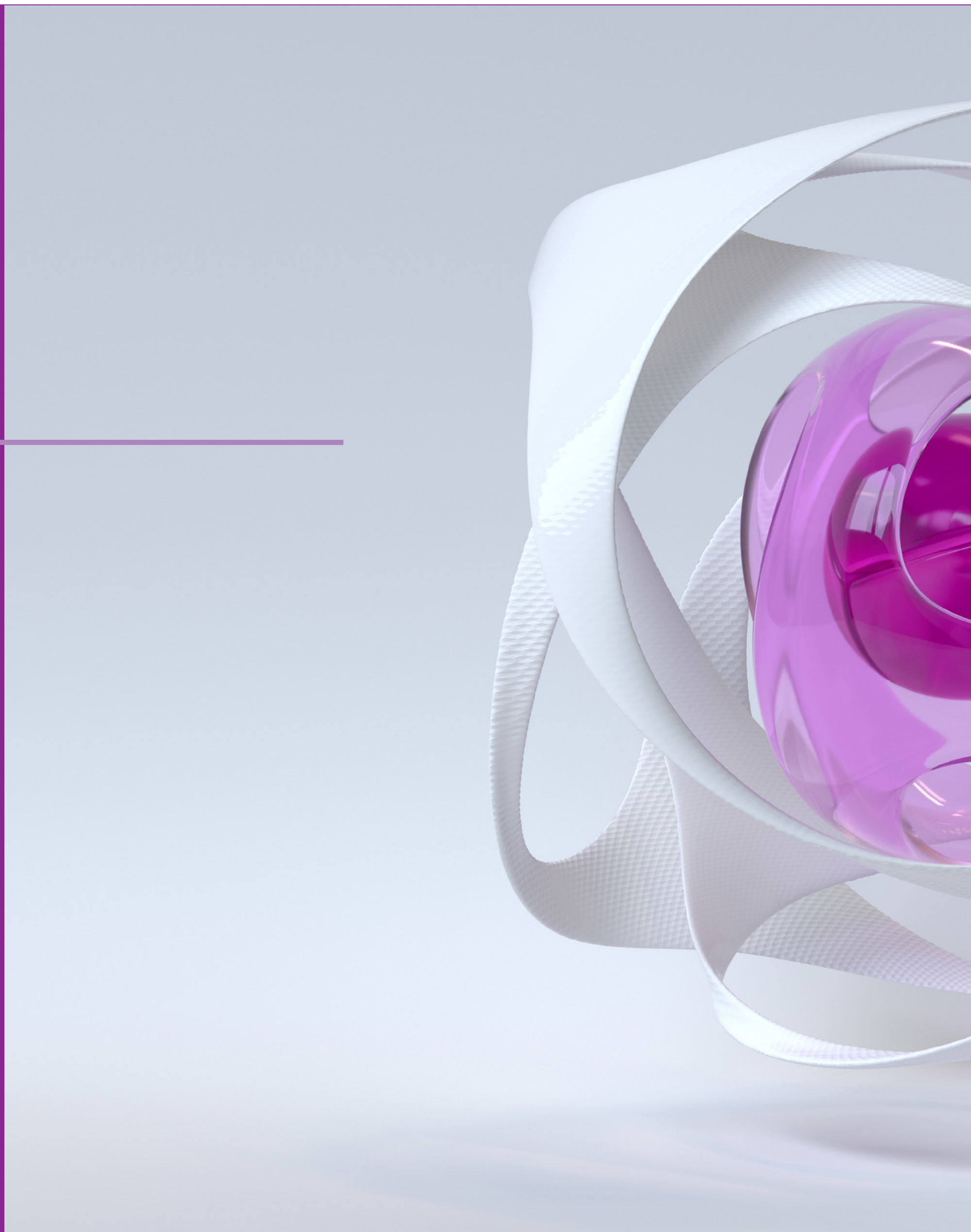
Have you ever realized that the first thing end-users experience when seeing and touching a 3D printed part is the material with which it has been produced? The problem is, a lot of credit is given to additive manufacturing machines, yet the true success of an application usually depends on an underappreciated component: ***material****. As we navigate through the set of indispensable ingredients in an AM production, we have decided to explore the area of opportunities materials enable. What better way to do so than by having a material producer by our side?*

Unlike most companies that announced their involvement in the additive manufacturing industry through stunning marketing actions, **Evonik** has first built up experience and expertise within its field of activity and has waited to have the certainty and the ability to provide real value **before coming out from stealth mode.**

Although it is best known for the materials it produces, the stock-listed German specialty chemicals company also provides **additives** as well as **quality assurance services**. Last year, the company marked a milestone in its AM journey as it decided to give a new direction to its AM materials by grouping them under the brand **INFINAM®.**

When asked if this name stands for a specific meaning, **Sylvia Monsheimer**, Head of Additive Manufacturing & New 3D Technologies at Evonik states:

"Our new INFINAM® brand stands for polymer-based materials – powders, resins and filaments – that enable infinite 3D applications. The brand name itself comes from INFINity + Additive Manufacturing and is aligned with our unique market communication approach which we, by the way, claim #InfinityMeetsReality. In other words, introducing INFINAM®,



we boost the chemistry of high-performance polymers and additives into ready-to-use materials for infinite 3D applications."

As you can see, a glimpse at a materials producer's activities like Evonik reveals that there is so much to say that it will require more than one article to cover each aspect related to the materials business.

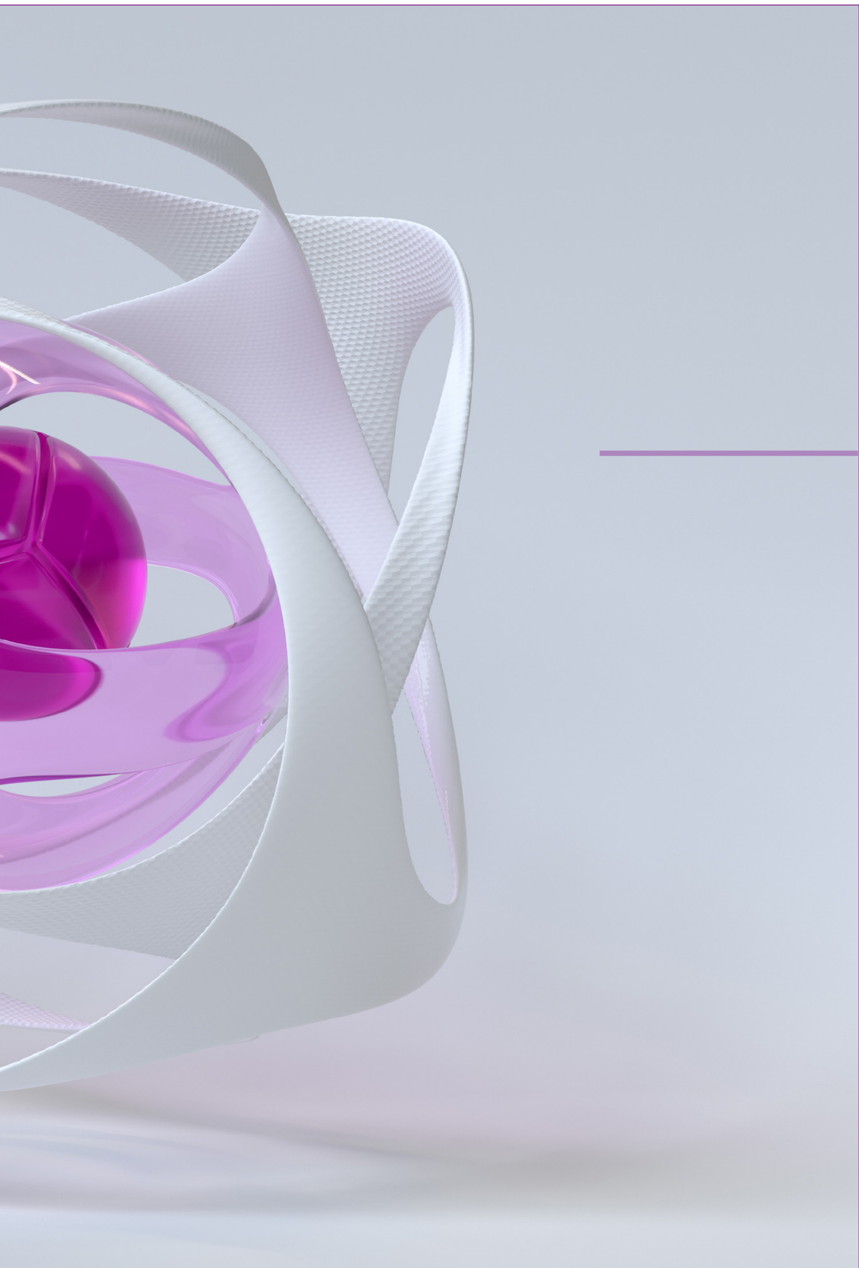
Recognizing all this, we have made a very deliberate

choice to address in this article, Evonik's approach to develop **medical 3D printing materials** as well as the next steps in terms of **materials development the company plans to focus on.**

The prism of 3D printing materials for medical applications: the case of polymers

Medical 3D printing breakthroughs keep on going. Current and projected applications can be divided into several categories:

- Tissue and organ fabrication;
- Tailor-made prosthetics, implants, and anatomical models;
- As well as pharmaceutical research, an area that deals with the development of drug dosage forms, delivery, and discovery.



Interestingly, these applications are often enabled through a non-exhaustive list of materials, which may include titanium alloys, cobalt-chrome (cobalt-chromium-molybdenum alloy), and polymers to name a few. The thing is, for a vital industry like the medical industry, most materials are often subjected to certifications and regulations before being used on a patient.

As a matter of fact, the term biomaterial has been coined to reflect the type of substance that can be introduced into the body as part of an implanted medical device or used to replace an organ, the function of a body part, etc.

In this vein, to avoid confusion and to make this very-much needed distinction between AM products dedicated to the medical industry and AM products dedicated to other industries, companies develop dedicated brands to meet the needs of this market. At Evonik, it was also crucial to make that distinction:

"Evonik offers the most extensive portfolio in the sector of 3D printable biomedical materials for medical technology. For plastic implants the portfolio includes, in addition to VESTAKEEP® i4 3DF PEEK filament for permanent body contact, also the RESOMER® product line with bioresorbable filaments, powders, and granules. These specialty materials are subject to strict standard specifications for polymers in medical applications that apply to the respective brands mentioned above. For this reason, these products have been excluded from transfer to the INFINAM® product family and will continue to be marketed under the VESTAKEEP® and RESOMER® brands", **Marc Knebel,** Head of Medical, Evonik explains.

Nonetheless, a report from the European Patent Office reveals that between 2010 and 2018 and despite the wide range of materials that exists, a great number of **patent applications were filed for 3D printing with polymers** compared to other groups of materials combined. This underlines an increasing interest in the use of polymers for medical applications. Apart from the biocompatibility of certain polymers, it should be noted that these materials provide a wide range of opportunities in terms of compositions. It is also possible to modify their structure and surface as well as requirements solicited by specific applications, including the addition of additives to improve the basic properties of plastic materials, as for example, antimicrobial compounds.

That being said, for researchers, **surface chemistry, mechanical properties, and topography of functional polymers** would be three key parameters that foster the effective use of polymers in AM technology. However, as polymers are available under different forms, Knebel advises medical professionals to keep in mind the final purpose of the applications in order to choose the one that best suits a production:

*"The most important factor is a good fit of material and processing technology that assure safety and effectiveness for the production of 3D printed medical devices. Powders as well as filaments are already successfully used for those applications. INFINAM® PA12 powders are used for **short-term body contact devices**. VESTAKEEP® PEEK filament is available **for long-term body implants**, as FFF is the state-of-the-art technology to produce high quality parts in a safe process with this material. When it comes to filaments, an additional advantage is the fact that FFF/FDM printers are typically smaller which can favour their use directly in a hospital environment, with the potential of point-of-care, production of implants. In any case, the freedom of design and the quality is the determining factor over the costs."*

As you may have guessed, **FDM** remains one of the most commonly used AM technology in medical 3D printing applications. Others include but are not limited to **extrusion-based bioprinting, material sintering, inkjet or binder jet printing, polyjet printing** or even **laminated object manufacturing**.

Despite this compatibility of AM technologies with medical applications, this niche segment still suffers from a lack of diversity in suitable biomaterials which results in a low number of applications in the field. Current 3D printing biomaterials are mostly utilized for either drug delivery or space-filling implantation purposes.

According to Evonik's Head of Medical, the main reason that explains this slow adoption might lie in the fact that the qualification process of a material takes a lot of time depending on regulatory authorities but also on the work of medical device manufacturers.

"Any new material and technology need to go through a careful step-by-step validation and approval process which does take time. Evonik is already offering a broad range of biomaterials of its VESTAKEEP® PEEK and RESOMER® brands with the

Marc Knebel, Head of Medical

required quality and with the needed documentation. Validation and qualification of the printers and printing processes are moving forward quickly. In addition, we note a high interest of medical device manufacturers across the globe, thus already in 2021 we are confident that biomaterials will be used in many different applications", he concludes.

Current and future state of materials development at Evonik

In addition to its **bioresorbable powder** and its **implant-grade PEEK filament for medical applications**, Evonik's 2020 AM activities were also marked by a co-branded **flexible high-performance specialty powder based on a thermoplastic amide grade** (TPA) and the opening of a new 3D Printing centre in the USA. On top of that, the materials producer has completed the construction of its first plant dedicated to new polyamide 12.

Monsheimer points out the polyamide 12's outstanding properties make it an ideal material candidate for applications where *"high stability paired with flexibility"* and *"high temperature resistance and low weight"* are required. Given its wide range of applications in automotive, oil and gas and even medical devices, *"the polyamide 12 market is posting annual growth rates exceeding 5 percent worldwide, significantly outpacing the global gross domestic product."* Speaking of the AM industry in particular, the materials expert announced that its growth rates even reach double digits.

"We plan to broaden our portfolio of polyamides but also non-polyamide polymers by developing materials with enhanced properties to open new

infinite applications. Our new 3D printing centre in Austin, Texas, on the one hand can supply application support to customers and on the other hand our new site has a focus on the material development manufactured by the structured polymers technology which complements our proven methods for powder production beside precipitated polymers", she announces.

No matter what direction Evonik follows, the company remains driven by the market needs. To do so, the company keeps in mind its primary goal which is to develop *"ready-to-use"* high-performance materials that can meet the requirements of various technology lines. A goal that necessarily requires an in-depth collaboration with 3D printer manufacturers as we saw with HP and today with **Evolve Additive Solutions** for the STEP technology – a process that would need a dedicated powder material.

In this vein, other developments we might expect from the company includes *"a new product line of photopolymer resins with unique combination of material properties"* which will fill *"the gap of today's commercially available photopolymers for VAT Polymerization."*

Last but not least, at the heart of these activities, also lies the ambition to contribute to a more sustainable industry, but the battle is even harder for a materials producer given the nature of their activity. That's why sustainability is pursued in various ways, within the group's Additive

Sylvia Monsheimer – Head of Additive Manufacturing & New 3D Technologies at Evonik

Manufacturing Innovation Growth Field:

"On the one hand, we are constantly improving our own production processes to make them as efficient and safe as possible. On the other hand, we are putting our innovative power into the development of, for instance, new powder materials to increase their reusability rate during a 3D printing process. As a matter of fact, some of our INFINAM® PA12 powders can already be reused by only replacing the powder needed for the parts of the previous job", **Monsheimer outlines**. And this for us, is the sign that sustainability is not just a topic they talk about, but a vision they are walking through.

QUALIFICATION & CERTIFICATION :

THEIR DIFFERENCES & NEXT CHALLENGES FOR ADDITIVE MANUFACTURING

One usually focuses so much on end-applications that it is easy to forget that what makes an additive manufacturing-based application viable for a given industry, is a pivotal end-to-end qualification and certification process. For a technology like additive manufacturing that has only started to be commercialized in the 1990s, the concept is much more complex than it seems. It takes a conversation with ***TÜV SÜD's Gregor Reischle*** *to understand the ins-and-outs of this evaluation and approval process.*

Additive Manufacturing Engineer by training, Reischle brings a decade of experience in the additive manufacturing industry to the table. His ability to develop products and his experience in leading AM companies like EOS made him the ideal resource person to lead the additive manufacturing unit at TÜV SÜD, a unit that debuted on the AM industry about four years ago, when Reischle joined the company.

It makes sense to see TÜV SÜD operate in the additive manufacturing industry when one knows that the structure is an internationally active, independent service company that tests, inspects and certifies technical systems, facilities and components of all kinds. However, the thing with AM technologies is that, if the first AM processes may have been commercialized in the 1990s, a whole guideline still needs to be developed to help existing and future industries properly & commercially leverage these technologies.

What are these guidelines?

As you may know, the ultimate goal for most industries adopting additive manufacturing is to produce and utilize qualified parts that can be used in mission-critical environments and markets. To do so, several frameworks are required, and according to **Reischle**, dedicated frameworks are designed for specific stakeholders:

"We focus on the "pain points" of each industry player: the users – those who utilize AM equipment for production purpose – as well as machine manufacturers, material producers & software providers.

Gregor Reischle

Each of these stakeholders will have unique needs: users, for instance, might need audit, training, advisory and certification, to ensure their additive manufacturing production readiness, a crucial step that requires assessing quality and viability of AM Systems and their surrounding operational processes. Furthermore, they must ensure that the AM equipment they leverage, meets health and safety requirements and their production environments must meet certain standards to minimize hazards and prevent damages. Not to mention that, beyond the reduction of hazards, and prevention of damages, a certified environment assures an organization's customers that it can deliver industrial conform services that encompass all the steps of the AM specifications in product

development & production lifecycle. From design, shop floor, to manufacturing and quality assurance.

Machine manufacturers & material producers on the other hand, have now the option to proof with a 3rd party certification that the industrial 3D printing equipment/ materials they develop, delivers reproducible results. As industrial 3D printers & materials are utilized to produce parts for different industries, they should also fulfil additional requirements for those sectors – which include medical, aerospace, space, to name a few.

And the ability to meet all these requirements is the "raison d'être" of TÜV SÜD's positioning in the AM industry", Reischle states from the outset.

Tangible examples where we saw the German company deliver a few of these services include but are not limited to the recent certification of the AM process of LUVOCOM® 3F filament and Ultimaker S5 Pro Bundle, the qualification of 12 Manufacturing sites. Rosswag as manufacturer of metal powder for additive manufacturing, – as well as the Part report services on validation for operational use of an additively manufactured mission critical parts in the railway sector.

The primary focus might be dedicated to industrial stakeholders but the global head of industrial additive manufacturing also points out the company's ability to address some health issues raised by desktop 3D printer emissions as well as specific concerns regarding the food industry.

A closer look at the qualification & certification processes for materials, equipment and 3D printed parts

Paths to qualifying materials and processes vary from one structure to another. As far as materials are concerned, we used to see their qualification for a given manufacturing process when they are approved by 3D printer manufacturers or after individual testing and inspection.

This latter process can also be applied for the qualification of 3D printers. It might include statistical-based qualification rooted in empirical testing, equivalence-based qualification if the idea is to demonstrate that a new material or process is similar to a material or process that has already been qualified or a model-based qualification. In this case, experts should prove the performance of the material or the equipment with simulation software and corroborate it with less testing.

At this point, for those who are not familiar with all this jargon, it is crucial to understand that **there is a difference between qualification and certification.**

The qualification of a prototype design/material /product during the development/testing phase aims to find out whether it meets the specified requirements for a specific phase. In this case, engineers are trying **to determine if they have designed or built the product as per the requirements**.

As for certification, it consists in assessing a material/product/ component during or at the end of the development process /regular production to confirm whether or not, it meets specified technical requirements. These are usually publicly known and released by standardisation bodies like DIN, ISO, ASTM and used for certification by institutions like TUV SUD. –

In both cases, TÜV SÜD has the ability to support AM companies. Despite the viability of the aforementioned qualification processes, organizations do not often look at the bigger picture, which in the end, leads to more expensive processes when they address qualification and certification modules one by one.

By highlighting TÜV SÜD's modular approach that their team has been developing during the past four years, Reischle focuses the debate on what should be the first point every organization should look at when it comes to qualification and certification in general: **employees**.

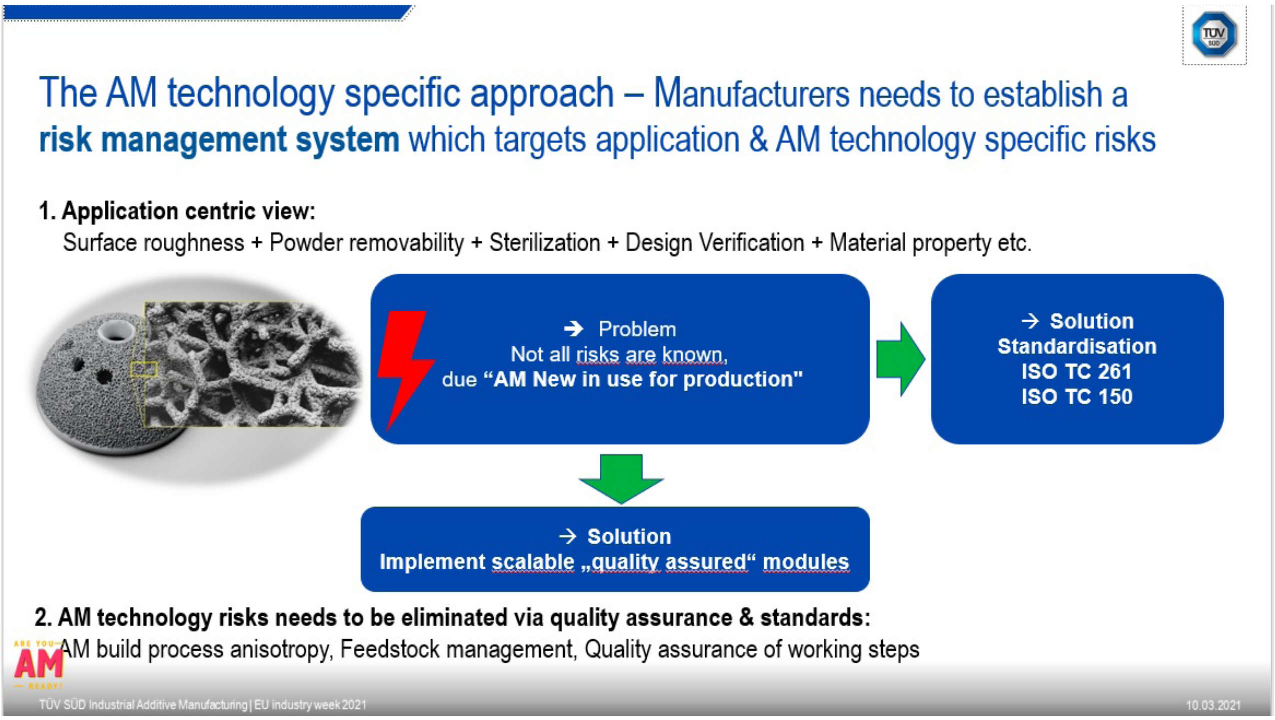
"We train professionals within their respective industrial AM area of expertise. Thereafter, we establish with organizations how to setup a state of the art quality assurance, which is especially important if they want to focus on production. To do so, the facility should meet AM specific DIN/ISO/ASTM standards developed within the TC 261.

Thereafter, we need to have a value proposition for the machines, materials and processes. With Ultimaker and LEHVOSS Group for instance, we combined the 3D printer and the material to certify the "reproducible print process". Once AM machines and materials are certified as explained before, it becomes much easier for every user to make the end-customers benefit from the production advantages.

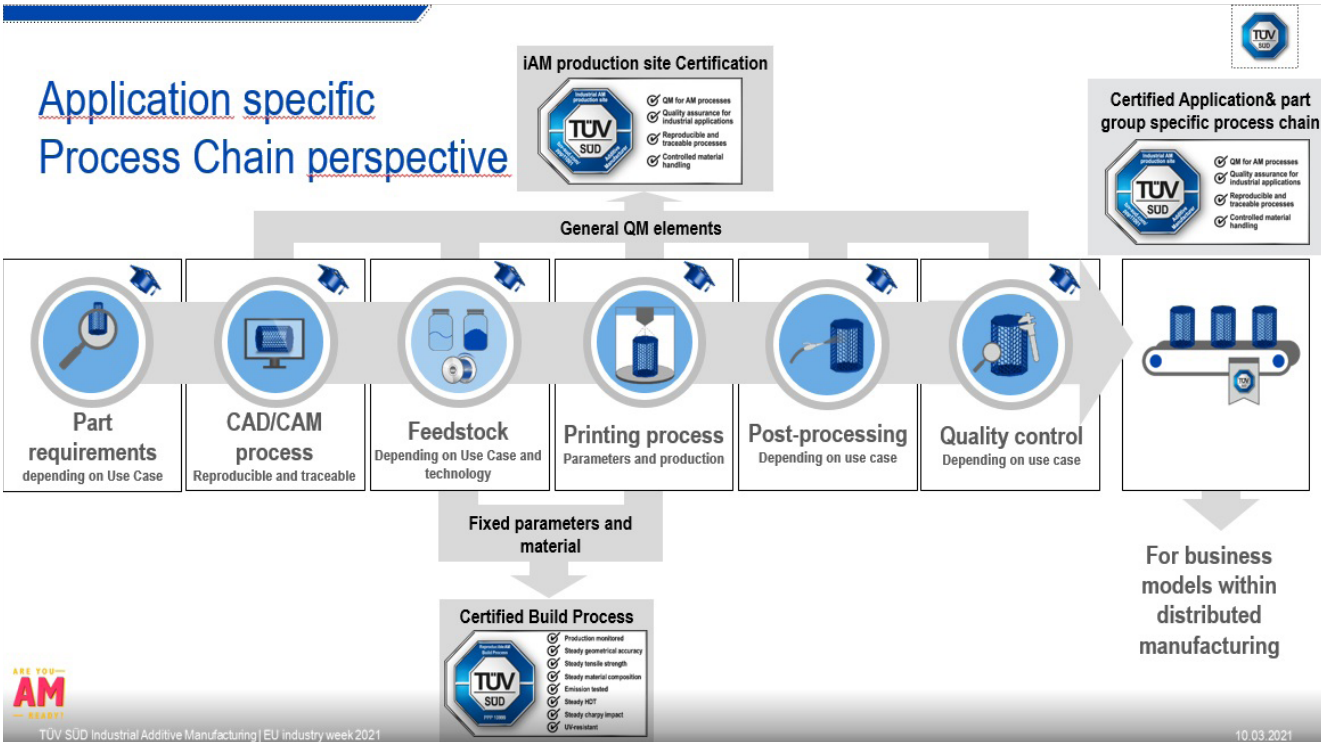
The truth is, the good old "trial & error» AM implementation approach is no longer "state of the art" and has to decrease. All new bees focusing on industrial AM should use the "standardised implementation approach. Otherwise the risk to fail remains very high. And the implementation of AM will not scale.

This is mainly due to the standardized implementation path that manages to answer all these questions industrials used to ask themselves: how to set up a production line? How to build up a quality management and production guide? How to set up a build process that enables reproducibility? etc. We are changing the way production is implemented in the industry by focusing on how to save time and costs, by supporting organizations to scale faster, to regulate their processes and to achieve industrial readiness.

As far as 3D printed products are concerned, we are also uniquely positioned to speed up their certification", he explains. Taking the example of the 3D printed part produced by [Siemens Mobility GmbH], the expert laid emphasis on the fact that the certification process is not that different from machines and materials certification. For specific applications, it is important to set up a risk management system that addresses both the applications & AM technology specific risks. Here, they needed to ensure that the part is safe and reproducible, hence the numerous tests the part underwent after its production at Siemens Mobility's facility. *"We thereafter issued a report on the remaining specifications risks dedicated to the application itself as it was crucial for the part to meet the additional requirements of the railway sector. As a notified body, TÜV SÜD also has the authority to assess the conformity of certain products before they are placed on the market"*, the expert points out.



The challenge with these application-centric processes is that not all risks can always be known due to the "relatively new usage of AM in production".



The next challenges to address

With the growing demand for standardization in additive manufacturing, several barriers need to be addressed across various key verticals adopting AM technologies and within manufacturing processes.

Speaking of standardization within manufacturing processes, **Reischle** outlines that there are various AM technologies and the team at TÜV SÜD understands that *"each AM technology is unique. Therefore, the challenges operators faced at the production level certainly vary from one technology to another. That's why we are collaborating with all involved industry players at the ISO/TC 261 that aims to standardise the processes of Additive Manufacturing, the process chains [(Data, Materials, Processes, Hard- and Software, Applications), test procedures, quality parameters, supply agreements, environment, health and safety, fundamentals and vocabularies]."*

As part of this group, Reischle is the convener for the JG 75 Conformity Assessment, Quality Assurance and risks and the JG 80, which takes care of 3D printing in the construction industry.

Moreover, with the increasing development of advanced manufacturing technologies and robotics, manufacturing is undergoing a transformation that requires a cross-functional implementation of seamless connected processes. This will inevitably lead to fundamental improvements, which will enable 100% **product transparency and traceability**.

Whilst this transformation drives data collection and connectivity, it also raises certain concerns when it comes to **security**. To prevent vulnerabilities or cyberattacks to occur throughout the component or system lifecycle, TÜV SÜD is capable to support with the implementation of the **international standard IEC 62443**. That guarantees that all applicable security

aspects are addressed in a structured manner. According to the company, this includes a systematic approach to cybersecurity throughout the stages of specification, integration, operation, maintenance and decommissioning.

Furthermore, in this mission to facilitate adoption and trust in AM technologies, the company joined forces with global standards organization ASTM International to develop new educational, advisory, qualification and certification services in sectors such as **transport (land and air), industrial plants, consumer products and healthcare**. Additionally TUV SUD is very active within the MgA Network , where over 100 international companies collaboratively work on the success of AM technologies.

In four years of activity on the AM market, TÜV SÜD can legitimately say it has raised awareness on the importance of qualification and certification for AM in Europe. With a global team across the world – in the ASEAN region with an entry point in Singapore as well as in Japan, the company is determined to *"move forward additive manufacturing implementation into the industrial world".*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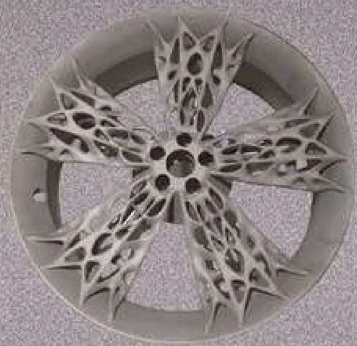

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Powder Production:

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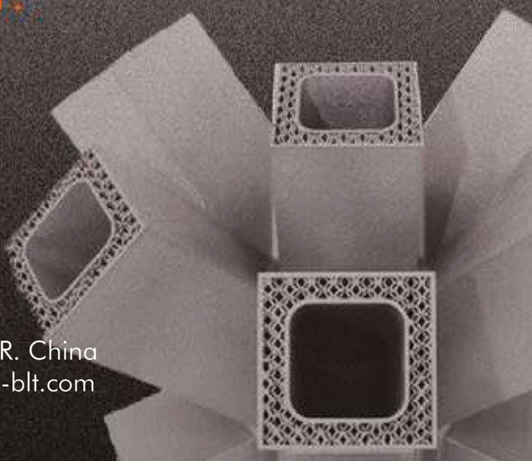

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WHAT ARE THE NEEDS NDUSTRIES WANT TO ADDRESS WHEN IT COMES TO POWDER REMOVAL OF 3D PRINTED PARTS?

SOLUKON TOLD US.

Amid the long list of post-processing jobs, operators need to perform before getting the final 3D printed part, metal AM post-processing is often considered as the most time-intensive part in the production. Beside the main challenges to address, the major reason for this lack of awareness might come down to the inability to properly assess one's needs and the solutions to address them.

Have you ever realized that the one thing that makes manufacturers opt for metal additive manufacturing for production might also be the one that makes post-processing so much complicated? That thing is **strength**. Reality shows that, although metal AM process is known for delivering exceptional strength to parts, this capability might not be well portrayed in the part if the post-processing steps have not been well performed.

From the moment, the manufacturing process of a part is done, and depending on the final requirements, metal prints can go through up to 9 steps before being ready to use: **powder removal and powder recycling, part removal and support removal, thermal post-processing, machining, surface treatments, inspection and testing**.

Here is the thing, in addition to part complexity, some of these tasks including powder removal, powder recycling; cleaning and finishing pose further challenges when it comes to mass production of parts. Machine manufacturer **Solukon Maschinenbau GmbH** has identified the challenges and risks for manufacturers who need to deliver serial production parts in order to provide them with dedicated automated post-processing solutions.

Demystifying needs and challenges

Solukon has explored the constraints raised by industrial manufacturing by taking into account powder-bed fusion, one of the most widely used metal AM processes in the current market.

The first urgent need for operators utilizing this technology is the removal of unfused powder right after the part comes out of the machine.

If you are not familiar with a powder-bed fusion process, then note that in the build chamber, layers are added one by one to the top of the build plate which means that, at the end of the process, the part seems to be buried in powder. When the parts and build plate have cooled, the operator must remove this remaining powder and sieve, filter or recycle it for later use – assuming there is a need to reuse it. **And this step does take a lot of time.**

The part seems "buried" in powder – Credit: Solukon

The problem is even harder when it comes to more complex parts. According to Solukon, *"after the print job has been completed, internal channels are frequently filled with powder, and attempts to clean the parts with air pressure are generally inadequate. 3D printed parts with complicated internal channels, such as heat exchangers or conformal cooling channels in injection molds or gas turbine parts, have presented highly difficult challenges for powder removal – in particular when the parts are large and heavy."*

If not well handled, operators expose themselves at a *"risk of explosion, occupational health, labor costs, powder recovery, cleaning quality and process repeatability."*

"A backdrop to these operational issues is a growing trend towards regulation and standardization, which pushes manufacturers to think more carefully about their manufacturing processes, both at the level of requirements for the part itself, such as cleanliness and process repeatability, and at the level of the manufacturing facility in general", the company explains.

The need for reproducible cleaning results. As the industry matures, it becomes vital for industrials to decrease process variability across the entire value chain: from metal powder production and handling, printing to post-processing steps. The need to achieve a repeatable process at all stages including this post-process stage is not only for the sake of simplicity. It also aims to avoid losing time and materials, profit, and parts that do not meet demanding customer specifications.

"Current powder removal processes are typically manual. On the surface, manual cleaning does not appear to require much knowhow and can be performed by using blowing or brushing. The truth is that manual cleaning very often is unable to remove stubborn powder consistently and reliably", the team at Solukon testifies.

To address these issues, Solukon has built up certain expertise across various industries thanks to its **SPR® (Smart Powder Recuperation)** technology.

Approved for safe and reliable processing of powder materials, including tough-to-handle and reactive metal powders like titanium, the company's automated depowering machines clean metal laser melted parts within a sealed process chamber, using adjustable vibration and automated two-axis part rotation.

"Through programmable rotation of the build-plate in two axes, unfused metal build material is completely removed from complex parts and support structures. Depending on the build material, the process chamber can be rendered inert with safety monitored inert gas infusion", the machine manufacturer assures.

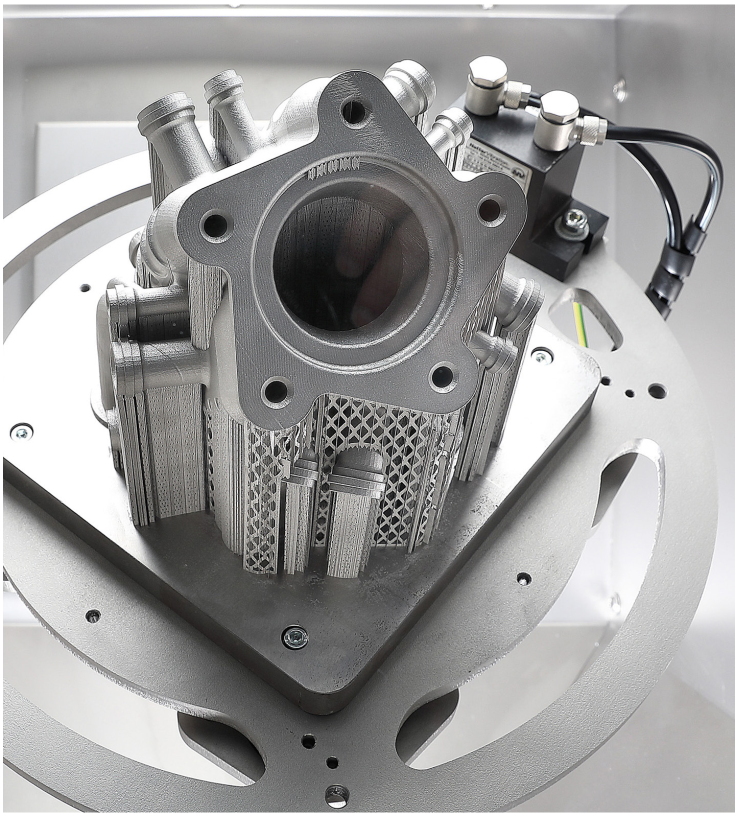
Another challenge that is often underestimated is related to the considerations at the design stage. Design process is often regarded as creative problem solving. However, most engineers still don't realize that some critical considerations in this stage, can greatly influence the post-processing phase in the overall workflow. That's the reason why, most engineers are often recommended to adapt their part design as much as possible to the machine specifications they will be using for production. Solukon has been working hard to remove this constraint and has integrated features that do no longer limit the powder removal process of large and complex designs on the shop floor.

Current and future trends

It's been six years today, that the German company has been developing automated powder removal systems that have convinced customers across the aerospace and space, energy, oil and gas, medical, automotive, governmental and defence industries.

At the heart of the company's work, lies the willingness to meet the market needs, hence the collaboration with **Siemens** to develop dedicated digital twin-based software that drives its systems today or even the collaboration with AMCM, an EOS company, in 2020. The latter led to the development of the SFM-AT1000-S, an automated powder removal machine designed for extraordinary high parts, such as rocket engines.

Although industries increasingly recognize the value of the company's highly automated de-powdering solutions, it should be noted that they are moving towards new applications for larger production runs. Productions that will necessarily require a greater focus on automation through the entire process chain but that's a challenge the team at Solukon is not afraid to address as they have set themselves the goal of consistently adapting their SPR® technology to the latest industrial requirements. And the recently released Digital Factory Tool might just be the first step towards this end.



3D printed part in a Solukon machine – credit: Solukon

Behind the Scenes

Behind the Scenes of this Germany-based company, there is **Andreas Hartmann** and **Dominik Schmid.** With almost two decades of experience in AM, both founders have worked together as development engineers and project managers before founding Solukon in 2013. The company first provided engineering services in a range of different industrial areas, such as food and packaging before positioning itself as a developer of AM peripheral equipment in the industry.

Solukon's entrepreneurial founders take in charge every step in the company's development, from engineering through purchasing and manufacturing, to sales and service. Today, Andreas Hartmann is responsible for technical development and engineering of the systems while Dominik Schmid takes in charge the company's organization and administration.

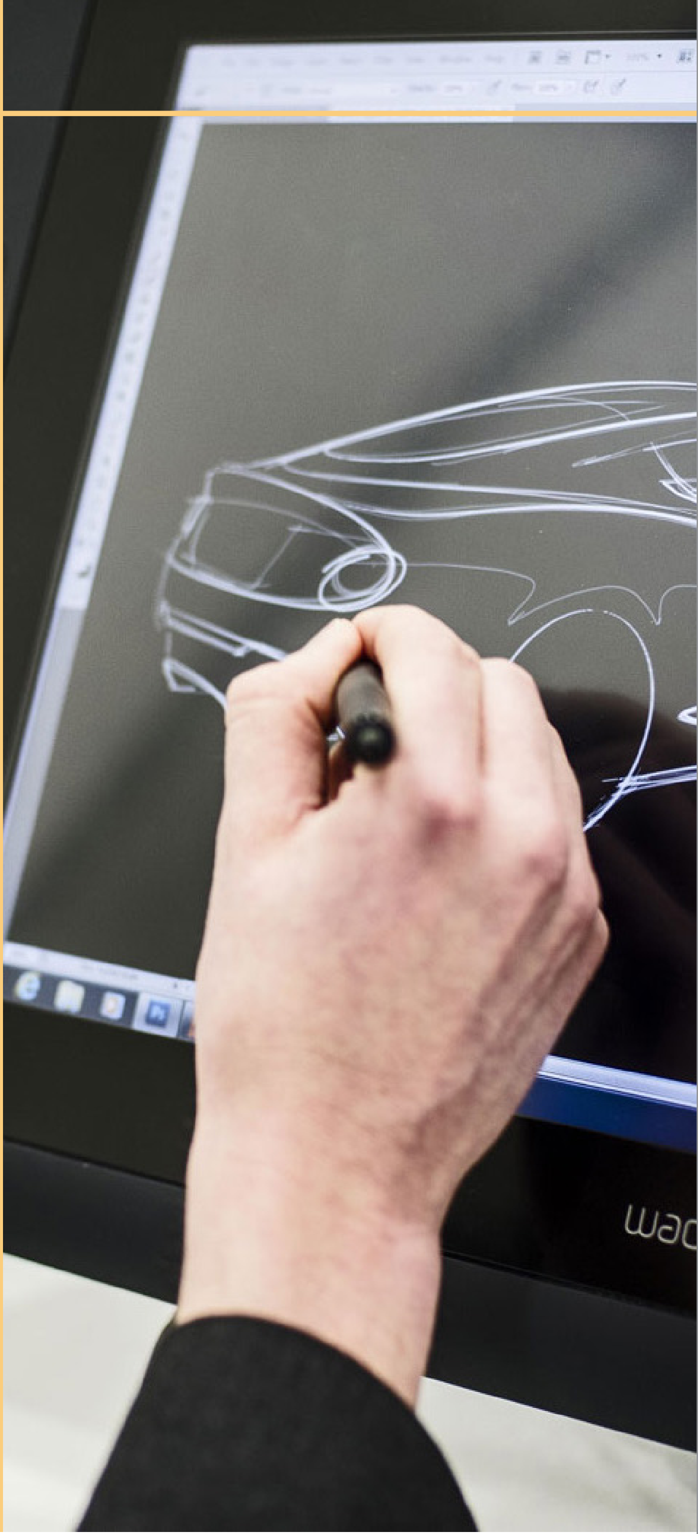
Important decisions, be it technical or commercial, are made jointly by both experts who act as co-CEOs. This ensures that every decision is well thought through and sustainable.

The core competencies of Solukon remain in-house. These include engineering, assembly and service. However, the company does not hesitate to avail itself of the experience and cost-effectiveness of the manufacturing ecosystem in Bavaria and elsewhere in Germany.

This content has been created in collaboration with Solukon Maschinenbau GmbH

Andreas Hartmann (Left) and Dominik Schmid (Right)

AUTOMOTIVE DESIGN FOR AM : ARE EXPECTATIONS NOT HIGHER THAN REALITY?



It's an interesting time in the world of automotive design. With major changes brought by new technologies, the world has witnessed a wide range of solutions that can be explored to design and produce better, and to get smarter vehicles. But there is still a gap between what's being showed and what's actually been made. Are expectations not higher than reality?

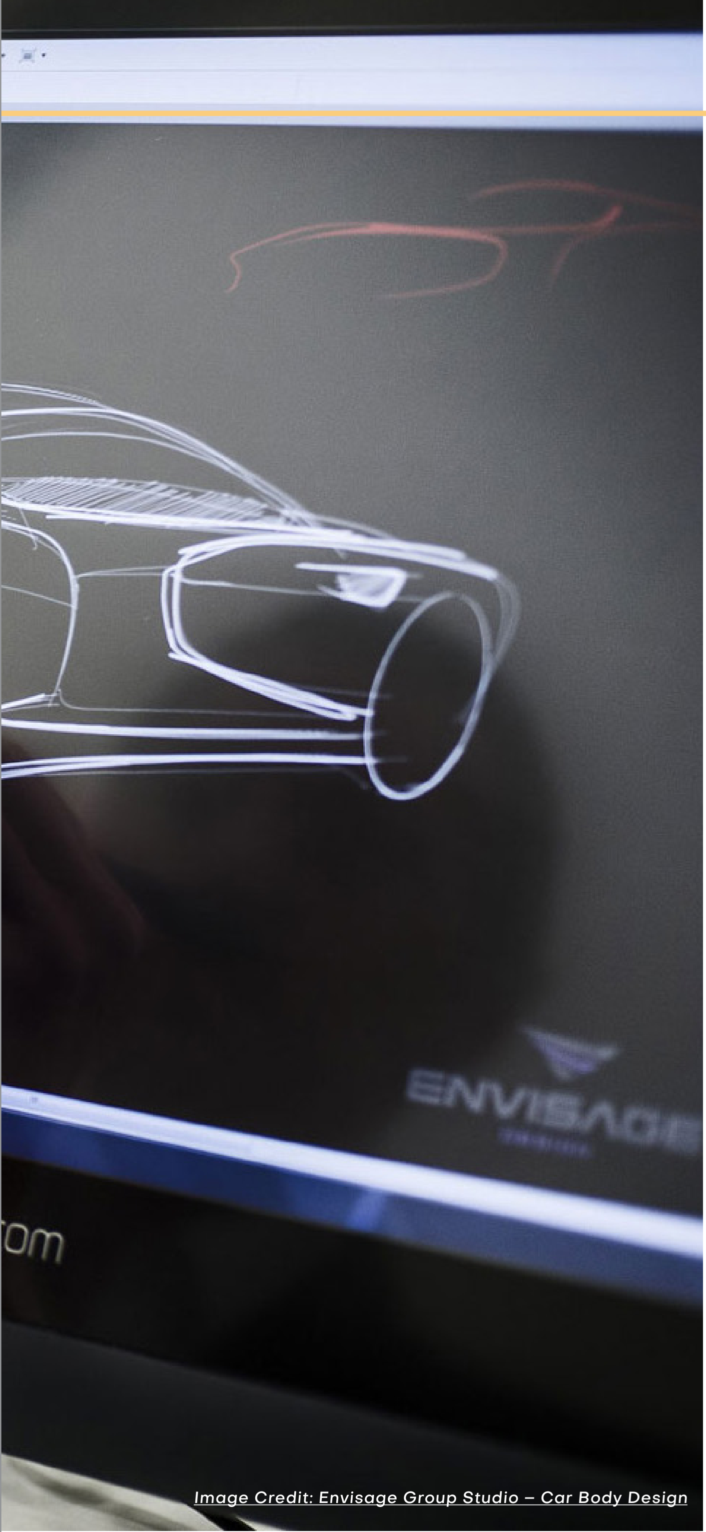


Image Credit: Envisage Group Studio – Car Body Design

At the beginning, most of the use cases that car manufacturers shared regarding their use of additive manufacturing highlighted the way the technology supported a given part development process by finding design issues prior to the fabrication of production tools. Over time, the opportunity to meet other needs has been raised; automotive designers have explored a certain flexibility with AM that they never experienced with any other technology, yet they said that the market has not reached an inflection point where the use of AM will become systematic for every part, for every design.

The reasons for this, might lie in the fact that there are too many design considerations/ crucial automotive requirements to meet, and areas for improvements that automotive designers expect from software providers to get there.

This article aims to discuss the current design considerations, automotive designers should take into account and the areas for improvement expected from AM technologies' providers. In this vein, we have gathered Altair and Sika Automotive around this "table".

Altair Engineering Inc. aka Altair provides product design and engineering, enterprise services, data analytics, IoT and cloud computing services across a wide range of services. In the AM industry, the software provider works closely with automotive OEMs and suppliers to **deliver additive manufacturing projects** while offering one single software solution that addresses the full breadth of designing to manufacturing. **Jaideep Bangal**, Design and Manufacturing – Global Technical Team, Altair Engineering has brought to this segment the perspective of a software provider.

Sika Automotive is a supplier of automotive bonding, sealing, damping and reinforcing solutions for vehicle BIW, body structure, interior, and exterior components. The company has been using AM for a few years now, to speed up the product development process for functional structural components that it delivers for various OEMs. **Thomas Gasparri**, Senior Program and Additive Manufacturing Manager, **Dimitri Marcq**, Lead Engineer CAD as well as **Jose Bautista**, Global Product Manager provide the perspective of a manufacturer of automotive parts in this topic.

A look at design considerations automotive engineers should absolutely take into account

A quick discussion with various engineers highlights a wide range of design considerations they often take into account in their work. Those considerations may vary depending on whether we are talking about interior parts or external parts of the vehicle.

The list seems to be non-exhaustive, but some items are mentioned more than others for internal parts. They include for instance, **weight, temperature, complex geometries, moisture, part consolidation and costs**.

Weight has always been mentioned as the number one requirement in automotive designs. To address this issue, automotive engineers often need to rely on advanced engineering materials and complex geometries to reduce weight while improving performance.

According to Bangal, Design and Manufacturing – Global Technical Team at Altair Engineering, the introduction of DfAM methods has provided the engineer with better tools to reduce weight of parts.

"Since the implementation of DfAM, automotive design has become better equipped to take full advantage of weight saving technologies like topology optimization. When these design technologies are coupled with a manufacturing process that can now drastically reduce the mass needed to manufacture the part, we experience new levels of lightweighting opportunities. A lighter vehicle equates to improved fuel economy or longer range", he explains.

The argument seems justified especially when it could also help save time by redesigning several parts as a single complex component (part consolidation). However, it does not always take into account other requirements such as temperature or moisture.

Reality shows that most automotive applications require significant heat deflection minimum, and heat deflection often depends on the material selected. Furthermore, most automotive parts must be moisture resistant, or even moisture proof.

For Bangal, *"there should be one solution for the entire 'design for additive manufacturing' product development cycle that will help designers create the most efficient designs for any given performance criteria regardless of any additive manufacturing method (SLM, binder jet, FDM etc.); optimize orientations and support structures; and quickly simulate printing process virtually to check manufacturing feasibility".*

Bangal is right. This would be the ideal process indeed, but the reality is different.

The "DfAM" method's paradox

In a **recent dossier of 3D ADEPT Mag entitled** "Design for additive manufacturing: how to increase the value of the part through intelligent optimisation", we were saying that there is no doubt, one designs for AM when the methods/tools used make them take into consideration topology optimisation, design for multiscale structures (lattice or cellular structures), multi-material design, mass customization or part consolidation. This list is not exhaustive since other tools can be added based on the AM technology used for a specific production.

In the automotive industry, the use of DfAM methods comes down to the taste of the chef in the kitchen, since **their utilization varies from one manufacturer to another, or from one application to another.**

Dimitri Marcq, Lead Engineer CAD at Sika Automotive told 3D ADEPT Media they had to adapt their guidelines. Taking the example of DfAM methods utilized to reduce printing time and material volume, he notes:

"At first, we start by defining the AM technology based on part type, end use, quantity to produce and lead time. Then the design is optimized for the selected technology: orientation, limitation of material quantity required to print the part, resolution definition to improve the printing speed [or even] part design based on material properties. Such guidelines are being developed within Sika Automotive for each technology. For some specific features, it can be interesting to use off-the-shelf parts fitted on the printed parts. This allows to decrease printing time, by removing some complexity".

Image : Altair & ExOne - Automotive bracket Original

Let's take the example of lattice structures. They can possess many superior properties to solid material and conventional structures and one advantage is that they are able to integrate more than one function into a physical part, which makes it attractive to applications beyond automotive.

"Lattice structures [are ideal] for our reinforcement applications (lighter parts, better energy absorption, etc.). We [have already produced] a few samples: they were easy to print and really stiff. This type of structure can only be 3D printed, and is therefore limited to small volumes production. On top of that, the software that we are using daily is not designed to engineer such geometries. Dedicated software would be required to progress in that direction", Marcq points out.

The question of costs: what increases costs? And most importantly, how to avoid an expensive cost of the final part during the manufacturing stage ?

As a manufacturer, the perfect value proposition would be to amortize the cost of tooling over a much wider volume and longer period. Additive cost models have changed the paradigm with the simple realization that you don't have to first build a tool anymore; you can go straight to building the part. Deloitte reports that the cost-benefit extends even further as unlike tools—that are typically built to support a five-year vehicle life cycle plus additional service part production—we can reuse the same AM printer across multiple vehicle programs and design generations.

However, some industries suggest that, despite its potential and benefits over traditional manufacturing, AM can increase the piece cost of making some parts versus using traditional methods by a factor of 10 to 100.

"Automotive has specific needs in terms of scale, cost and materials that differ from other industries. Production speed and part costs are the top barriers to overcome in order to increase the use of AM in the automotive industry", **Thomas Gasparri** from Sika Automotive recognizes.

Design changes can be a double-edged sword in that they can increase or reduce the final cost of the part- depending on the angle from which you analyse.

When compared with traditional manufacturing, **Gasparri** explains that AM wins over traditional manufacturing which does not take into account the multiple **design changes** that are likely to increase costs in the end:

"AM enables designers and engineers to try numerous iterations simultaneously that may reduce upfront costs caused by tooling design modifications. Mistakes in the tool design do not show until after machining. Multiple design changes go from the designer to the tool engineer until the final tool design and quality are achieved. This adds costs and increases the time to market.

AM is a bridge between concept and final mass production. It allows to jump in and test a design without having to invest in that tooling. The final design is printed by AM to validate the performance. Once a functional design is approved, the tool machining can start and the expensive design changes can be avoided."

However, according to Altair's expert, an exclusive focus on AM reveals that *"more than 40% of the costs associated with additive manufacturing have come from waste. This includes: material waste by printing tons of supports and post-processing afterwards (because of a wrong design/part selection for 3D printing); time waste by printing using incorrect orientations (resulting in print failures); as well as financial waste via trial and error printing methods, rework labour and machine costs, etc."*

Furthermore, complex meshes and tubing structures might also lead to prohibitive costs that could raise the price of a vehicle by thousands of dollars, hence the time engineers spend negotiating quotes prior to production.

To avoid the final expensive costs, the expert says *"designers must understand the manufacturing constraints, 3D printer-specific design guidelines, and most importantly, that predicting and fixing manufacturing defects early is the key for avoiding the above-mentioned cost."*

Areas for improvement & future outlooks

Every car goes through a tremendous and complex design and development process. Cloud manufacturing has made automotive design easier, faster and affordable for companies that do not want to spend time on such in-house development.

To those automotive engineers who are working on their designs in-house, Bangal affirms that "learning to use [these DfAM] tools is the easy part. "Getting out of one's comfort zone and adapting to next generation design and manufacturing methods is a slow change." Speaking of Altair's contribution in this field, he adds: *"Altair has developed a novel design methodology that quickly and efficiently identifies opportunities through design exploration, converging the appropriate KPI mix that is desirable to our customers. This process continues to be refined as new technologies are developed and has proven to be very successful in arriving at substantial weight savings within acceptable performance and cost boundaries. This methodology is currently being advanced through our new Design AI tool that collects optimal datasets, auto-selects the best machine learning model, and enables the user to do quick what-if studies for fast, collaborative design improvements. The bottom line: the challenge is to not only develop a cool design, but more importantly, to achieve the appropriate cost, weight and performance mix."*

Last but not least, to advance the automotive industry, a collective effort beyond what OEMs can achieve is indispensable. Although, software providers and automotive engineers/designers from part manufacturers were the first involved in this article, it should be noted that these efforts also include material suppliers and next-gen machine manufacturers.

In this vein, to make their work as part manufacturers easier, **Gasparri** urges software providers to develop tools that *"will help [them] get the best orientation, depending on the technology selected, in order to optimize the part / support material ratio; tools that will help [them] define the optimum batch size"* and to machine manufacturers a *"plug & play eco-system (printers / materials / parameters), with an open-source strategy."*

Various 3D printed parts produced by SIKA Automotive – Credit: Sika Automotive

COUNTRY FOCUS : THE NETHERLANDS

The current reality of «printed electronics for automotive applications»

*Car manufacturers are currently envisioning a future where most self-driving cars will have an interior to entertain or relax drivers and passengers, the ultimate goal being to go through an experience, which is beyond driving. To do so, they are gambling on **"printed electronics"**.*

Photo by Andrea Kratzenberg

Simply put, printed electronics refers to a manufacturing process that creates electronic devices by printing on a variety of substrates. The concept has gained momentum with the increasing demand for wearable devices and thinner electronics, raising a number of questions on the appropriate techniques, the benefits and challenges it brought to each application. We caught up with Margreet de Kok, Program Manager Structural Electronics at Holst Centre to discuss this topic with a key focus on automotive applications.

For those who do not know, Holst Centre is a Dutch independent research and innovation centre that is part of TNO, Netherlands Organisation for Applied Scientific Research. The not-for-profit organization collaborates with public and private companies to develop technology solutions that can be commercialized. The organization is particularly acknowledged for its expertise in wireless sensor technologies and flexible electronics for products in form factors ranging from stretchable, flexible, textile integrated to structural.

Potential for printed electronics in the automotive industry

Needless to say, that the current societal and economic environment encourages the consumer automotive market to consider increased safety, interactivity with low-energy, low-carbon and other environmental concerns in their choice.

According to experts, printed electronics could help address these needs in a non-obtrusive, aesthetically satisfying way. The manufacturing process is interesting because it provides manufacturers with the possibility of easily preparing stacks of micro-structured layers, not to mention that as it is the case with various AM technologies, it can enable to deliver new and/or improved functionalities to the printed product. That's why, it is often considered as an entire new niche of the AM industry.

Here too, there are various types of processes: from sheet-based to roll-to-roll-based processes ideal for low volume productions as well as gravure, offset and flexographic printing methods that are often utilized for high volume productions.

de Kok explains from the outset: *Structural electronics consists of integrating printed circuitry and discrete electronic components into thermoformed and / or injection moulded plastics. [Confusion is not to be made with 3D printed electronics which is a set of printing methods used to create electrical devices on various substrates.] We also have a team that is exploring the possibility of 3D printing as an alternative to create the shape by the printing itself, whereas structural electronics starts from a flat plastic substrate onto which we add layers additively for aesthetic purposes, or to fulfil specific electronic functions. This flat plastic substrate is then shaped to a 3D form using thermoforming. Backside injection moulding is thereafter used to give the product its final thickness, form and sturdiness. This means that with the new alternative enabled by 3D printing, designers will benefit for more design freedom and*

Margreet de Kok
Program Manager Structural Electronics at Holst Centre

depending on the functionalities we are looking for, it is also possible to combine materials and electronic components by lamination, thereby seamlessly integrating light, embed sensors, displays and driving chips into a part."

Nowadays, printed electronics enables a wide range of applications that goes beyond the automotive industry. They include for instance flexible screens, intelligent labels, packaging, interactive books to name a few. However, in the automotive industry, possible applications usually aim to meet **key purposes like lighting, sensing, feedback, and information** and **entertainment**. Such a smart surface is referred to as **a Human Machine Interface.**

According to de Kok, since lighting is switchable, intuitive and responsive, it can deliver a wide range of functionalities.

*"**Light's** primary function is to eliminate darkness. It can also be used to indicate a certain status in the vehicle, to turn your dashboard into a real screen – light is seen in this case as a means to communicate and the transformation of a dashboard into an interactive display is also a means to deliver **entertainment** and information."* , de Kok enumerates.

As far as **sensing** is concerned, we also learned that printed sensors detect touch or proximity but also help measure temperature, pressure, movements or monitor structural integrity. In certain cases, they can also help to activate entertainment systems. The Program Manager Structural Electronics mentions light sensors and temperature sensors as examples here. Interestingly, embedded touch and 'touch less' sensing can open new possibilities in terms of new design features and help customize the cabin based on the user needs by a new means of interaction.

The hybrid approach to printed electronics

While she was speaking about applications that printed electronics enable, de Kok laid emphasis on the development of **hybrid printed electronics and low-cost substrates**. This manufacturing approach therefore combines flexible printed electronics with conventionally manufactured ones.

"We could first print a part and find another way to embed an integrated circuit into that part to increase its performance. A proximity sensor or a microprocessor are some examples of applications that would be a great fit for hybrid printed electronics. The key to making this type of application successful is to deposit materials only where you need them to be: printing is an additive technology. This is not the case with conventional manufacturing, where a multi-step subtractive process based on lithography is required to create one layer of electronics.

Image: Holst Centre - Together with the automotive industry, Holst Centre develops non-contact sensing solutions based on printed electronics technologies.

As a matter of fact, hybrid printed electronics becomes especially interesting when one wants to reduce weight and gain space. Not only does it improve the part rendering, but it also enhances design freedom, providing therefore a couple of new multimodal functionalities. Some microprocessors are so complex and so optimised that it is impossible to produce them properly with printable materials. So, we need to combine the best of both worlds to get a product with the desired properties at an affordable price", she explains.

"Cost vs. benefits"

Whether it is printed electronics or hybrid printed electronics, the recurring question consists in discovering if these processes bring more advantages than other manufacturing methods. To that, Holst Centre's representative said that the **question should be "costs vs. benefits"**.

At first glance, the advantages seem undeniable: **more versatility, flexibility** and **cost-effectiveness**. From a technical perspective, and while listening to de Kok's

Credit: COPT Zentrum - Organic and Printed Electronics description of hybrid printed electronics, the process would require fewer input materials and less energy, not to mention the possibility to produce flexible devices. The part would benefit from reduced thickness, and weight – thereby contributing to lower emissions while integrating new functionalities.

"From a sustainability point of view, the process is better, less costly and enables a very efficient use of materials. Depending on the application, the post-processing step might only include a curing step of 120°C to create the circuits. In the automotive industry, especially, we are convinced that printed electronics is not only cost-benefit but it also enhances the design", the expert points out.

What slows down the adoption in the automotive industry?

3D printed/structural electronics is still an emerging technology at the intersection of 3D printing and printed electronics. This means that a lot still needs to be done in terms of **certification** and **costs**. The technology is maturing but is still being explored at various levels of R&D.

"When a technology is relatively new, there is a great chance that prices are more expensive, but the more commercial examples appear on the market, the more prices will drop", de Kok outlines.

Furthermore, for now, professionals have only revealed a limited number of automotive applications made possible via printed electronics. Currently, there is no doubt **printed sensors** and **heating elements** have proved their worth in vehicle seats as they are the most widely seen applications. However, the interaction between passengers and future information and entertainment systems, are some of the applications that are still at their infancy.

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GUEST COLUMN

Speeco aims at filling the void between mass volume and out of range, exotic components in cycling by effectively implementing additive technologies.

By Noah van Horen and Thom Spermon

*Two (ex-) competitive cyclists, **Jules de Cock** and **Noah van Horen** have always been intrigued by factors that influence a cycling race. They have founded **SPEECO** to explore solutions that will improve the cycling experience of professionals and enthusiasts in the field. At the heart of SPEECO, there is the production of custom bike handlebars using 3D printers. In this guest column, **Noah van Horen** and **Thom Spermon**, Mechanical Engineer, recount the experience cyclists can go through, the reasons why 3D printing comes into play, its advantages but also what they wish to improve.*

The fall and rise of custom products in cycling

Custom products have been common in road cycling since the early days. For many years, pro riders had their individual preferred frame builder that welded a couple of frames, which were then repainted in the team sponsor's colours and decals.

To counteract riders getting unfair advantages from custom inaccessible components the **international cycling union (UCI)** introduced rules on the mandatory commercialization of components and additionally homologation of frames and wheels in 1997. Meaning all components used in a race must be available to a customer within a 3 month lead-time, and frames and wheels must have all sizes and variations permitted by the UCI.

Custom products disappeared and breakthroughs were made in mass producing composite frames that fit an as large as possible range of people, keeping the amount of moulds and different processes to a minimum. Until 2015, when team **Sky** provided professional cyclist **Bradley**

Wiggins with a set of titanium, **3D printed time trial extensions**, which support and enclose his forearms in an aerodynamic position, for his hour record attempt. In 2017, the entire team sponsored by **Sky** rode on custom 3D printed time trial extensions, and soon the rest of the peloton couldn't stay behind.

Dutch provider of speedbars **Speedbar™** therefore followed the same path. It first produced handmade custom time trial extensions for the world record attempt of Belgian cyclist Victor **Campenaerts** and thereafter, supplies them for 'normal races' later.

The big difference however is the company's use of a relatively cheaper material, carbon fibre, but a much more labor-intensive process involving handmade molds. Resulting in the case of both the titanium, as the carbon fibre options being out of the league of most riders at €4500-€8000 ($5291 – $9407).

A constant tradeoff between labor and cost

We believe there is a golden mean. When **Jules de Cock** – **SPEECO's** Co-founder did his graduating project in 'standard' composite manufacturing, there was a foundation to start designing and testing different processes. After a couple of months, we were able to manufacture a carbon fibre end-product from simple, FDM printed molds.

To further cut down labour, we took two new riders, looked at possible variations between their individual needs, and developed a parametric design for time trial extensions. We found out, it was possible to get dimensions from riders who were not near us or even on the same continent. Once a 3D model based on their dimensions is 3D printed using a FDM 3D printer and PLA as material, the riders receive the sample, review it, provide feedback, and the carbon fiber end-products are built only after we receive this feedback. A whole process that enables us to minimize as much as possible labour.

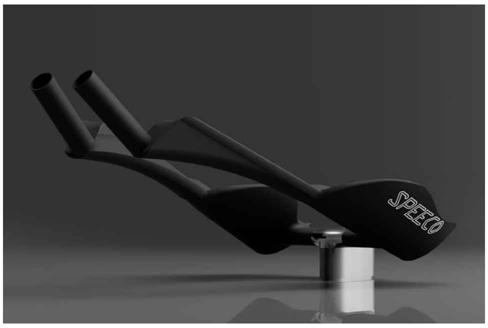
This process has now been extended to **three different products**, with more products launching this summer. For the new products, we collaborate with a discipline pioneer to develop a perfectly fitting product, then parametrize the model and sell it worldwide. While that works, there is still room for improvement and implementation of more additive technologies.

What we aim to achieve moving forward

We have spoken about what we already achieved, but we want to look forward as well. While polishing our current processes, we are researching and developing new products as well. In the **current production process, labour is still predominant.**

One way to overcome it would be to automate more parts of the process by integrating different parts of the end-product in one larger print and saving time on alignment. Due to the complexity of the parts, this would require a new approach of the FDM process, one in which the process is elevated to a true 3D process, in which the print head moves over all axis at the same time ensuring a better finish in which stepping will not be as present. This could be done with a setup similar to most 3D printers that are currently in the market, which makes it accessible within the near future.

Another approach could be to use a robot arm in a manner that is similar to WAAM. With adequate cooling, this would allow for very complex shapes to be printable. Within such a setup, it would also be possible to integrate a multi material process that would allow for TPU printing within the handlebars, opening up a new realm of possibilities for the customization of products.



Images - Courtesy of SPEECO - Final design of Speeco's monobridge solution for the specialized shiv tri.

Another solution that comes to mind could be to use a filled material, which would enable to skip the carbon layering or at least part of the layering process. There are already a lot of different carbon and kevlar-filled materials on the market, with all kinds of different base materials to print with. These materials can produce very durable end-use parts in different (industrial) applications, one of the drawbacks however is that these materials usually require a high infill or even solid print to ensure stiffness and strength. The products we currently produce require a certain degree of lightness and in most cases a way of internally routing cables as well. Both of these requirements make it harder to make end-use parts with printing.

Another crucial point is the orientation of the parts, the way that strength is dependent on layer orientation in FDM printing and the complexity of the parts means that it is almost impossible to find an orientation in which parts are strong enough without any additional carbon layering. It is very challenging to address this issue but not impossible. Indeed, the dynamic load produced by the rider on the parts, especially during a race, can be very harsh. It often happens that, riders cycle closely together at high speeds during a race. The consequences of a crash during such a moment are tremendous. This means that it is of utmost priority that the parts are able to endure these loads. Not to mention that the structure of carbon fiber and kevlar mats minimize the risk of a product failure, but such a structure and insurance is hard to replicate with just 3D printing.


Thom Spermon

The innovation in the 3D printing industry is so rapid that the possibilities of producing end-use cycling parts are getting closer every day.

Despite the array of possibilities 3D printing enables, we currently focus on producing mostly handlebars and handlebar extensions. Too much sport equipment has been standardized over the years, creating products that almost fits everybody, but in reality fits nobody. Utilizing additive technologies opens up possibilities to disrupt this and we are looking forward to seeing where it leads.

ADDITIVE MANUFACTURING SHAPERS

"NOT EVERYONE WANTS THE SAME THING"

Autonomous driving, e-cars, digital services and more features: a lot is requested from car manufacturers who continuously need to be efficient, cost relevant and more responsive to the market's changes. At the heart of these requests, lies the need for a cleaner, more sustainable future of both vehicle use and production, a need that XEV has well understood and is determined to address.

With over two decades in the automotive industry, **Lou TIK** has built up extensive experience in leading Chinese car companies where he held management positions and helped launch more than 15 cars. Despite the slow speed of 3D printing when he first discovered it, he felt it could play an important role in car manufacturing. It has been three years that TIK has founded XEV and additive manufacturing is at the heart of its production technologies. We caught up with the founder to know where the company is headed.

How did you decide that AM will be the main enabler in your production environment?

In 2015, we took part in a European competition dedicated to new mobility and production solutions. We proposed a solution that aims to drastically improve the user experience by providing zero emission with maximum freedom.

At the time, the 3D printing market had already evolved compared to what I knew in 2010 and following the feedback we got at this European competition, I couldn't stop thinking that I must bring this technology in a new company. I therefore decided to found the company at the end of 2017 and we began our operations in 2018.

At XEV, we focus on core problems surrounding urban mobility by providing affordable, individual transport responsible for the environment.

What changed since then?

Obviously, over time, we discovered the various areas of improvements that still need to be made to make the technology viable for our production

Lou TIK

needs. So, we looked for ways to improve and automate the AM process.

Fortunately, we have built up a team that brings to the table an expertise in the main domains we must be experts in: automotive and additive manufacturing. With experts from this key vertical industry and experts from the AM industry, we are uniquely positioned to meet the expectations of the automotive market, and to develop technology solutions that take into account the manufacturing requirements.

Could you please elaborate on your manufacturing process?

Yes, sure. First, I want to point out that we co-developed FDM-based industrial 3D printers in collaboration with a partner.

The AM systems can achieve multiple tasks into one go due to the automated features that have been especially developed for the systems. One of our goals was to achieve quality printing and accuracy while achieving mass production. We put all our know-how in postprocessing and used robots in order to achieve an "injection molding look and feel". This entire process is our key value: from manufacturing to the desired final part.

We came to realize how valuable this process is in 2019 when several automakers reached out to us to leverage our 3D printing solutions.

XEV ambitioned to mass-produce its YOYO series using AM. At what stage is the project now?

*We were very ambitious at the beginning, as we wanted to produce the entire car using additive manufacturing. We came to realize that the technology was not mature enough to meet that purpose. We have therefore decided to produce parts that are usually produced via moulds with AM. Our FDM printing solutions will be dedicated to the production of parts such as the **big cover of the dashboard, the inside of the front tanker, the door blade** to name a few.*

We will increase the database of car components that can be 3D printed and will release the 3D printable parts over time. We will give multiple choices to the customer so that he chooses the version that suits him best. We understand that not everyone wants the same thing, which is why we have implemented a modular approach that will enable to provide the customer with a tailor-made vehicle. Two from years now, we will see a full 3D printed car on the road, but we are not there yet.

We know the company opened an innovation center in Shanghai but will the YOYO series be available on the European market as well?

The car will be for the European market first. It has been designed for the European market and its production requirements comply with the European legislation. It will probably be the much affordable car on the market (~ 10 000 €).

This issue of 3D ADEPT Mag has a key focus on "automotive design in additive manufacturing" in its "Applications" segment. According to you, what challenges do designers still need to overcome at this level?

I think the big change is that there is a transition in the way designers work. With "Design for AM", designers have more possibilities compared to the way they worked with conventional manufacturing processes. One thing they need to acquire is experience. There are so many things to master in DfAM and there are no real standard guidelines yet. Therefore, they can only reach this mastery of tools with experience.

Anything else you would like to share?

I believe that even though machine manufacturers improve the AM processes, it's up to companies like us to use the technology, explore its applications, and push its boundaries. That being said, we can't wait to officially launch our YOYO series in the upcoming months.

Legend: door blade – image via XEV

Legend: door blade – image via XEV

NEWS ROUND UP

This news round-up sheds light on key developments in terms of 3D printers, post-processing, materials, software, as well as developments from organizers of events during the months of March & April. Scan the barcode or click on the title to read the full article on www.3dadept.com.

Thermwood completes first LSAM 1010 3D Printer with Fixed Table

The print and trim heads weigh over 7,000 pounds (3175 kg), resulting in a live load of over 18,000 pounds (8165 kg) but don't let this weight fool you.

SCAN ME

DyeMansion focuses on "the right processes" as part of the development of its three new postprocessing systems

"A machine itself does not solve customer problems, which is why we have put such a big focus on the development of the right processes" Philipp Kramer, CTO & Co-founder of DyeMansion.

SCAN ME

One Click Metal keeps affordability and productivity in mind thanks to two key features in its new metal 3D printer

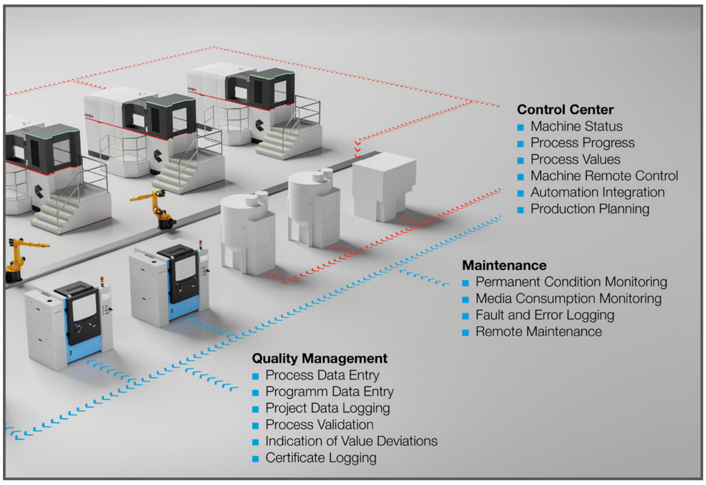
The release of the new MPRINT+ reveals that two other ingredients have been added to One Click Metal's fabrication recipe.

SCAN ME

Formnext 2021: real-life encounters, digital elements and flexible solutions offered to exhibitors

Following a year that saw physical events turned into digital events, Mesago Messe Frankfurt GmbH, has announced a hybrid concept for the 2021 edition of Formnext as well as flexible planning for exhibitors.

SCAN ME



Solukon brings Quality Management to the next level with enhanced automation and new IoT Solutions for AM Powder Removal

Reproducibility can only be achieved when every step of production is clearly outlined, paving this way an easier path to the very much needed certification & quality assurance.

SCAN ME

Inkbit unveils its Additive Manufacturing System Inkbit Vista, based on scalable inkjet deposition and 3D machine vision.

The company was spun out of MIT in 2017. In four years of activity, it secured $15 million in equity investments from various investors. Here are the main benefits of its Vista Additive Manufacturing machine.

SCAN ME

Evonik unveils a new PEEK filament for industrial 3D printing applications

Launched under the brand name INFINAM® PEEK 9359 F, the new filament could be used as a metal replacement in certain applications.

SCAN ME

NEWS ROUND UP

Sindoh's first industrial Polymer 3D Printer is the first to process Materialise Bluesint PA12

Materialise acquires five of the first industrial Polymer 3D printers of Sindoh that will process for the first time Bluesint PA12.

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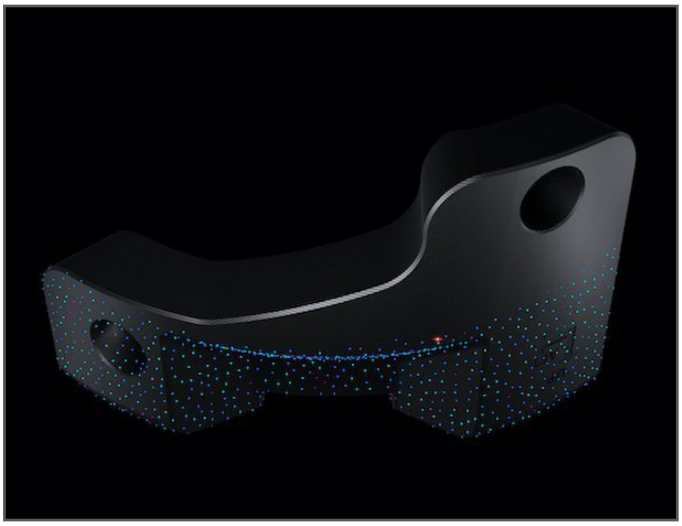
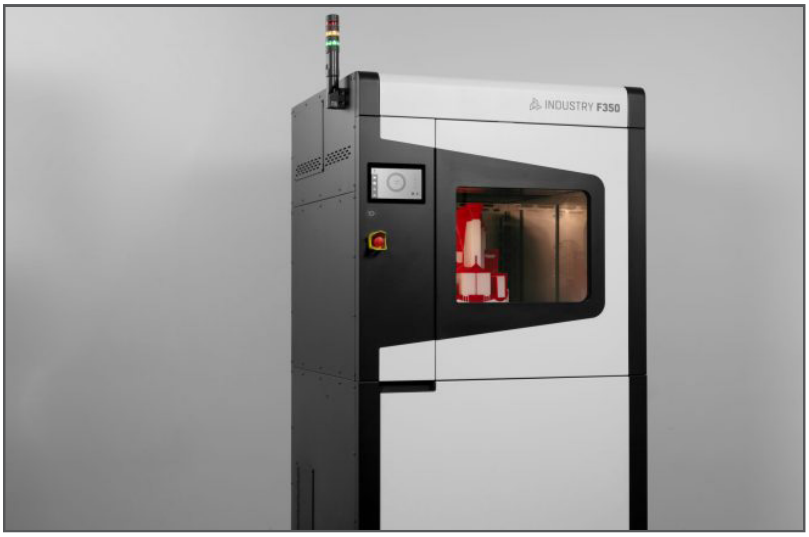
Markforged unveils AI-powered software Blacksmith for X7 3D printing system

Blacksmith learns through AI and streamlines workflow to give manufacturers accurate parts, right from the print bed.

SCAN ME





3DGence adds new FFF 3D Printer to its high-performance INDUSTRY Line Portfolio

With three different interchangeable modules, the INDUSTRY F350 can process a wide range of materials including PEEK, PA6, PA-CF, PC, ABS, ASA and PLA.

SCAN ME

AM Solutions, a brand of Rösler, to leverage a PostProcess Technologies Solution for Automated 3D Printed Metal Surface Finishing

AM Solutions is known for its dedicated post-processing solutions; and a commercial partner of PostProcess Technologies. However, the company has also launched a 3D Printing service, that will leverage the PostProcess™ DECI Duo™ Solution to increase the number of finishing options for 3D printed parts.

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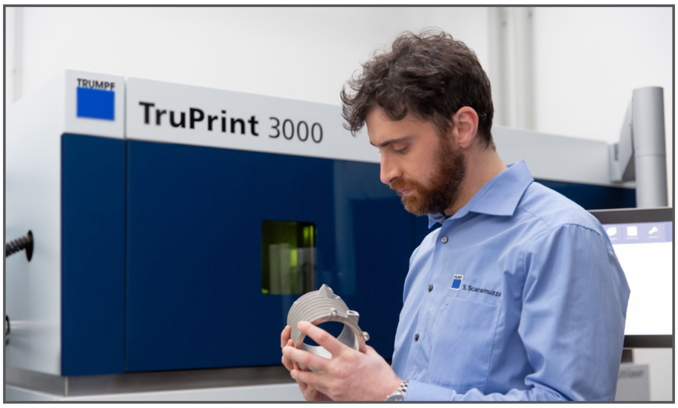
CADS Additive & designairspace unveil a SaaS solution for metal 3D printing

CADS Additive GmbH and designairspace have just been added to the exhaustive list of companies that provide SaaS solutions in the additive manufacturing industry.

SCAN ME



New Trumpf's TruPrint 3000 3D printer comes with a second laser as well as improved inert gas delivery and melt pool monitoring

With the ability to process all weldable materials including steels, nickel-based alloys, titanium and aluminium, the 3D printer manufacturer has improved key aspects of the 3D printer.

SCAN ME

SCAN ME

Jeol unveils new JAM-5200EBM metal Additive Manufacturing machine

It took a long time to Jeol, an expert in high quality electron beam source production to develop a metal 3D printer based in EBM but it finally did it.

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2021

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