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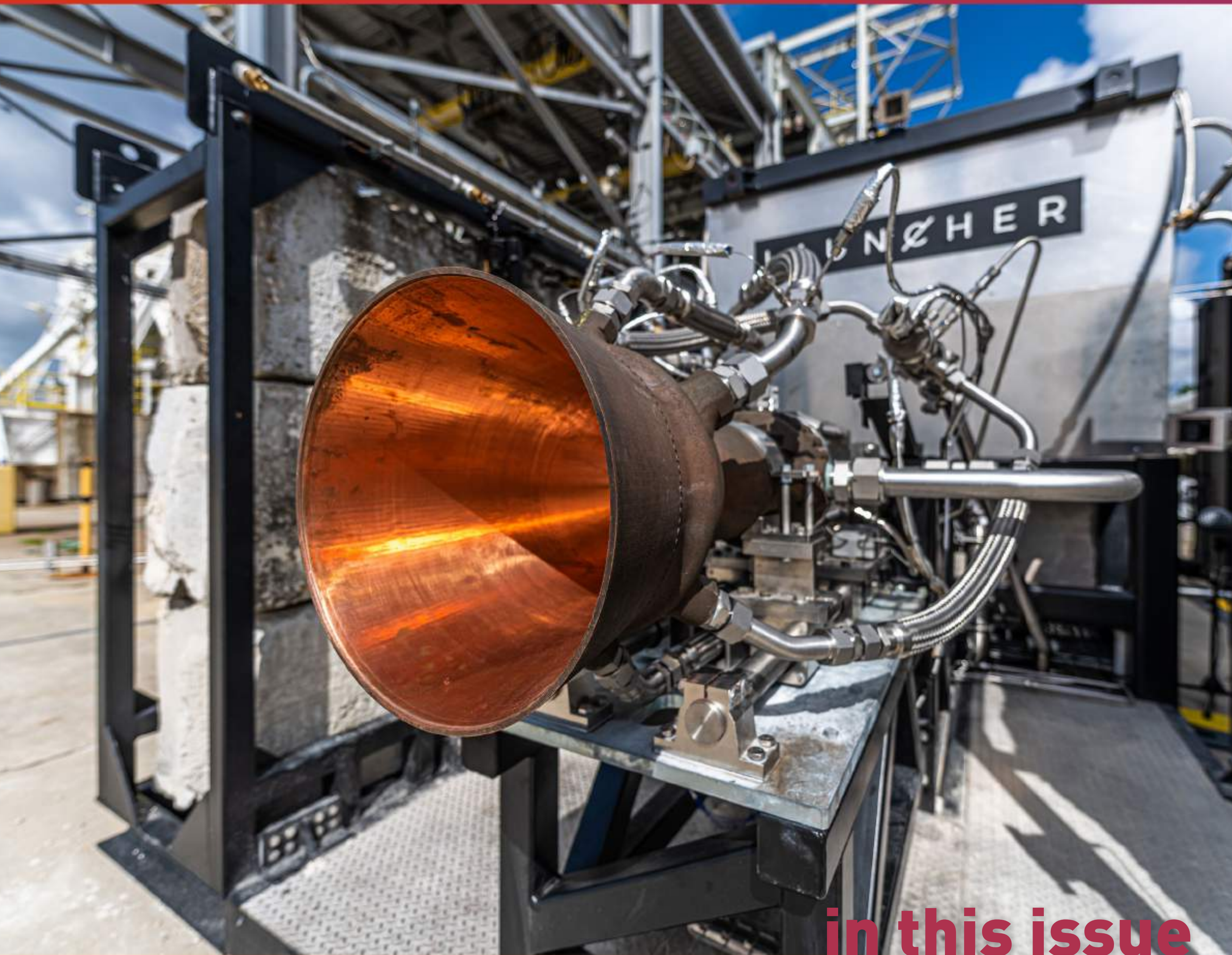
THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

# METAL AM



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**LAUNCHER & THE NEW SPACE RACE**

**FALCONTECH'S SUPER AM FACTORY**

**AUTOMATION IN METAL AM**

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METAL
ADDITIVE
MANUFACTURING

## Bigger, faster, better, smarter

One can identify trends in metal Additive Manufacturing that head in every possible direction – even smaller parts, even larger parts, more lasers, new material groups and, of course, a constantly expanding range of real-world applications that are either in, or close to, series production.

In this issue of *Metal AM* magazine, two distinct trends stand out: the ever-increasing size of Laser Beam Powder Bed Fusion (PBF-LB) machines, and the recognition from within the industry that we need to be working smarter and more efficiently, through increased automation of both the physical and digital aspects of the AM process chain.

When it comes to pushing the boundaries of PBF-LB build sizes, our cover article, featuring Launcher and AMCM GmbH, clearly illustrates the huge potential market for large-sized machines, and demonstrates that the technology to deliver metre-tall PBF-LB parts is here and ready. Elsewhere, including in our article on China's Falcontech and in our industry news section, there are a number of other stories that highlight the push towards larger PBF-LB machines.

As for the second trend, working smarter, two articles in this issue address the potential to dramatically improve upon the efficiency and capabilities of the physical and digital AM process chain. Joseph Kowen considers progress and obstacles to the increased automation of PBF-LB and metal Binder Jetting, whilst Chelsea Cummings and John Barnes explain how the vast amount of data generated by AM could be used to develop Machine Learning tools that can improve and industrialise the AM process at nearly every point in the workflow.

Nick Williams
Managing Director

**Cover image**
*Launcher's E-2 engine on the test stand at NASA's Stennis Space Center (Courtesy Launcher/John Kraus)*

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**103** **Falcontech: The journey from materials engineering to large-scale metal Additive Manufacturing**

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In the early days of metal Additive Manufacturing process development, automation was off the radar of machine manufacturers. Technologies created for rapid prototyping simply had no need for it and, until the last decade, few truly anticipated the pace at which Laser Beam Powder Bed Fusion and Binder Jetting have evolved in the race towards the series production of metal parts. In this article, Joseph Kowen reports on how the industry has addressed the challenges of automation so far, and what developments we can expect in the near future >>>

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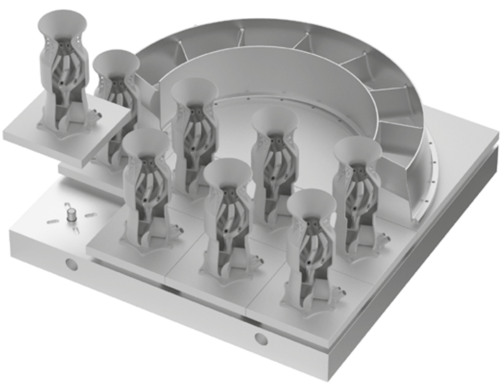
In conventional subtractive manufacturing process chains, components move efficiently throughout a production chain using pallets and standard referencing and clamping systems, enabling parts to be automatically processed by a variety of technologies as they move through a facility. GF Machining Solutions' System 3R division has leveraged its expertise in this area to create a tooling solution tailored to Laser Beam Powder Bed Fusion (PBF-LB) production. As Dogan Basic, Product Manager AM, explains, this optimises workflow, increasing the potential for AM automation and, as a result, for successful series production >>>



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# Industry news

## Fraunhofer and Fiat Chrysler AM sports car wheel components

The Fraunhofer Research Institution for Additive Production Technologies (IAPT), Hamburg, Germany, and Fiat Chrysler Automobiles (FCA) have collaborated to develop an additively manufactured wheel carrier with an integrated brake caliper for an FCA sports car. The part is said to represent the first step towards serial Additive Manufacturing of FCA vehicle components.

The research collaboration began with a focus on developing a complete suspension system for a sports car using AM. Presently, this system still consists of various individual parts such as the wheel carrier, brake caliper including hydraulics, and heat shield. In the past, these components were manufactured individually and then assembled in several steps using screws, seals, and washers to form a complete, functioning system - said to be a complex, time-consuming, and expensive process.

"We had, together with the FCA design team, to completely rethink the entire wheel suspension in order to achieve a one-piece bionic structure that fulfilled all the functions of the previous assembly at least equally as well, absorbed all the forces, was weight-optimised and could be produced additively," stated Yanik Senkel, Fraunhofer IAPT design engineer.

By using topology optimisation, the research team has developed a prototype that weighs 36% less than the twelve individual parts of the conventionally manufactured component. The bionically-optimised design reduces the assembly effort enormously, increases the fatigue strength thanks to its more robust construction and should also perform better, in terms of noise, vibration, and harshness (NVH).

The integral design reportedly eliminates many typical weak points and therefore extends its lifetime. Carlo Carcioffi, Head of Advanced Processes and Materials - Body, Interiors, Chassis, commented, "Together with our innovation partner Fraunhofer IAPT, we are cutting the costs and production effort for key vehicle parts. The knowledge transfer will help us to improve Additive Manufacturing competence in the fields of integrated design, materials, and process technology across the group."

Carcioffi added, "The component demonstrates the potential of Additive Manufacturing for future cars and, on top of that, it's a real eye-catcher."

The additively manufactured wheel carrier with an integrated brake caliper, said to be the first of its kind, is only the beginning, explains Fraunhofer IAPT. In numerous joint workshops, which also covered the areas of material and process development and quality assurance, several components in lightweight and integral construction were completely redeveloped.

Ruben Meuth, Head of Business Development at Fraunhofer IAPT, reported, "The overall focus is on the reduction of manufacturing costs, for example, by significantly increasing production speed. This innovation project is an excellent example of the collaboration between industry and research. This component shows how Additive Manufacturing can be implemented into series production for luxury and sports cars."

www.iapt.fraunhofer.de
www.fcagroup.com

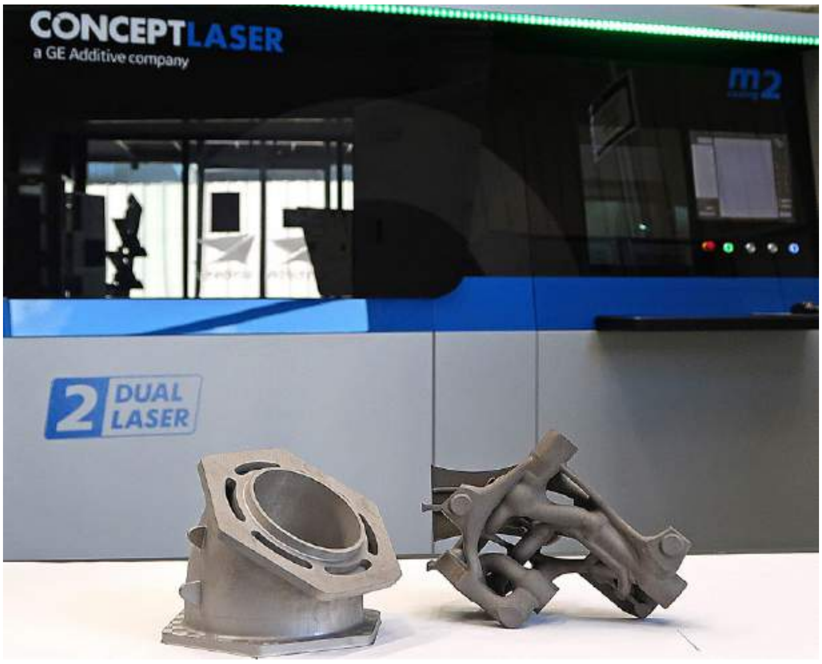

*Fraunhofer IAPT and Fiat Chrysler's additively manufactured wheel carrier with integrated brake caliper (Courtesy Fraunhofer IAPT/ Fiat Chrysler Automobiles)*

# Airbus validates Premium Aerotec and GE Additive's multi-laser titanium AM parts

Premium Aerotec, Augsburg, Germany, and GE Additive, Cincinnati, Ohio, USA have reached what they describe as a new milestone for AM within the aerospace industry, following the successful certification of a multi-laser process used to build a single component.

In 2019, the process for the manufacture of titanium components on the GE Additive Concept Laser M2 was successfully validated; however, this initial qualification was limited to the parallel assembly of components, with one laser being used for each part. For larger components occupying the majority of the build space, this meant that productivity could not be increased through the use of multiple lasers to build a single part.

Premium Aerotec reports that this limitation has now been removed, following the successful validation of multi-laser single-component builds by its customer Airbus. In the newest certification, the process-critical area is where the exposure zones of the lasers overlap, also known as the stitching zone. The highest precision in the calibration of the optical systems and sophisticated compensation of the influence of the process heat, for example, is necessary to achieve the desired material properties.




*An additively manufactured titanium vent bend and brake manifold in front of a GE Additive Concept Laser M2 multi-laser AM machine (Courtesy GE Additive)*

"With this advanced technology, we are now able to achieve a homogeneous, quasi-isotropic structure with excellent material properties in the overlap area, which does not show any discernible differences from the previous quality standard. At the same time, with our partner GE Additive, we have succeeded in increasing productivity in component production by more than 30%," stated Thomas Bielefeld, Project Manager, Premium Aerotec.

The Concept Laser M2 is a dual-laser machine with a build volume of 250 x 250 x 350 mm and a 3D optic variable spot diameter. The current generation of the machine was developed to meet the exacting regulations of industries such as aerospace and medicine in terms of accuracy, uniformity, repeatability and safety.

"We are thrilled and satisfied to have reached this milestone in cooperation with PAG. We owe this success primarily to the teams at PAG and GE Additive, who, for many years, have worked well and closely together on this project. This was not the first success and it will certainly not be the last," commented Udo Burggraf, Senior Key Account Director, GE Additive.

The partners are now planning the next steps to significantly increase achievable build rates and in turn make Additive Manufacturing economically attractive for an expanded range of parts. Premium Aerotec will use its newly-validated laser system to produce components for the Airbus A320 family.

www.premium-aerotec.com
www.ge.com/additive

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## SLM Solutions launches 12-laser metal Additive Manufacturing machine

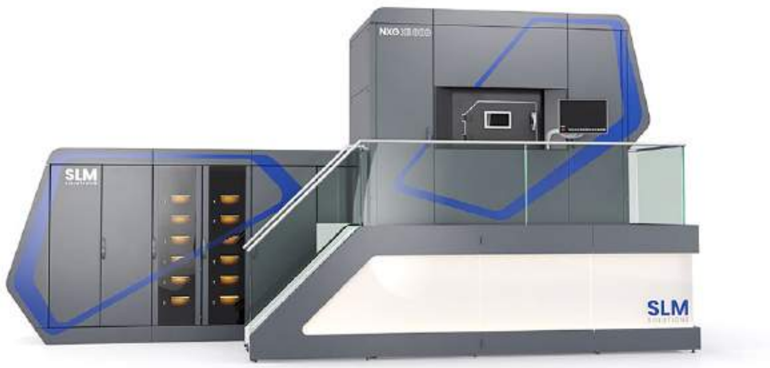
SLM Solutions Group AG, Lübeck, Germany, has launched its new Additive Manufacturing machine, the NXG XII 600. The Laser Beam Powder Bed Fusion (PBF-LB) machine is equipped with twelve 1 kW lasers and features a build envelope of 600 x 600 x 600 mm. The company reports that the NXG XII 600 offers build speeds twenty times faster than possible with a single-laser machine, and is designed to be used in serial production for high-volume applications as well as for building large parts.

According to SLM Solutions, the NXG XII 600 was designed from scratch for serial production and features a new optic system, said to be the most compact on the market. It enables large overlap and is based on a tailor-made laser scanning system to best fit the build area. All twelve optics provide spot size definition via a double lens system zoom function, enabling customers to choose between different spot sizes in the focal plane, boosting build rates to 1000 $cm^3/h$, and more. To facilitate the integration of the NXG XII 600 into factories and supply chains, several automated features like an automatic build cylinder exchange, automatic build start, and external preheating station and depowder station, have been included.

In order to achieve homogeneous part properties all over the building platform, the company has developed a new gas-flow setup along with an optimised chamber design. The company's patented bi-directional recoating has also been redesigned to be more compact and gas-flow optimised. Additionally, the machine comes with a new UI concept which SLM Solutions states optimises the workflow and reduces operator training requirements. The machine is available with gravity-based and vacuum-based powder handling options.

"The NXG XII 600 is a revolution in industrial manufacturing. Up until now, the limit had been considered to be that of a quad laser system – what we deliver here with 12 kW of installed laser power is truly groundbreaking and a major step forward, not just for Additive Manufacturing, but for manufacturing in general," stated Sam O'Leary, COO at SLM Solutions. "The potential cost reduction and productivity gains that this machine offers you means for the first time in the history of Additive Manufacturing, you can have true serial production fully integrated into your supply chain."

www.slm-solutions.com




*SLM Solutions has officially launched its new AM machine, the NXG XII 600 (Courtesy SLM Solutions Group AG)*

## VDM Metals adds two AM alloys for chemical and oil & gas applications

VDM Metals International GmbH, Werdohl, Germany, part of the Acerinox S.A. Group, has developed two new alloys for Additive Manufacturing aimed at the chemical process and oil & gas industries. VDM® Alloy 699 XA and VDM® Alloy 718 CTP are produced in conventional product form and in powder form as VDM® Powder 699 XA and VDM® Powder 718 CTP.

VDM Powder 699 XA (2.4842/N06699) is a nickel-chromium-aluminium alloy suitable for application in the petrochemical industry under metal dusting conditions at high pressure. The alloy was designed to be used in the production of hydrogen, ammonia, and methanol where metal dusting – a type of corrosion in the range of 400–800°C in gases containing hydrogen and carbon monoxide with low oxygen content – appears. Metal dusting is a challenge in production plants as it leads to the decomposition of metal into carbon and metallic particles.

The new alloy is suited to applications both in and outside the chemical process industry, for example, in static components for gas turbines. It can be produced not only as conventional semi-finished products and powder, but also in wire form.

VDM Powder 718 CTP (2.4668/N07718) is the powder variant of an age-hardenable nickel-chromium-iron-molybdenum Alloy 718 CTP that is within the standard specification of Alloy 718. The material is said to offer versatility for use in the oil & gas, offshore and marine engineering industries. In comparison to standard Alloy 718, the new alloy contains less C and Nb, and is aimed at powder- and wire-based AM applications. This means that it could be used for a wide range of process possibilities, based on its better segregation behaviour during the building process, and offer reduced cracking. The alloy could also find applications outside the oil & gas industry, for example, in nozzle construction for space applications.

www.vdm-metals.com

## Mitsubishi Power establishes licensing agreement with Aubert & Duval as it nears launch of new AM business

Mitsubishi Power, Ltd., a subsidiary of Mitsubishi Heavy Industries Group (MHI), Yokohama, Japan, and Aubert & Duval, a subsidiary of the High Performance Alloys Division of Eramet group, based in Paris, France, have announced a licensing agreement for the production and distribution of metal powders for AM.

The agreement is expected to pave the way for the full-scale launch of Mitsubishi Power's AM business, which follows the recent creation of an AM-Zone® at its Hitachi Works in Ibaraki Prefecture, Japan, to serve as a development and manufacturing base for its Additive Manufacturing business.

*Prototype of a gas turbine combustor component (Courtesy Mitsubishi Power)*

The new facility is equipped with powder manufacturing equipment and metal AM machines, and is said to be capable of fully-integrated production – from the development of powder and wire materials to metal AM and product finishing. Mitsubishi Power explains that it possesses proprietary material technologies in metal AM, and can optimally prepare raw materials for each application required. It also has technologies that significantly enhance the performance of powder manufacturing equipment, where the company's specially-developed gas nozzles are used to produce metal powder materials by atomising inert gas into vacuum-fused metals.

Under the new agreement, Aubert & Duval's knowledge in the composition and manufacturing of powders for AM will be combined with Mitsubishi Power's technologies to enable the provision of powders optimally suited to metal Additive Manufacturing. Along with the creation of the AM-Zone, Mitsubishi Power will become involved in all aspects of metal AM processing, from material development to final product manufacture.

https://power.mhi.com
www.aubertduval.com

## Mimete releases new iron-base powders F51 and F53 for demanding applications

Mimete S.r.l., Biassono, Monza, Italy, has released two new iron-base powders, Duplex MARS F51 and Super-duplex F53. The company, a division of Italy's Fomas Group, established a new powder production plant in May 2019 utilising a customised vacuum inert gas atomisation (VIGA) system. While the company initially focused on the production of standard powder grades, with some experimentation on customised alloys, research was also undertaken on which alloys could guarantee the easiest entrance into the market for metal Additive Manufacturing powders used in highly demanding industries such as oil & gas, power generation and aerospace. This led to the production of a number of special alloys, such as F51, together with high-carbon steels and Ni-base alloys. These materials were produced in a wide range of grades, suitable for different AM processes (BJT, PBF and DED) along with coating and HIP applications.

Duplex steel F51 is a widely-used material, where the relatively high content of Cr, Mo and Ni generates improved mechanical properties when compared to austenitic stainless steel. It also offers good pitting corrosion resistance and stress cracking resistance. F53 is a highly alloyed duplex steel, referred to as a super-duplex, distinguished by its much higher corrosion resistance, making it suited to highly critical atmospheres and environments.

"Mimete's team effort and dedication are bringing our duplex and super duplex stainless steel powder to the market. We are proud to provide our customers with high-quality powders that will be used in applications where maximum performance is required," stated Andrea Tarabiono, Mimete's Manufacturing Director.

Duplex and super-duplex mechanical properties are well known to the oil & gas and maritime industries. These industries are looking at AM with deep interest, as it could lead to lower operating costs by streamlining production processes and developing a lean supply chain. By offering materials that are known to these industry sectors, it is hoped that Mimete can help to increase the adoption of AM.

www.mimete.com

# Optomec announces two new DED AM machines

Optomec, Albuquerque, New Mexico, USA, has launched two new metal Additive Manufacturing machines, the CS250 and the HC-TBR. The systems are based on Directed Energy Deposition (DED), a powder-based metal AM process that Optomec developed under the LENS trademark. They both feature a 250 x 250 x 250 mm build volume, suitable for small part production and repair, including batch processing. The systems are available in three-axis or five-axis versions capable of simultaneous five-axis coordinated motion for full free space building.

The new machines are equipped with a build head that is capable of automatically changing the laser spot size and output power on the fly, enabling material to be applied faster to larger areas of the part, yet still create fine features with lower heat input to thinner areas of the build. There is an optional inert processing capability that is optimised for building reflective and reactive alloys like copper, aluminium and titanium, in addition to a wide variety of other common metals including steel, nickel, etc.

The CS250 machine, designed for research, is an all-in-one system with up to four integrated powder feeders, enabling rapid alloy development and graded-material part creation. It is small enough to pass through a standard doorway, facilitating use in many existing research labs. The base machine pricing starts at under $300,000.

The HC-TBR machine is designed for high-volume production applications, and includes the capability of automatically moving and processing titanium parts into and out of an inert atmosphere, a feature which is said to be critical for high-quality metallurgy and plant safety.

For additive repair applications, such as production turbine blade restoration, the HC-TBR also includes an integrated vision system with proprietary AutoCLAD software that scans each part individually and uses pattern recognition to create a custom tool path and additive repair recipe for the part, compensating for part-to-part variation while minimising the heat input into the component. The HC-TBR was designed for easy integration into automated work cells and includes automatic antechamber doors which can be loaded and unloaded robotically.

"The HC-TBR is the first machine capable of high volume production for reactive metals like aluminium and titanium," commented Mike Dean, Optomec Marketing Director. "We've seen quite an increase in demand for these materials from our customers and expect the trend to continue as manufacturers move to lighter-weight designs."

www.optomec.com

*The new CS250 and HC-TBR metal AM machines (Courtesy Optomec)*

# 3D Systems to sell its Cimatron CAD/CAM businesses for $65 million

3D Systems Corporation, Rock Hill, South Carolina, USA, reports that it has agreed to sell Cimatron Ltd., and its related subsidiaries, which operate the Cimatron® integrated CAD/CAM software and GibbsCAM® CNC programming software businesses, to Battery Ventures, Boston, Massachusetts, a technology-focused investment firm, for a purchase price of $65 million.

Cimatron and GibbsCAM will reportedly join a manufacturing portfolio that includes SigmaTEK Systems, a CAD/CAM software provider for the metal fabrication industry.

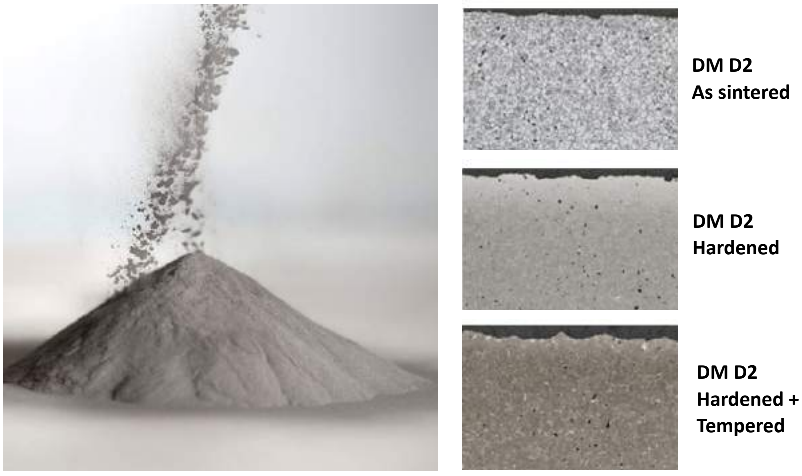
This action is said to be part of 3D Systems' recently announced reorganisation and restructuring plan, designed to focus the company on its strategic purpose as leaders in enabling Additive Manufacturing solutions for applications in growing markets that demand high-reliability products.

"Over the last several months, we've made significant progress in aligning our business to our core strengths to achieve growth," stated Dr Jeffrey Graves, president and Chief Executive Officer, 3D Systems. "With this announcement, we continue to demonstrate our commitment to focus on Additive Manufacturing, creating value through solutions designed to address our customers' unique application needs."

www.3dsystems.com
www.battery.com

## Digital Metal launches D2 tool steel alloy for Binder Jetting

Digital Metal, part of Sweden's Höganäs Group, has expanded its range of materials for metal binder jet Additive Manufacturing with the launch of DM D2™, a tool steel alloy powder providing an effective combination of abrasive wear resistance and toughness. The company states that it is suitable for a wide range of applications, but most specifically for cutting and deformation tools. The DM D2 metal powder has been qualified for use in Digital Metal's DM P2500 Binder Jetting systems.




*Digital Metal's new DM D2 tool steel, showing as sintered, hardened and hardened + tempered micrographs (Courtesy Digital Metal)*

Toolmakers often choose D2 because of its hardness, meaning it is appropriate for tasks such as stamping and forming other metals without losing its shape. Digital Metal explains that DM D2 is a versatile, high-carbon, high-chromium tool steel alloy that can be heat treated to high hardness and compressive strength. Due to its high wear resistance, it is suited to cold work applications that require sharp edges and abrasion resistance.

"We have been receiving more and more requests for a D2 tool steel suitable for use with our printers," stated Christian Lönne, CEO at Digital Metal. "We have designed the DM D2 to deliver excellent surface finish, flexibility, as well as strength and hardness. This alloy is very stable during heat treatments, which allows for tailoring of the final material properties through various heat treatments after sintering."

www.digitalmetal.tech

## Additive Industries announces new flagship metal AM machine

Additive Industries, Eindhoven, the Netherlands, has announced its new flagship model MetalFAB-600 metal Additive Manufacturing machine, which the company plans to launch towards the end of 2021. The new model will offer a build size of 600 x 600 x 1000 mm, said to be one of the largest volumes in the industry, and five times larger in volume than the company's current MetalFAB1 metal AM machine. The MetalFAB-600 will offer high productivity, with a deposition rate up to 1000 $cm^3$/hour, using ten 1kW lasers, states Additive Industries. It is developed on a platform that reportedly allows further expansion of the build volume and productivity in the future.

According to the company, the new model builds upon the knowledge and experience gained with the MetalFAB1 in robustness and automating key production processes. The automation will focus on powder handling, alignments, and calibrations to ensure the highest possible output. The MetalFAB-600 is designed to achieve the lowest cost per part, targeting the traditional casting and machining industries.

In light of this project's importance and other projects on the horizon for Additive Industries, acting CEO, Mark Vaes, will reassume his role as CTO and manage the MetalFAB-600 development team. Jonas Wintermans, co-founder of the company, will assume the role of acting CEO. "Right now it is crucial for Additive Industries to develop and innovate. The new MetalFAB-600 project is very relevant for our customers and therefore important for Additive Industries. A larger build volume opens doors to more applications and more productivity. Larger build jobs also mean a need for higher laser power and maximum robustness, because users want their parts to reach the finish line when printing multiple day jobs," stated Wintermans. "The existing MetalFAB1 (420 x 420), which will be developed even further in terms of simplification and laser power, excels in building long and heavy jobs up to 150 kg parts. Its new sibling, the MetalFAB-600 should build on that knowledge. We have an excellent team in place, led by Mark, and are confident to be able to enrich our industry with this new model, as well as with our current portfolio."

In order to support Additive Industries' growth and development, Highlands Beheer, the investment company of the Wintermans family, has reportedly invested and committed a total of $33 million in the company in 2020.

www.additiveindustries.com

## Extremely hard austenitic stainless steel developed by Kolibri Metals

Kolibri Metals GmbH, Amtzell, Germany, has developed a new stainless steel powder for metal Additive Manufacturing that is reported to offer a hardness of more than 40 HRC. Named Pacayal, the new austenitic stainless steel achieves its hardness during the Additive Manufacturing build process, without requiring any subsequent heat treatments.

Pacayal, which can be processed using Laser Beam Powder Bed Fusion (PBF-LB), also provides a higher acid resistance when compared to ferritic or martensitic stainless steels. A hardness of 40 HRC is around twice as high as that offered by the more widespread 1.4404 steel, often used in AM, which usually has a hardness of approximately 20 HRC.

Kolibri Metals stated that the main reason for the development of the new material was the increased demand from its customers for harder corrosion- and acid-resistant steels. These materials are increasingly being used in the field of fluid conveyance in pharmacy, medical technology or nozzle manufacturing.

www.kolibri.de.com

*Components manufactured with Pacayal, a new austenitic stainless steel with a hardness of 40 HRC (Courtesy Kolibri Metals)*

## Epson Atmix increases water atomised powder production capacity, anticipates growing demand from AM

Epson Atmix Corporation, Aomori, Japan, an Epson Group company, has begun operations on a new production line at its Kita-Inter Plant, Hachinohe, Japan. Built with an investment of approximately JP¥1.5 billion, the new line uses the company's water atomisation process to produce what it calls 'superfine' alloy powders. The line will enable Epson Atmix, which also produces superfine alloy powders at its Head Office Plant, to increase its total production capacity to around 15,000 tons per year, about 1.5 times its current production capacity, by 2025.

The company's water atomised superfine alloy powders are classified into two main types, depending on what they are made from and how they will be used: powders for magnetic applications and powders for Metal Injection Moulding. The company's water atomisation process, in which high-pressure jets of water are used to atomise a molten metal stream generated by a high-frequency induction furnace, enables the production of micron-order particles to create alloy powders that are well-suited to MIM, with a uniform composition and characteristics. Particle size can be adjusted according to the application to increase sintered part density and strength.

The company's water atomised MIM-grade powders are well established in the global MIM industry and are used for components that have complex shapes and that require high dimensional accuracy and strength, such as parts for medical devices, automotive engine applications, consumer electronics, and office automation equipment. The company stated that, in addition to growth from the MIM industry, demand is also expected to increase as metal Additive Manufacturing technologies become increasingly widely adopted throughout industry. Epson Atmix's lineup of MIM-grade powders includes stainless steels and low-alloy steels.

Magnetic-grade powders serve as the raw materials for electronic components such as inductors, choke coils, and reactors required to control the voltage of high-performance mobile devices such as smartphones and laptop computers. The market for these powders is expected to expand further in the future thanks to an increase in the use of electrical components in automobiles and in the number of inductors installed in hybrid and electric vehicles. Epson Atmix's magnetic-grade powders are said to contribute to the manufacture of magnetic components with low levels of magnetic loss and, as such, also contribute significantly to reducing the power consumption and size of these types of components.

www.atmix.co.jp

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# Ricoh develops Binder Jetting process for aluminium part production

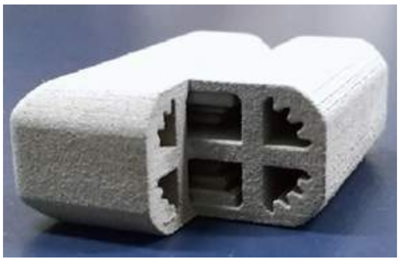


*Fig. 1 Binder jet sample part incorporating internal channels (Courtesy Ricoh)*

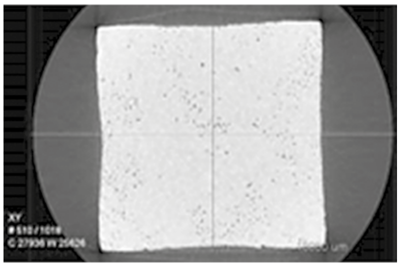


*Fig. 2 X-ray CT of the sintered sample, approx.15 x 15 mm (Courtesy Ricoh)*

With metal Binder Jetting (BJT) systems now offering the potential for the high-volume, cost-effective Additive Manufacturing of complex parts, there is a growing demand to broaden the range of material options available. Aluminium is one such metal that could offer the potential to produce a variety of new parts; however, the metal can be difficult to process in the sintering stage.

To alleviate this problem, a team of researchers at Ricoh Company Ltd, based in Kanagawa, Japan, has developed a unique binder material that, when combined with a suitable debind and sinter stage, offers the potential to use typical aluminium powders in the Binder Jetting process. Furthermore, the use of a liquid immersion technique developed at Ricoh for removing excess powder is said to make it possible to form complex internal channels during the process – an option the company says is not possible with conventional processes (Fig. 1).

For the development of this new binder system, the team used an AlSi alloy powder with an average particle size of 35 µm, coated with what is described as a resin. The main objective of the resin coating, explains Ricoh, is to allow bonding through a mutual interaction with the binder liquid, as well as reducing the risk of explosion. The binder liquid used incorporates an organic solvent and an additive to ensure the cross-linking of the resin-coated powder particles.

Ricoh used a prototype Binder Jetting machine, developed in-house, to create a powder layer thickness of 84 µm with a binder liquid drop resolution of 300 x 300 dpi. The resulting green body was said to be resistant to specific solvents due to the cross-linking. Immersing the parts in a solvent for a set time therefore enables the efficient removal of excess powder, particularly from small internal channels.

Following a solvent drying stage, the parts undergo a liquid-phase sintering operation. A target liquid phase amount of approximately 20–30% is required, with the parts maintaining a temperature appropriate for elution of the liquid phase amount for between two and five hours.

The researchers reported that tensile strength testing, thermal conductivity testing, cross-section structure observation, and X-ray CT internal observation were performed on the resulting sintered parts. The tensile strength and stretch values of a test sample were reported to be 100 MPa, equivalent to that of a typical pure aluminium material. Using a xenon flash analyser, thermal conductivity was determined to be 188 W/mK, equivalent to AlSi die-cast products.

An X-ray CT image of a sintered block, measuring roughly 15 mm per side, is shown in Fig. 2. The sample's relative density reached 98.4%, and it was confirmed that sintering was accomplished well, with no large pores. The results of microstructural observations found that grain sizes were approximately 50 µm, equivalent to a typical cast structure.

The relationship between the amount of powder coating resin and the minimum ignition energy is highlighted in Fig. 3, showing that when the resin amount exceeds 2 wt.%, the minimum ignition energy increases, greatly stabilising the coated powder in comparison to uncoated powder. The researchers state that the resin coating appears to suppress the transfer of explosive energy between particles.

This testing confirmed that it was possible to form 90 mm long internal channels with diameters of 2 mm. The company states that it is now working on the creation of a prototype with a larger build chamber and even thinner internal channels. The team is also working to expand the range of alloys that this method can be used with.

www.ricoh.com

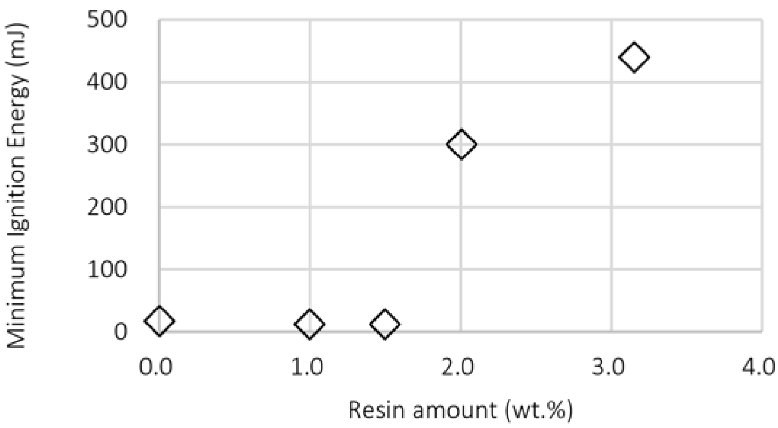



*Fig. 3 Resin coating amount / minimum ignition temperature (Courtesy Ricoh)*

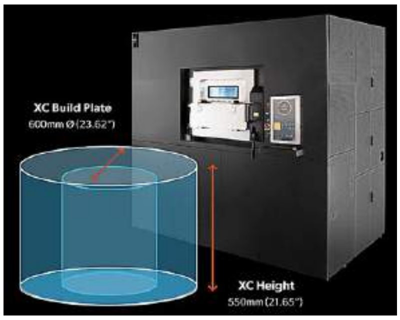
# Velo3D announces large-format Sapphire XC metal AM machine

Velo3D, Campbell, California, USA, has announced the Sapphire XC, a large-format metal Additive Manufacturing machine. The new machine is said to increase production throughput by five times, whilst reducing cost-per-part by up to 75%, when compared to the company's existing Sapphire machine. The new Sapphire XC features a build volume of 600 mm x 550 mm, with productivity increased thanks to the use of eight 1 kW lasers.

The company has also announced plans to roll-out Sapphire Gen 2, a software and hardware upgrade to the current machine. Users can expect an improvement of anywhere between 10–50% in productivity and part-cost metrics when compared to the current Sapphire system. The Sapphire Gen 2 upgrade will be available to retrofit on all installed systems starting in Q2 2021.

The Sapphire product family now includes Sapphire Gen 2, the one-metre tall Sapphire 1MZ and Sapphire XC — all using the Laser Beam Powder Bed Fusion (PBF-LB) process with patented capabilities to build without consideration of support structures. Sapphire machines are said to be targeted specifically at the aerospace, power generation and energy markets' need for quality-assured manufacturing of uncompromised geometries.

"Printing larger parts without the Additive Manufacturing constraints of support structures is highly attractive to many industrial end-users," stated Benny Buller, founder and CEO of Velo3D. "For the first time, customers will be able to 3D-print uncompromised geometries, with the highest confidence in part quality, in a large format system."




*The Sapphire XC (Courtesy Velo3D)*

"Quality assurance with large-scale components is critical because the economic impact of failed builds is very significant. We have demonstrated that our integrated solution is capable of producing a greater yield of high-quality parts, and that foundational technology will transfer to our new Sapphire XC," he added.

Velo3D states that, to date, it has received thirteen advance orders for its new metal Additive Manufacturing system, with delivery of the Sapphire XC expected to begin in Q4 2021.

www.velo3d.com

## South China MIM & AM summit highlights new business opportunities for part manufacturers

The second South China MIM & Additive Manufacturing Technology and Application Summit took place on November 26, 2020, at the Lotus Villa Hotel in Chang'an, Dongguan, China. Co-organised by China Powder Metallurgy Alliance (CPMA), Guangzhou Guangya Messe Frankfurt Co Ltd and Uniris Exhibition Shanghai Co Ltd, the summit welcomed over 200 attendees and highlighted the latest developments within the Metal Injection Moulding and Additive Manufacturing sectors.

Industry experts and academic speakers shared their market insights within the automotive, medical, consumer electronics, and communications industries and also unveiled the latest market intelligence and development opportunities. The summit was moderated and chaired by Professor Li Yimin of the Powder Metallurgy Research Institute of Central South University and Deng Zhongyong, Dean of the Central Research Institute of Shanghai Fuchi High-Tech Co Ltd.

Zhang Zhiheng, Secretary General of Professional Committee of CPMA, Professor Yan Biao, Chairman of the Shanghai Powder Metallurgy Industry Association, and Louis Leung, Deputy General Manager of Guangzhou Guangya Messe Frankfurt Co Ltd delivered their opening remarks during the summit's opening ceremony and stated that the convergence of AM and MIM technologies is presenting new business opportunities for part manufacturers.

In addition, twelve experts representing the National Tungsten Engineering and Technology Research Center, Shanghai Materials Research Institute, University of Science and Technology Beijing, Tongji University, Southern Medical University, Southern University of Science and Technology, Guangdong University of Technology presented their research and perspectives on AM and MIM, as well as an analysis of industry trends and market prospects.

Approaching the end of the summit, Dr Yaohong Qiu, Chief Lecturer and founder of the You Need Technology Consultation Company, hosted the Summit Salon, which was the final session of the event that included opportunities for networking and a Q&A session for participants and speakers.

The organisers stated that they view the summit as a 'warm-up' event for the Formnext + PM South China trade show, which will take place for the first time on September 9–11, 2021, in Shenzhen, China. The summit advocated the importance and advantages of the new fair to the industry and featured the expected highlights of the upcoming exhibition.

www.formnext-pm.com

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## Kingsbury to sell SLM Solutions AM machines in the UK and Irish markets

SLM Solutions Group AG, Lübeck, Germany, has appointed Kingsbury, Gosport, Hampshire, UK, to sell its Additive Manufacturing products in the British and Irish markets, with effect from December 1, 2020.

SLM Solutions specialises in Laser Beam Powder Bed Fusion (PBF-LB), with its machines capable of producing parts in aluminium, titanium, nickel, cobalt, iron and copper alloys. The company recently expanded its model range with the launch of its NXG XII 600 AM machine, equipped with twelve 1 kW lasers. The NXG XII 600 is said to be up to twenty times faster than a standard single-laser system, and is designed to be used for high-volume production as well as for large parts.

"We are delighted to be able to offer such a comprehensive range of production-oriented powder bed AM solutions," Richard Kingsbury, Managing Director of Kingsbury, stated. "We see the technology, with the freedom of design that it brings to production, becoming increasingly important as we emerge from the COVID-19 pandemic, as it will enable the manufacturing industry to innovate and become more competitive."

SLM's machines include features such as bi-directional recoating, multi-laser overlap strategy and laminar gas flow. In addition, the open architecture allows parameters to be modified without additional cost, so a user is able to customise the process to suit specific applications and to develop completely new alloys.

David Wilckens, Regional Sales Manager of SLM Solutions, commented, "The choice of Kingsbury to sell and service our systems was down to their already representing many well-known German machine tool manufacturers of high-value capital equipment, all of which see themselves as a technology leader, as we do. The match is made even better by the agent already being committed to AM technology and having an established department, with business development and applications engineering already in place."

"We and Kingsbury have a number of UK customers in common in various industries including medical, aerospace and defence, which will be excellent reference sites for prospective users. A dedicated demonstration machine will be installed in early 2021," Wilckens concluded.

www.slm-solutions.com
www.kingsburyuk.com

## Tritone announces first installations of its Dominant sinter-based metal AM machines

Tritone Technologies, a metal AM technology company based in Rosh Haayin, Israel, has installed its first Tritone® Dominant beta AM machine at Israel-based Runout, a provider of CNC machining and milling for industrial, high-tech and aerospace applications. A further beta installation of Tritone Dominant is planned before the end of 2020 at a customer site in Germany.

Tritone Dominant enables the industrial-scale production of high-quality metal parts and is based on Tritone's patent-pending MoldJet® technology, a sinter-based process designed for producing large quantities of high-density parts with complex geometries, explains the company. Since its introduction at Formnext 2019, Frankfurt, Germany, Tritone states that it has improved the Dominant AM machine and increased its set of available alloys to address the rigorous requirements of industrial applications.

"Tritone Dominant is an important addition to our operations," stated Arnon Langevitz, co-CEO and founder of Runout. "With its high-quality AM capabilities, we are better equipped to serve our customers in various applications. We are able to produce very accurate, repeatable parts in short timelines at a reduced cost."

"The Dominant system opens new opportunities of re-engineering and designs for our customers, which were not feasible before," Langevitz continued. "We can now support them with weight reduction, producing a single merged part instead of separate pieces before, and complex internal passages."

Omer Sagi, VP Products and Business Development at Tritone, commented, "We are very excited to see Runout utilising the Tritone Dominant. Following the unveiling of Dominant last year, we have made tremendous progress in adjusting it to the needs of serial production, from cut design to end parts."

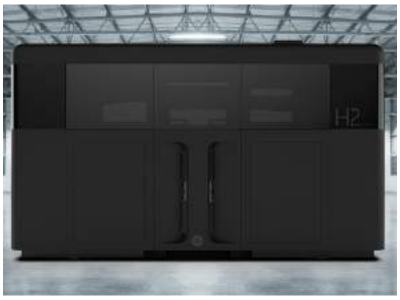
*A Tritone Dominant beta metal AM machine has been installed at Runout for producing industrial metal AM parts (Courtesy Tritone Technologies)*

"We continue to add more options of raw materials to address the market demands. The Runout installation marks a significant milestone for Tritone. We are ready to support them in making the best use of the system and looking forward to additional deployments," Sagi concluded.

www.tritoneam.com

# Sandvik Additive Manufacturing joins GE Additive's binder jet beta partner programme

GE Additive reports that Sandvik Additive Manufacturing, a division of Sandvik AB, headquartered in Stockholm, Sweden, has joined its binder jet beta partner programme. Sandvik has one of the widest alloy programmes for Additive Manufacturing, marketed under the Osprey® brand.




*GE Additive's H2 Binder Jet beta machine, which will continue to be developed as part of the first phase of the binder jet beta partner programme (Courtesy GE Additive)*

Sandvik will work closely with GE Additive to become a certified powder supplier for a range of Osprey alloys that complement GE Additive and AP&C's own materials portfolio, and will reportedly also use GE Additive's H2 Binder Jet beta machine to support its internal and external customers.

GE Additive's binder jet beta partner programme hopes to leverage its strength in industrialising Additive Manufacturing technology with strong technical and innovative partners to rapidly grow its Binder Jetting technology. The first phase is said to involve developing the beta H2 system into pilot lines, and eventually into a commercially-available factory solution in 2021.

"Our approach to binder jet is making additive mass production a reality in every industry," stated Jacob Brunsberg, Binder Jet Product Line Leader, GE Additive. "And while it would be relatively easier to launch individual machines, we continue to hear from customers, especially in the automotive industry, that they need a complete solution that can scale."

Brunsberg continued, "Attracting partners like Sandvik – with know-how in industrialising innovation, deep materials knowledge, and a shared vision for the potential for additive technology – remains a cornerstone of our binder jet commercialisation strategy."

Kristian Egeberg, president of Sandvik Additive Manufacturing, commented, "Sandvik is a leading expert in gas-atomised Additive Manufacturing powders, as well as in optimising the materials to customers' specific print processes and applications. The materials collaboration with GE Additive offers great opportunities to qualify our wide range of Osprey metal powders for their new binder jet platform, to enhance end-customer productivity and product performance."

www.ge.com/additive
www.additive.sandvik

# Oqton and EOS integrate manufacturing software and hardware for AM

Oqton, an industrial automation company headquartered in San Francisco, California, USA, and EOS GmbH, Krailling, Germany, have announced the integration of EOS' software capabilities into Oqton FactoryOS™, an end-to-end production platform. The partnership is said to enable an unprecedented connection between manufacturing software and hardware.

According to Oqton, the integration between Oqton FactoryOS's cloud manufacturing platform and EOS' open hardware system will enable users to send an Additive Manufacturing job from the cloud directly to an AM machine, receive alerts on a mobile device when a build is ready, deliver a full job quality report with every produced part and automatically optimise nests and schedule build jobs to maximise machine utilisation.

Oqton's AI-driven optimisation reportedly captures best production practices, leading to improved quality and increased machine utilisation, which results in significant increases in ROI for mutual customers. For example, 100% automation can be achieved in dental and jewellery verticals, resulting in 30% overall cost reduction.

"I am impressed by the level of build preparation automation and increases in productivity that can be achieved by leveraging Oqton FactoryOS as MES and IoT platform," stated Martin Steuer, EOS's SVP Software Division. "With that and the easy-to-implement high-standard cybersecurity capabilities it is a unique cloud-based solution and we are happy that EOS customers can now benefit from it."

Ben Schrauwen, Oqton's CTO, commented, "This integration was only possible because of the open software architecture of EOS products and the support through the EOS Developer Network (EDN), making it easy to use the EOSPRINT and EOSCONNECT APIs in our cloud platform. We were able to deeply integrate our AI-automated build preparation workflow directly to the EOS systems of our customers, allowing to drive, manage and track them directly from the cloud."

www.oqton.com
www.eos.info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## Satair uses metal AM to produce certified flying Airbus spares

Satair, an Airbus services company, has provided one of its airline customers in the US with what it reports is the "first certified metal printed flying spare part" – a wingtip fence for the A320ceo. The part was no longer procurable from the original supplier, and by using metal Additive Manufacturing to replace it, the company has been able to reduce the likelihood of the aircraft being grounded. Satair is a standalone Airbus subsidiary and part of the Airbus Customer Services unit, operating from ten locations worldwide. The company offers full-lifecycle aircraft support with a portfolio of material management products, services, and support modules across all platforms.

The A320ceo's wingtip fences are installed in four different versions – starboard, port, upper and lower. According to Satair, the original spare parts supplier had difficulties providing the cast part, leading to a regular loss of the moulds and resulting in a potentially high investment cost for Satair to replace the moulds for individual orders. The company studied other conventional options to replace the part, such as redesigning it for machining technology, but the resulting cost and lead-time implications were not competitive.

Felix Hammerschmidt, Satair's HO Additive Manufacturing, explained, "We received an order for replacement parts and our AOG [Aircraft on Ground] procurement department turned to the Additive Manufacturing team for a solution. After a short pre-assessment, the part was handed over to the RapidSpares design offices at Airbus. Using a new certification process, they were able to re-certify the former cast part within five weeks and adapt it to titanium, which is a qualified airworthy Additive Manufacturing material. The lead time for certification is expected to reduce even further in the future once the technology becomes more of a standard."

The wingtip fence parts were additively manufactured at the Reference Manufacturing shop in Airbus Filton, which was process qualified in 2019 and is now able to produce airworthy parts regularly. Four parts (full shipset for one aircraft) were built simultaneously in a twenty-six hour build job, reducing the cost per piece and the build time per part.

After Additive Manufacturing, the part required post-processing to become an airworthy part, making it a one-to-one replacement for the original part whilst meeting the same safety requirements as the conventional part. The new AM part is supplied with an EASA Form 1 certification approval. The shipset was delivered earlier this year – making the airline the first operator with an Airbus metal additively manufactured spare part. Compared to conventional solutions, total non-recurring costs were said to have been reduced by 45%, making it a cheaper solution for customers, as well as reducing the total lead time.

Bart Reijnen, CEO of Satair, stated, "Satair is leading the way in providing additive manufactured parts for the aviation aftermarket and we currently have more than 300 part numbers certified for the technology covering every Airbus aircraft family type including tools and Ground Support Equipment."

"With more than 7,000 A320ceo Family aircraft in service worldwide, the demand for this specific additive manufactured part is likely to increase, and with this Additive Manufacturing supply chain now in place, we will be able to produce these parts within a shorter lead-time," he added. "Four more customers have already requested that same part following this successful delivery."

"We have already identified more titanium parts for which Additive Manufacturing could as well become a more economical way of production, with higher flexibility and shorter lead times," he concluded.

www.satair.com

# AML3D's Wire Arc AM selected for use in naval shipbuilding

*AML3D's Wire Arc AM technology has the potential to participate in ASC Shipbuilding's activities (Courtesy AML3D Limited)*

AML3D Limited, Edinburgh, Australia, reports that its WAM® metal Additive Manufacturing technology has been selected by ASC Shipbuilding, a subsidiary of BAE Systems Australia, as having the potential to participate in its shipbuilding activities. Since December 2018, ASC Shipbuilding has been contracted by Australia's Department of Defence to design and build nine Hunter class frigates for the Royal Australian Navy.

To drive innovation, ASC Shipbuilding wishes to highlight new technologies that maximise the cost-effectiveness of local manufacturing, while minimising lead-times for ship sustainment in Australia.

Under the initial commercial evaluation and validation testing programme, AML3D will use WAM®, a Wire Arc Additive Manufacturing (WAAM) technology and type of Directed Energy Deposition (DED), to produce various parts in a range of metal alloys, with the objective of meeting BAE's internal standards for additively manufactured components.

The results of testing will be used by ASC Shipbuilding to determine whether AML3D's technology is a suitable manufacturing solution to support the continuous naval shipbuilding and sustainment sovereign capability as laid out in the Australian Government's Naval Shipbuilding Plan.

Andrew Sales, AML3D's Managing Director, commented, "We are pleased to commence this project with ASC Shipbuilding. Having the stringent customer evaluation of AML3D's proprietary wire Additive Manufacturing process will not only enhance exposure of our technology for marine and defence applications, but the successful endeavour would lead to a sustainable local shipbuilding industry for future generations."

www.aml3d.com

## 3YOURMIND partners with 3D Alliances to advance its North American business

3YOURMIND, Berlin, Germany, reports that it is partnering with 3D Alliances, Herzliya, Israel, in order to accelerate the acquisition of new sales partners in North America, to support the company's business expansion in the Additive Manufacturing market. 3D Alliances specialises in the deployment of AM channel networks.

Created to provide enterprise customers with widespread access to Additive Manufacturing, 3YOURMIND's software standardises and evaluates AM data, automates the business processes associated with distributed manufacturing, and optimises production execution along with quality assurance. The company states that these tools enable data-driven production decisions and are building a foundation for automated agile manufacturing. So far, the company has raised a total of $15 million in funding, with a series A+ funding round this September having raised $5.5 million. As with other partners of 3D Alliances in the AM industry, 3YOURMIND will now be able to leverage a network of over 2,000 active AM resellers from seventy-four countries.

"We are very excited to partner with 3D Alliances to support our growth," stated Alexander Donnadieu-Deray, North America Managing Director, 3YOURMIND. "The demand for our technology is accelerating and we are now looking for the right reselling / integrators partners to leverage this trend."

www.3yourmind.com

www.3dalliances.com

## Titomic appoints Norbert Schulze as interim CEO

Titomic Limited, Melbourne, Australia, has appointed Norbert Schulze as interim CEO. He succeeds Jeff Lang, Titomic's founder, who assumes the role of Executive Director and CTO, maintaining his role as a director of the board. The board has initiated a search for a permanent CEO. Schulze has over forty years of experience in the global defence, manufacturing and automotive industries and owns a consulting company advising global defence companies on strategy and growth opportunities. He previously served as Senior Executive of Rheinmetall and RENK Group in Europe and Africa, which included overseeing sales to Australia.

"Norbert's an industry veteran with a proven track record working in complex environments and bringing new technologies to clients within global defence and manufacturing industries," stated Dr Andreas Schwer, Titomic chairman. "His appointment is part of the new board's efforts to strengthen the execution of Titomic's strategic vision and transformation into a global Additive Manufacturing company and create value for shareholders."

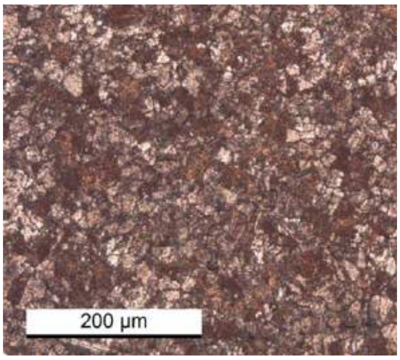
Schulze commented, "It's an honour to accept this position on an interim basis. As a team, Titomic's employees have worked hard to position Titomic as a leading global Additive Manufacturing company. Our mission won't change and I'm committed to driving the transformation, creating value for our shareholders and clients, and fulfilling my role as interim CEO of this outstanding company."

Jeff Lang, Titomic's Executive Director & CTO added, "While we have made significant progress in the last few years, we must continue to develop our operations and innovation across the company."

www.titomic.com

# Desktop Metal releases pure copper for Studio System

Desktop Metal, Burlington, Massachusetts, USA, has announced the launch of pure copper for use with its Studio System™, a Material Extrusion (MEX) Additive Manufacturing machine designed for low-volume production.




*Desktop Metal has added pure copper for use in its Studio System (Courtesy Desktop Metal)*

Due to its high thermal and electrical conductivity, copper is considered an ideal material for transferring heat or electricity and is used in virtually every electronic device made, as well as many of the heat exchangers used across a variety of industries, including oil and gas, automotive, and consumer products.

In laser-based Additive Manufacturing processes such as Laser Beam Powder Bed Fusion (PBF-LB), copper alloys are often used, as pure copper would be extremely difficult to process using this method. However, using Desktop Metal's proprietary 'Bound Metal Deposition™' process, a form of Fused Filament Fabrication (FFF), the Studio System is able to build parts in pure copper, enabling users to take full advantage of the material's benefits.

"Known for its excellent thermal and electrical conductivity, copper is a highly desired material for a variety of industries and applications, such as heat exchangers and electrical components for heavy industries to consumer products," stated Jonah Myerberg, CTO and co-founder of Desktop Metal. "Whether for heat sinks, electrical motor and power grid components, or resistance welding electrodes, 3D printed copper on the Studio System is an ideal choice for manufacturing parts featuring s geometries."

In addition to copper, the Studio System's materials library includes 4140 chromoly steel, H13 tool steel, and 316L and 17-4 PH stainless steel. In addition to those materials already available, the company states that its team of materials scientists is continuously working to develop new materials and processes to make AM accessible to broader industries and applications.

www.desktopmetal.com

# Blue Power and Amazemet develop compact ultrasonic atomiser

Blue Power Casting Systems GmbH, Walzbachtal, Germany, in cooperation with Amazemet Sp. z o.o., a Warsaw University of Technology spin-off company, has developed a compact ultrasonic atomisation unit for R&D purposes and small powder batch production. Dr Fischer-Bühner, Head of R&D at Blue Power, stated that the atomiser unit enables users to produce small batches of high quality, spherical powder for the same target application as gas atomised powder at an affordable price and without complex infrastructure.

The ultrasonic atomiser solution features a crucible-based induction heating system which allows the melting temperature to be precisely controlled, thereby preventing the loss of alloy ingredients such as zinc and chromium through evaporation. The melting can either take place under vacuum or in a controllable atmosphere. The powerful medium-frequency induction generator produces excellent stirring/mixing effect, improving the quality of the alloying. "A crucible-based induction heating system has many economic benefits over plasma-assisted ultrasonic atomisation," commented Mateusz Ostrysz, co-founder of Amazemet.

The loss of alloy ingredients through evaporation is prevented without the need for any sophisticated and expensive filtration systems, state the developers. The system is not restricted to just pre-alloyed wire and bar; the feedstock can be any shape. This means that users can avoid the time and effort needed to produce complex and expensive wire, no longer needing the associated infrastructure such as continuous casting machines and drawing benches.

Very small batch sizes, of around 100 g or less, are reported to be both technically and financially viable, while larger production capacity of up to several kg (bronze) per hour is possible. An increased powder yield is made possible due to operating at a higher frequency (up to 80 kHz). For example, bronze particle sizes in the range of D50=40–60 µm can be easily achieved, with further improvements on the horizon.

The ultrasonic process is said to offer the flexibility users require in terms of both inputs and outputs. The plant can reportedly handle almost any non-ferrous metal in any shape with a melting temperature less than 1300°C, with the company also developing an 1800°C version. No calibration is needed; pre-installed programs cover the basic materials and alloys.

www.bluepower-casting.com
www.amazemet.com

## Sandvik increases focus on digital solutions in business reorganisation

Sweden's Sandvik AB is reorganising its tool business to further strengthen its position within future digital solutions, also known as Industry 4.0, explains Stefan Widing, CEO of Sandvik. According to Widing, the smart factory is the heart of Industry 4.0., therefore Sandvik is carrying out a reorganisation with the aim of expanding digital technology to help make customers more productive and sustainable. With this in mind, Sandvik Machining Solutions, the business area for metal-cutting processing, has changed its name to Sandvik Manufacturing and Machining Solutions, and has been divided into two separate business area segments:

*Stefan Widing, president and CEO of Sandvik (Courtesy Sandvik)*

Sandvik Machining Solutions and Sandvik Manufacturing Solutions.

The Sandvik Machining Solutions business segment includes the traditional tool business and brands such as Sandvik Coromant, Walter, Wolfram, Seco and Dormer Pramet. Sandvik Manufacturing Solutions will reportedly focus on related technologies and digital solutions, including the divisions for Metrology, Additive Manufacturing and Design and Planning Automation. These technology areas are expected to grow strongly, with the current providers of these services often not being Sandvik's existing competitors, states the group.

"One of the purposes of the reorganisation is to create new business opportunities," commented Widing. "The new Sandvik Manufacturing Solutions segment strengthens our position within digital manufacturing and contributes to our market-leading position. These areas need a dedicated focus and to some extent a different direction. They are often smaller, with characteristics of software companies, rather than the manufacturing industry. To run them successfully, a different governance model is required."

Widing will lead Sandvik Manufacturing Solutions for a year, starting on January 1, 2021, in parallel with his role as CEO. He added, "This is because it is a very important area for the future. It is broad and complex and will require investments through acquisitions in areas such as metrology, planning tools, tool data management and 3D printing. If and when we find the right company, we must be able to act quickly."

Additionally, digitisation continues to be a focus area for the core business. Widing further added, "Our core business in metal cutting is on a journey from only providing tools to providing complete solutions, including everything from sensors and connected tools that exchange data via the cloud to digitised planning tools."

Digitisation means that experiences and knowledge from manufacturing are shared in real-time, both internally and externally and between people and machines. The growth ambitions in the digital area are said to be high, within both Sandvik Manufacturing Solutions and Sandvik Machining Solutions. The 2025 target for the business area segments is to have total sales of SEK 5 billion connected to digital solutions and services.

www.home.sandvik

## CADS Additive and m4p material solutions optimise qualification of powder quality parameters

CADS Additive GmbH, Perg, Austria, a manufacturer of high-performance data processing algorithms, services and software for Additive Manufacturing processes, has partnered with m4p material solutions GmbH, a powder technology and service provider located in Austria and Germany, to optimise industry productivity and standards using the AM-Studio software for the qualification of powder quality parameters.

The AM-Studio developed by CADS Additive is a data preparation suite for converting CAD data into AM machine code. The core features are highly developed algorithms for optimised part orientation, support geometries and layer data generation, which work at maximum computing speed with minimal computer memory requirements.

m4p is a metal powder supplier for AM machine manufacturers such as EOS, SLM Solutions, DMG-ReaLizer, Renishaw, and Sisma-Trumpf and is regularly expanding its material portfolio. Dr Andreas Pelz, CTO of m4p, stated, "In order to be able to meet all the needs of our customers and the requirements of the market, we at m4p need a flexible, easy-to-use and independent tool that is designed to connect the developed parameters for materials with as many AM metal systems as possible and to translate."

Peter Leitner, Head of Innovation at CADS Additive, stated, "The direct connection to m4p and the access to your test and production equipment enables us to steadily stabilise and expand our AM studio performance for advanced industrial production processes. In addition, the cooperation gives us direct feedback from the market through an experienced team."

www.cads-additive.com
www.metals4printing.com

## AMGTA publishes first research paper on sustainability in AM

The Additive Manufacturer Green Trade Association (AMGTA), a global trade group based in Hollywood, Florida, USA, has announced the publication of its first commissioned university research project: a literature-based systematic review of the environmental benefits of metal Additive Manufacturing. The paper, titled, 'State of Knowledge on the Environmental Impacts of Metal Additive Manufacturing' was written by Dr Jeremy Faludi from Delft University of Technology in the Netherlands and Corrie Van Sice from Dartmouth College in New Hampshire, USA.

According to its authors, the report "synthesises existing academic literature comparing the environmental impacts of metal AM with conventional manufacturing methods, and provides context with impacts of common metals and processing methods found in a materials database."

Key takeaways from the report include that, while "AM generally has much higher carbon footprints per kg of material processed than conventional manufacturing (CM) when considering the direct manufacturing process itself, impacts depend greatly on part geometry — a solid cube will be much lower impact to produce by machining, while a hollow shell or lattice can be lower impact to produce by AM." The report further recognises the need for additional life cycle assessment (LCA) studies to quantify environmental impacts: "More LCA studies are necessary to definitively compare metal AM to CM; especially direct comparisons of AM to machining, and especially for technologies such as Binder Jetting and DED. These LCAs should ideally also include more of the product life cycle."

Sherry Handel, the Executive Director of the AMGTA, commented, "We were pleased to work with Dr Faludi and Ms Van Sice on this study. No one should expect metal AM to be a more sustainable way to manufacture basic metal parts given the focused energy inherent in laser melting, but AM should present a more sustainable course for manufacturing finished precision components. These findings validate the AMGTA's plans to provide the industry with rigorous, independent, and ongoing research. The AMGTA will continue to commission studies and publish research findings in an effort to update the industry and other key stakeholders on what our eco-footprint is now and what we will need to focus on in the future to be more sustainable."

www.amgta.org

## Relativity Space closes $500 million Series D funding round

Relativity Space, Los Angeles, California, USA, has closed a $500 million Series D equity funding round. The round was led by Tiger Global Management with participation from new investors Fidelity Management & Research Company LLC, Baillie Gifford, Iconiq Capital, General Catalyst, XN, Senator Investment Group, and Elad Gil. Existing investors also participating in the round include Bond, Tribe Capital, K5 Global, 3L, Playground Global, Mark Cuban, Spencer Rascoff, and Allen & Company LLC, among others. In connection with the Series D financing, Allen & Company LLC served as Relativity Space's financial advisor, and Fenwick & West LLP served as Relativity Space's legal advisor.

According to Relativity Space, the Series D equity funding validates the company's sector-leading momentum across commercial execution, technical milestones and talent growth. The funding will enable the company to accelerate its planned initiatives, including its factory of the future, launch vehicle development and Additive Manufacturing technologies.

"This past year drove change in every industry, including aerospace," stated Tim Ellis, Relativity's co-founder and CEO. "Throughout 2020, Relativity achieved unprecedented growth, attracted top talent, and stepped up to deliver results we could have only imagined when we started the company less than five years ago. We are on track to launch our first Terran 1 rocket to orbit next year with existing capital on our balance sheet. With this new Series D funding, we will now dramatically accelerate the development of our long-term plans and look beyond first launch."

Relativity Space explains that its radically simplified supply chain enables it to build its orbital rocket, Terran 1, with a hundred times fewer parts in less than sixty days. By fusing metal Additive Manufacturing, artificial intelligence, proprietary software, and autonomous robotics, the company states that its team is creating an entirely new value chain for aerospace, starting with orbital launch.

"Aerospace still relies on the same fundamental toolset it did sixty years ago when rockets were first launched to the Moon and global aviation was in full swing: giant factories full of fixed tooling, with complex supply chains and hundreds of thousands to millions of individual parts assembled one at a time by hand, using hundreds of diverse manufacturing processes," Ellis added. "What we are building at Relativity fundamentally rewrites that tech stack. At its heart, 3D printing is an automation technology, one that transforms physical complexity into software by stitching many components together."

www.relativityspace.com

# Authentise and nebumind to integrate 'digital twin' visualisation in AMES

Authentise, a developer of data-driven workflow tools for Additive Manufacturing based in Philadelphia, Pennsylvania, USA, and nebumind GmbH, Taufkirchen, Germany, a provider of visualisation and analytics tools for manufacturing data, have announced the integration of nebumind's tools into the Authentise Manufacturing Execution System (AMES).

nebumind produces 'digital twin' visualisations, which fuse machine parameters and sensor data with the original part geometry. The integration of these visualisations with AMES will help users identify problem zones in each part more easily and lead to less time-intensive and more accurate inspections, states Authentise.

In addition, real-time alerts generated by the nebumind system inside AMES will reportedly help the user address any deviations during the process, reducing waste. Since AMES already captures data from the machines and manages the buildable geometry, the system passes this information on to nebumind automatically, saving the user from locating and uploading this information separately. The insight generated is appended to the existing AMES part report to ensure end-to-end traceability.

"Additive users need to be able to review data at a single glance," stated Franz Engel, co-CEO at nebumind. "To date, all they are given is long and complex tables of sensor data that are difficult to make head or tail of. Thanks to the integration with AMES, we can get this data automatically and fuse it with the shape being produced. That way, the user can see an instant heatmap of potential problem areas, and deep dive into every voxel to understand the underlying data, if necessary."

"This view can help customers identify rework needs up to ten times faster and reduce production rejects by up to 90%," continued Engel. "Integrating this view with AMES makes sense, since that's where production is managed, and data is held. We're excited to be collaborating with Authentise to make the additive process more seamless and reliable for users."

Andre Wegner, CEO of Authentise commented, "We're excited to be welcoming nebumind to the Authentise platform. Together we can accomplish the goal of a seamless, failproof additive process. The collaboration proves once again that trying to do so single-handedly leads to failure and harms customers."

"For years, they have had to put up with sub-optimal data analysis, in several different software tools. Now it's all in one place, instantly accessible, and cutting edge. This partnership proves once again how much we can move this industry forward if industry leaders work together, and not against one another."

www.authentise.com
www.nebumind.com

*The Authentise AMES (Courtesy Authentise / nebumind)*

# NanoAL commercialises Addalloy 5T aluminium powder for AM

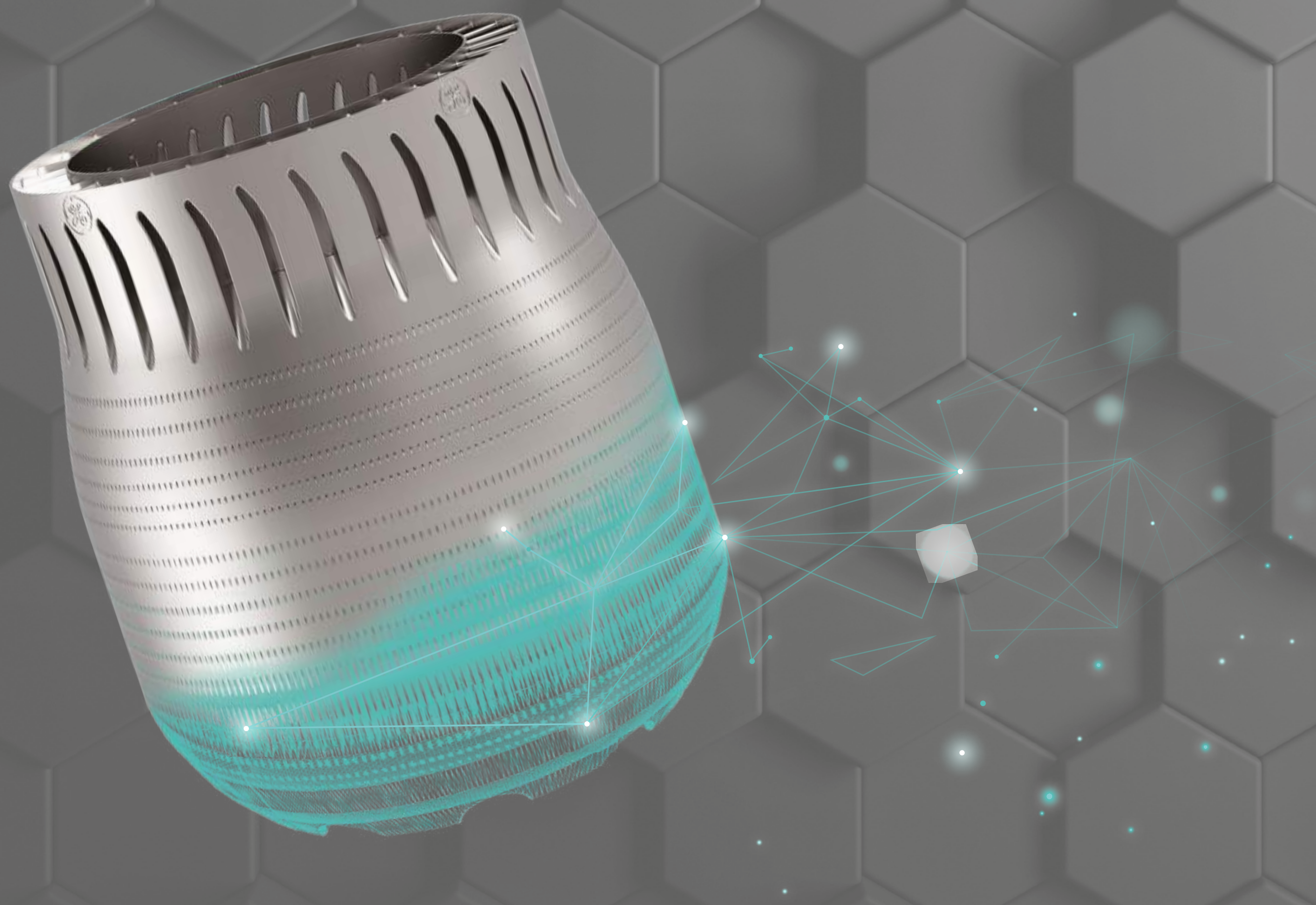
Materials research and technology company NanoAL, LLC, Boston, Massachusetts, USA, reports that it has commercialised its award-winning metal Additive Manufacturing technology, Addalloy® 5T aluminium alloy powder.

Addalloy 5T is designed and developed for Laser Beam Powder Bed Fusion (PBF-LB) metal AM and is a proprietary, high-performance aluminium-magnesium-based alloy that is reportedly easy to use and cost-effective to process. The company explains that Addalloy 5T powder is 100% pre-alloyed, eliminating secondary powder treatments or blends and simplifying useability. High performance is said to be achieved without using expensive alloying elements or adding ceramic particles.

NanoAL also stated that Additive Manufacturing speeds with Addalloy 5T can meet or exceed the productivity of aluminium alloys available in today's market.

Dr Nhon Vo, CEO of NanoAL LLC, commented, "I'm excited to see Addalloy powder product commercialised, enabling engineers and designers to fully leverage the technology advancement of 3D-printing and attractive characteristics of high-performance aluminium alloys."

www.nanoal.com

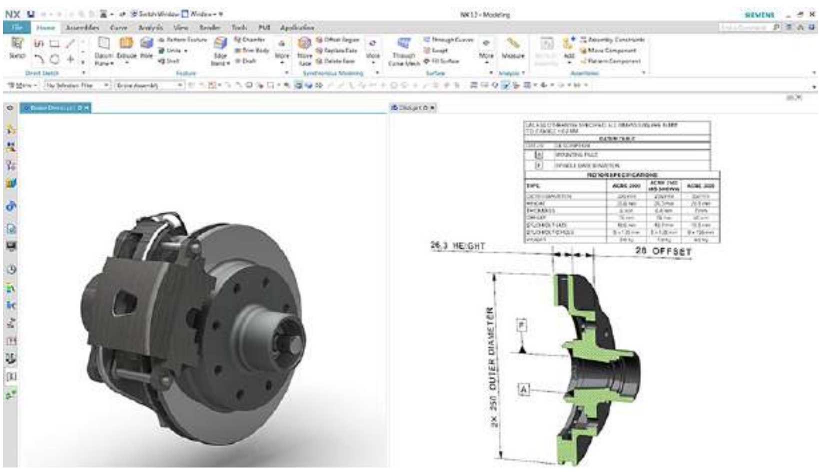


## Siemens releases the latest version of its NX Model Based Definition software

The latest version of Siemens NX™, by Siemens Digital Industries Software, is now available. The updated software allows companies to use a rules and knowledge-based approach to Model Based Definition, which builds in best practices and leverages artificial intelligence to significantly improve productivity.

NX Model Based Definition provides a rich set of data that defines a variety of characteristics beyond size and shape to enable a truly comprehensive digital twin, states the company. By including non-geometric data within the CAD model, engineers can now produce a complete digital definition of a product in an annotated and organised manner, creating alignment throughout the production process, from design to production through validation.

Siemens' NX Model Based Definition reportedly answers many of the challenges companies face when digitalising the design process and transitioning from 2D to 3D. According to Siemens, in trying to replicate a drawing-based workflow in the context of 3D CAD design, many companies end up with a 3D drawing, which does not have the tools to capture the true business intelligence needed to take advantage of the digital twin and digital thread.




*Siemens has released the latest version of its NX software (Courtesy Siemens)*

By using NX Model Based Definition, designers and engineers can automatically create and reuse data, adding more intelligence to the model, and subsequently leverage the data to inform other products and decisions, thus moving to a model-based enterprise. The company notes that avoiding the manual process of data validation and correction can help enterprises leverage their designs in a new and innovative way, enhancing productivity across the business.

After reviewing the technology, Tom Gill, Senior Consultant at CIMdata commented, "I've been in the CAD/PLM game my entire career, over thirty-five years. Rarely have I been as impressed by a big leap forward as we saw today. Siemens continues to innovate and reimagine CAD design in a way that truly looks to the future of design."

www.sw.siemens.com

## Kittyhawk partners with Synertech PM to provide build plates for AM

Hot Isostatic Pressing (HIP) company Kittyhawk, headquartered in Garden Grove, California, USA, has entered a partnership with Synertech PM Inc, a Powder Metallurgy parts manufacturer also based in Garden Grove, to offer a range of build plates for Additive Manufacturing machines.

Build plates are an essential element in providing stability and quality in Additive Manufacturing processes. However, Kittyhawk explains that some of them are not readily available and can be costly. The company states that it can also be difficult to acquire thicker plates when a process requires them, for example. Additionally, the inherent anisotropy of rolled plates can impact the dimensional precision of the AM process.

Jointly, the companies will provide uniform and homogeneous PM HIPed rectangular blanks, yielding the necessary amount of build plates to the optimal thickness for AM machines. Build plates made by Powder Metallurgy and HIPed are 100% dense with fine-grain micro-structure, states Kittyhawk, resulting in minimised warping during Additive Manufacturing processes and producing fewer restrictions on the positioning of the built parts on their surface.

Kittyhawk states that its HIP equipment and canning technology enables the production of blanks with the cross-sections from 25 x 25 cm up to 76 x 127 cm. Lead time for the blanks are four-five weeks, with readily available materials including Ti 6-4 Grade 5, Ti 6-4 Grade 23, Ti Grade 2, IN 718 and IN 625.

www.kittyhawkinc.com
www.synertechpm.com

## 3D Systems progresses development of 'world's largest and fastest' AM machine

3D Systems Corporation, Rock Hill, South Carolina, USA, reports that it has achieved significant progress in the creation of what it states is the world's largest, fastest, most precise powder metal Additive Manufacturing machine. Under development for the U.S. Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL), following a $15 million contract awarded in 2019, 3D Systems is building a nine-laser, 1 m x 1 m x 600 mm metal AM machine said to incorporate a unique selective powder deposition processes.

At the end of October 2020, 3D Systems completed the first test build using its selective powder deposition process. The method limits the amount of material needed to produce very large parts by depositing the powder only where it is needed in the build. This accelerates time to final part and reduces material cost. The build chamber also includes a heated build plate to reduce thermal stress and improve deposition quality during the build.

To create this next-generation platform, 3D Systems is leveraging key technologies from its current Direct Metal Printing (DMP) platform. According to the company, one of the most important components is the optical train that equips each of the next-generation AM machine's nine lasers with its own melt pool monitoring system for enhanced quality control. By employing the same optical system used in its DMP platform, the company can use its existing material library, which has been extensively tested and fine-tuned for optimal performance. Pulling from the data associated with these high-performance materials will also accelerate development of new materials.

The company is also integrating its vacuum chamber concept for high, repeatable quality. The inerting process reduces the oxygen level during processing to below 25 ppm compared to the 500–1,000 ppm in most conventional metal AM machines. This results in exceptionally strong parts of high chemical purity, while powder quality remains high through the lifetime of the material's usage.

Once completed, the Army will install the new large-scale systems in its depots and labs. Subsequently, 3D Systems and its partners plan to make the new AM machine available to leading aerospace and defence suppliers.

"Our collaboration with ARL is allowing us to elevate our research and development efforts, achieving many industry firsts on our way to empowering the ARL to meet their goals," stated Chuck Hull, co-founder and chief technology officer, 3D Systems. "Our accomplishments through the first phases of this project will fuel the next, on our way to helping ARL scale their capabilities and bolstering their supply chain."

www.3dsystems.com

## VBN Components selects HTL as distributor for Vibenite in Japan

VBN Components, Uppsala, Sweden, has announced a strategic partnership with HTL Co. Japan Ltd., based in Tokyo, Japan, which will be a distributor for VBN's Vibenite materials as the company aims to establish its presence in the Japanese market. VBN Components develops metal alloys with extreme wear and heat resistance, including alloys such as Vibenite® 290, said to be the world's hardest commercially available steel, and Vibenite® 480, reportedly the world's only additively manufactured cemented carbide.

According to VBN Components, HTL has been identified as a preferred partner due to its vast experience in business development, sales and marketing in high-tech markets such as the semiconductor, Additive Manufacturing, and aerospace industries. Additionally, HTL has long-term business relations with universities, governmental agencies, and institutes.

"We are proud and honoured to have agreed with HTL, a Japanese enterprise in the field of high technology business, to represent us in the area of Additive Manufacturing," stated Johan Bäckström, CEO of VBN Components. "We are convinced that this strategic agreement will be most important in the business development on the Japanese market."

A K Acharya, president at HTL Co. Japan Ltd., commented, "It is an honour and pleasure for us to represent VBN Components, with its world-leading wear-resistant materials for Additive Manufacturing and their skills in materials, AM design, and production."

Acharya concluded, "We are convinced that by combining our unique skills in materials and Additive Manufacturing with the understanding of the Japanese industry, we will create a winning team for the benefit of all stakeholders."

*HTL Co. Japan Ltd., will distribute VBN Components' Vibenite materials (Courtesy VBN Components)*

www.vbncomponents.se
www.htlco.co.jp

## Liberty Powder Metals begins powder production at new atomiser facility

Liberty Powder Metals, part of GFG Alliance's Liberty Steel Group, has started commercial production at its new high-tech powder metal facility in Teesside, UK, targeting the demand for Additive Manufacturing materials. With the new facility, Liberty Powder Metals will produce a range of stainless steel and nickel superalloy powders aimed at the market for precision components within the automotive, aerospace, and engineering sectors.

The UK's Atomising Systems Ltd and Consarc Engineering worked closely with Liberty Powder Metals on equipment design for the facility. In the powder production process, spherical powder particles are formed in a vacuum induction argon gas atomiser, incorporating an anti-satellite facility said to increase productivity.

The facility launch is the culmination of a two-year collaboration with the Tees Valley Mayor Ben Houchen and the Combined Authority, which provided £4.6 million of funding, and the Materials Processing Institute, which housed the atomiser within its own research facilities. Installation and commissioning have successfully overcome significant challenges caused by the coronavirus (COVID-19) pandemic in 2020, which has restricted the number of contractors able to work on-site and impacted on the delivery of equipment.

*The atomiser at Liberty Powder Metals' new facility in Teesside, UK (Courtesy Liberty Powder Metals)*

Commissioning of the atomiser includes a series of 'acceptance melts', which Liberty Powder Metals must perform before the plant is handed over for full operation. The atomiser enables the company to melt a range of defined chemistries and pour the liquid stream through an aperture, using inert gas to break it into fine droplets which then solidify into a powder which is secured and confined to avoid contamination from outside sources. Powders then undergo further processing, including optimisation and characterisation, before final testing and dispatch to customers. The same post-atomisation processing activities are deployed for all metal powders in the company's portfolio, which includes aluminium, titanium and cobalt alloys.

Simon Pike, General Manager of Liberty Powder Metals, stated, "This has been a great achievement amid unprecedented challenges from the COVID pandemic. The resolve and resilience of our team and our contractors to overcome supply chain constraints has been invaluable."

www.libertysteelgroup.com

## nLIGHT launches programmable laser for metal AM

nLIGHT, Inc., Vancouver, Washington, USA, a provider of high-power semiconductor and fibre lasers for industrial, micro-fabrication, aerospace and defence applications, has launched the AFX-1000 for the Powder Bed Fusion (PBF) metal Additive Manufacturing market. This programmable high-power fibre laser can switch between a single-mode beam and other beam profiles without the use of free space optics.

The company states that the AFX ring mode geometry stabilises large melt pools, reducing the amount of soot and spatter in the build chamber to improve material quality and production yields.

Discrete AFX beam profiles can be selected 'on the fly'as quickly as thirty times per second, offering new degrees of freedom to control melting and solidification rates, physical microstructure and thermal strain that can lead to stress fractures, a frequent cause of part failure. Ring mode processing with a single AFX laser has been shown to produce fully-dense material (> 99.5%) at build rates exceeding 100 cm$^3$/hr with a single laser.

"The AFX-1000 is the world's first single-mode fibre laser with the beam shaping function performed entirely inside the laser," commented Rob Martinsen, nLIGHT CTO and General Manager for Additive Manufacturing. "Developed for Additive Manufacturing, AFX enables OEMs and end-users to significantly improve build rates, thereby reducing cost per part."

"We expect AFX to fundamentally change the economics of AM and to promote broader adoption for series production," he concluded.

www.nlight.net

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# BASF's Forward AM launches Ultrafuse 17-4 PH filament for metal AM applications

Forward AM, an Additive Manufacturing solutions brand of BASF 3D Printing Solutions GmbH, headquartered in Heidelberg, Germany, has launched Ultrafuse® 17-4 PH for the Material Extrusion (MEX)-based Additive Manufacturing process Fused Filament Fabrication (FFF). The new filament, combining stainless steel powder with a polymer binder, complements the company's existing Ultrafuse 316L filament.

Offering high mechanical strength and hardness, the new AM material is said to be ideally suited for a wide range of applications, such as tooling, jigs and fixtures, and functional prototypes, states Forward AM. Good corrosion resistance and the ability to be fully heat treated to high levels of strength and hardness make Ultrafuse 17-4 PH a suitable choice for a range of industries including petrochemicals, aerospace, automotive, and medical.

*The new metal filament Ultrafuse 17-4 PH (Courtesy Forward AM)*

Ultrafuse metal filaments are specifically developed to work on all common open source FFF machines, from beginner to industrial level, which the company notes makes it one of the easiest and most cost-effective technologies in metal Additive Manufacturing. In 2019, Forward AM launched the company's first metal filament with Ultrafuse 316L.

"Ultrafuse 17-4 PH is an outstanding result of our strong R&D commitment," commented Firat Hizal, Head of Metal Systems Group, BASF 3D Printing Solutions. "We filamented more than ten different metals from titanium to tool-grade steels, and several alternative materials to print support structures within this year. Going forward we will continue to introduce the new filaments that the market and our customers demand."

Hizal added, "We have already established a distribution network that collaborates closely with our debinding and sintering service partners in different regions and can thus deliver an integrated end-to-end solution. We are proud to extend our portfolio with Ultrafuse 17-4 PH."

www.forward-am.com

## Desktop Metal begins global shipments of Shop System

*Desktop Metal begins shipments of its Shop System to customers globally (Courtesy Desktop Metal)*

Desktop Metal, Burlington, Massachusetts, USA, reports that its Shop System™, said to be the first metal Binder Jetting system designed for use in machine shops, has entered volume production and is now being shipped to customers globally. The company states that installations are underway throughout North America, EMEA and APAC, at manufacturers such as Jade Creaction LDA, Portugal; Wall Colmonoy Limited, UK; Alpha Precision Group, USA, E.A.C., France; and Hong Kong Productivity Council (HKPC), Hong Kong.

Launched at Formnext 2019, Frankfurt, Germany, the Shop System is designed to bring metal Additive Manufacturing to machine and job shops with an affordable, turnkey solution said to achieve exceptional surface finish parts with high levels of feature detail at speeds up to ten times those of Powder Bed Fusion (PBF) Additive Manufacturing technologies. The Shop System can be used in the AM of end-use metal parts for a variety of industries, from automotive and oil & gas to consumer products and electronics.

"The Shop System offers the most cost-effective, highest resolution mid-volume production solutions in the industry. Its high-speed, single-pass print engine introduces high-quality Binder Jetting to an entirely new market of machine shops, casting foundries, and powder metal component suppliers," stated Ric Fulop, CEO and co-founder, Desktop Metal. "With the Shop System, engineers and plant operators can now eliminate many of the constraints previously imposed by traditional manufacturing methods, like CNC machining, and achieve affordable, reliable, and flexible batch production of complex parts."

www.desktopmetal.com

# Canadian-based research partners launch 3D anatomical reconstruction laboratory

A collaborative project established by Canadian-based industrial research centre, Investissement Québec – CRIQ, and university hospital centre, the CHU de Québec–Université Laval, have launched the 3D anatomical reconstruction laboratory, the Laboratoire de reconstruction anatomique 3D (LARA 3D).

Said to be the only facility of its kind in Canada, LARA 3D provides Québec with the equipment and expertise required for the production of patient-specific implantable prostheses thanks to the use of 3D imaging, modelling and Additive Manufacturing technologies. The partners of the collaborative project, which also includes the participation of SOVAR, an organisation dedicated to the emergence, development and deployment of responsible technological and social innovations stemming from cutting-edge research, have invested over $8 million to purchase AM machines and specialised equipment, set up research spaces, design and manufacture the first prototypes, conduct usability tests and launch the approval process for new products with a view to their commercialisation.

*The Arcam and SLM Solutions machines at the LARA 3D laboratory (Courtesy Investment Québec)*

The Québec government has reportedly contributed $3,477,873 from the research infrastructure financing component of its research support programme. According to the project partners, the first innovation to emerge from LARA 3D is an implantable mandibular reconstruction plate for people with oral cancer affecting the jawbone.

Additive Manufacturing makes it possible to solve the conformity problems encountered with industrial prostheses, which are standardised for a typical patient and, therefore, never perfectly adapted to individuals. An implant can now be custom-designed based on internal imaging of the patient to match the unique contours of the bone to be repaired. The implant is then additively manufactured from biocompatible metals using either Laser Beam Powder Bed Fusion (PBF-LB) or Electron Beam Powder Bed Fusion (PBF-EB).

LARA 3D also houses specialised equipment that can be used to finish products, ensure their quality and traceability, and clean and sterilise them before they are delivered to the medical team. In addition, the ISO 13485 certification process is said to be underway to ensure that the development and manufacturing of specific prostheses meet the strictest quality requirements for the production of medical devices. Work is also continuing in anticipation of applying for a licence from Health Canada, with the aim of being the first Canadian manufacturer to receive approval for an additively manufactured implantable medical device.

The use of AM for the production of orthopaedic prostheses is expected to raise the quality of care in Québec and reduce the time spent in surgery, and thus the associated costs. In addition, since the implant is a better fit and more comfortable, patients are expected to recover faster, state the project partners.

The entire Additive Manufacturing sector in Québec are expected to benefit from LARA 3D's equipment and expertise and will be able to participate in advancing knowledge and techniques. Alkom Digital (a manufacturer of orthopaedic screws) and AP&C (which produces metal powders for AM) are already partnering on the implantable mandibular plate project.

LARA 3D will also make it possible to design and produce other orthopaedic implants in partnership with the private sector and will foster the creation of very high-quality specialised jobs.

"Medical 3D printing will significantly change hospitals by facilitating difficult reconstruction surgery, reducing both operating time and patients' recovery time and making it possible to produce custom implants at accessible costs," stated Lyne Dubois, vice president, Investissement Québec – CRIQ.

"As a leader in Additive Manufacturing in Québec, Investissement Québec – CRIQ is proud to open up new possibilities, not only for the health care sector but for the Québec's entire 3D printing ecosystem, because this infrastructure will also enable other companies to develop their own expertise and innovative products."

Martin Beaumont, president and CEO, CHU de Québec – Université Laval, commented, "Innovation is one of the core values of the CHU de Québec–Université Laval, and advances in medical 3D printing are concrete examples of the scope of our clinical research mission and ensure that we are constantly expanding the boundaries of science."

Beaumont added, "We're very proud of this personalised medicine project piloted by Gaston Bernier's team and our partners at Investissement Québec – CRIQ, who took on this adventure for the benefit of our patients."

www.crchudequebec.ulaval.ca
www.criq.qc.ca


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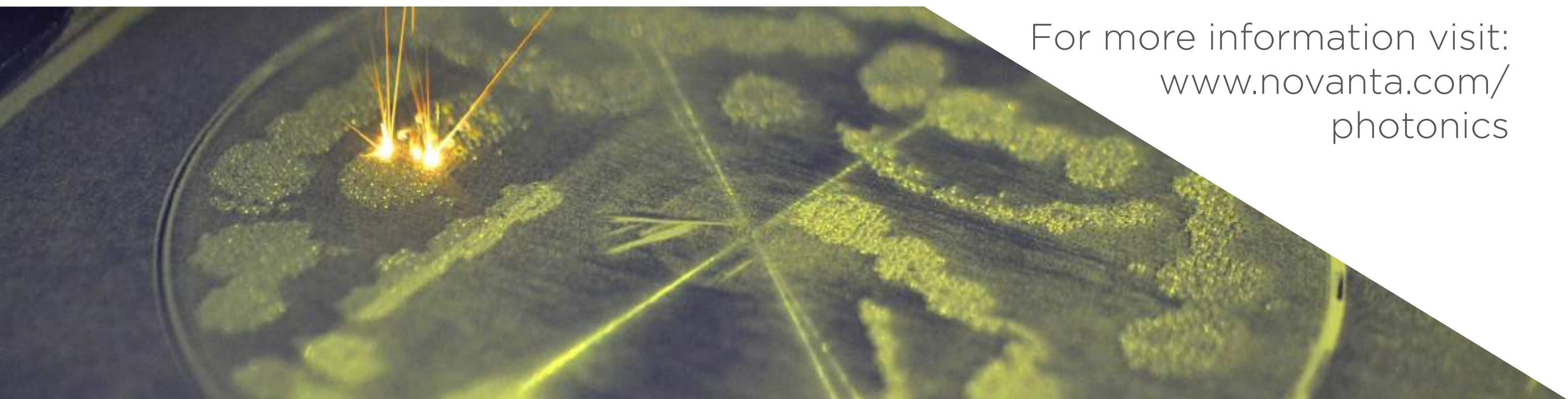

## New technology and test centre for Rösler's AM Solutions

AM Solutions – 3D post processing technology, the Additive Manufacturing brand of Rösler Oberflächentechnik GmbH, Untermerzbach, Germany, has launched a new technology and test centre at Rösler's headquarters in Untermerzbach. The new centre is expected to aid the development of AM Solutions' processes and products for the post-processing of AM parts. The new centre, which has a total area of 400 $m^2$, houses various Additive Manufacturing systems, with the main focus being on a well-equipped post-processing section, where AM Solutions can demonstrate a range of machinery for the post-processing of AM components.

Manuel Laux, Head of AM Solutions – 3D post processing technology, explained, "It is our declared goal to develop the best possible process solutions for our customers. To do this we must be able to fully understand every detail of the Additive Manufacturing process and must actually be in a position to demonstrate the various manufacturing stages. Only with such a hands-on approach will we be able take into account all the facets of Additive Manufacturing."

The new centre is not only equipped with the latest engineering, AM and post-processing hardware and software, but incorporates air intake and venting systems to maintain exact temperature and humidity levels in the pressure area.

For engineering and topology optimisation it will utilise NX CAD software from Siemens. The 3D scanner Atos from GOM will allow quick and precise optimisation of engineering operations and, in addition, will be used for quality control. The Additive Manufacturing areas at the centre are strictly separated by material categories. Metal AM is carried out on an EOS M 290 system from EOS GmbH, Krailling, Germany.

To allow test trials for the development of optimum, automated post-processing solutions and to select the most suitable equipment, AM Solutions – 3D post processing technology has installed its own post-processing equipment line in the form of the models S1, S2 and S3, and M1, M2 and M3.

The test centre is equipped with various post-processing systems from AM Solutions' partners Gpainnova and PostProcess Technologies. These include a Gpainnova DLyte 100 and the DLyte 10.000. In addition, the DEMI, DECI, DECI Duo and Rador from PostProcess Technologies are available for test trials.

www.solutions-for-am.com

## Euro PM2020 Virtual Congress brings PM community together online

The European Powder Metallurgy Association (EPMA) held its Euro PM2020 Virtual Congress from October 5–7, 2020. The Virtual Congress, the first online edition of the EPMA's annual Powder Metallurgy Congress, included over 160 oral presentations, with interactive Q&A discussions with the authors following each technical session.

The technical programme represented all areas of Powder Metallurgy, including Additive Manufacturing, functional materials, hard materials and diamond tools, Hot Isostatic Pressing, Metal Injection Moulding, new materials, processes and applications, and conventional press and sinter PM.

"Moving to a digital platform was a big challenge, but I am delighted with the event we were able to deliver. We had such a strong technical programme this year that it would have been truly unfair to the speakers not to have the opportunity to present their work," stated Lionel Aboussouan, EPMA Executive Director.

Ralf Carlström, EPMA president, opened the Plenary Presentations with an overview of the status and trends in the European PM industry. This was followed by Jean-Marie Reveille of automotive benchmarking company A2MAC1, who presented on current and new opportunities for PM components in new mobility.

"Our members are always enthusiastic about the latest research in PM and I think we found a great method of delivering it to them," concluded Aboussouan.

www.epma.com

## APP completes expansion

Advanced Powder Products, Inc. (APP), Philipsburg, Pennsylvania, USA, a company specialising in MIM and metal Additive Manufacturing, has announced the completion of a 2,300 $m^2$ expansion of its manufacturing facility.

With the MIM industry said to be growing at a rate of 5–7%, APP explains that the expansion will allow the company to better serve its customers and facilitate its continued growth, adding capacity for subsequent years. The new facility houses a state-of-the-art quality lab, increased processing capabilities, automation development facilities and a research and development centre. The company's growth plans include the hiring of skilled professionals, engineers, and technicians, as well as entry-level manufacturing support.

www.advancedpowderproducts.com


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# University of Pisa adds Exaddon's CERES machine for microscale metal AM research

The University of Pisa, Italy, has purchased a CERES microscale Additive Manufacturing machine from microscale AM provider Exaddon AG, a Cytosurge AG spin-off company operating as an independent business since 2019. Acquired through the framework of the Center for Instrument Sharing University of Pisa (CISUP), the CERES machine will be utilised by Professor Giuseppe Barillaro, Associate Professor at the Information Engineering Department at the University of Pisa, and his team to further their research on the unique capabilities of microscale metal Additive Manufacturing.

Prof Barillaro explains that the CERES machine "will be exploited to carry out frontier research on advanced micro and nano materials and structures with application in electronics and photonics, biomedics and medicine, life-sciences and nuclear physics."

Among this vast range of disciplines, cell transfection using nanoneedles is said to be just one area of research which Prof Barillaro cited as a target use for the CERES machine, referring to a 2016 study published in *Applied Materials and Interfaces*. The study aimed to show how cell membranes had different responses when brought into contact with arrays of different shaped micropillars.

In the study, the team used electrochemical micromachining, specifically lithography and acid etching, to create silicon pillar arrays. When the cells contacted these pillars, the cell walls were permeated, whilst the cells remained viable, thus allowing certain molecules to be trafficked into the cells. This process, known as biomolecular trafficking, is said to be extremely relevant in modern biotechnology. Through changing the diameter and height of the pillars, the team were able to influence how this process occurred.

They found that different parameters of the pillars (diameter, spacing, etc.) informed different cell responses. This study demonstrates an ideal use case for the CERES machine: creating arrays of microscale pillars, but this time, out of pure metal - impossible with processes like lithography and etching.

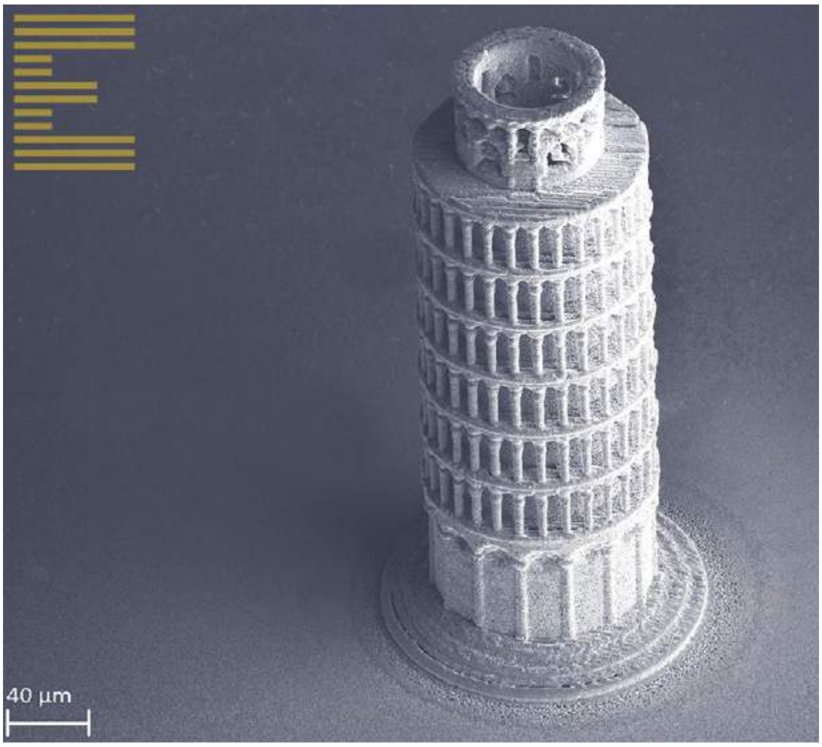
As a test scenario, Exaddon R&D engineers additively manufactured 1 x 1 mm arrays of micropillars to test uniformity and repeatability of AM objects. The results can be seen above, and the translation to the cell transaction use case is readily apparent. The pillar diameters of the silicon arrays in the 2016 study were either 500 nm or 1000 nm, depending on the array. As a comparison to this, the CERES machine can reportedly additively manufacture 1000 nm diameter pillars with a standard AM tip, and pillars with as little as ~250 nm diameter with a custom tip. Furthermore, these pillars can be additively manufactured in gold or copper, and on a variety of substrates, including gold, copper, and flexible polymers such as PEDOT.

According to Prof Barillaro, the CERES machine marks an important point for the use of microscale metal AM in biological research applications. Additionally, the wide range of research fields in which CISUP intends to use the CERES machine is expected to provide an excellent test of its versatility and applicability in fundamental research.

To mark the occasion, the Exaddon team created a scale replica of the famed Leaning Tower of Pisa, additively manufactured in pure copper with their CERES machine and at just 360 µm in height.

www.exaddon.com

www.unipi.it




*The Exaddon team created a scale replica of the famed Leaning Tower of Pisa, additively manufactured in pure copper at just 360 µm in height (Courtesy Exaddon AG)*

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# Cobra Golf launches new putter produced using HP Metal Jet, expands range of MIM wedges

Golf club manufacturer Cobra Golf, headquartered in Carlsbad, California, USA, has launched the King Supersport-35 putter, the company's first club produced using metal Binder Jetting. The development of this first additively manufactured golf club follows the company's earlier move into Metal Injection Moulding for its King MIM wedges in 2019 and the recently announced King MIM Black wedge.

Developed over the past two years in collaboration with Cobra engineers and the teams at HP and Parmatech – a leading MIM producer and launch partner in HP's Metal Jet program based in Petaluma, California, USA – the limited edition Supersport-35 putter features a fully additively manufactured 316 stainless steel body with an intricate lattice structure to optimise weight distribution and deliver the highest-possible Moment of Intertia (MOI) in a blade shape (Fig. 1).

During the final step of the manufacturing process, the surfaces of the putter were precision milled using a Computer Numeric Controlled (CNC) machine to ensure precise shaping and detail while adding the finishing cosmetic touches (Fig. 2). The Supersport features a high MOI heel-toe weighted design for maximum stability, and a plumber neck hosel with a 35° toe hang suitable for slight arc putting strokes. Cobra Golf explains that the additively manufactured putter represents a revolutionary advancement in the way golf clubs are designed and manufactured. The company selected HP as its partner to pioneer Additive Manufacturing in golf due to the advantages that HP's Metal Jet Binder Jetting technology, a sinter-based AM technology which shares post-processing steps and some aspects of part design and quality with MIM, presented over traditional manufacturing and other AM processes.

With its quicker processing time and greater design adaptability, the company states that its engineers were able to design, prototype, and test multiple iterations and bring the product to market much faster than has previously been possible.

Cobra and HP began working together in early 2019 and created thirty-five different design iterations over the course of eight months, showcasing the design freedom and speed of product innovation available using the HP Metal Jet machine, notes Cobra Golf.

In addition to this launch, the brands are reportedly working together on a strategic, multi-year product roadmap that leverages the design and manufacturing benefits of HP's Binder Jetting technology to deliver future golf equipment that raises performance and golfer satisfaction. Cobra plans to launch two additional products in 2021 that feature Additive Manufacturing technology.

"At Cobra Golf we strive to deliver high-performance products that help golfers of all levels play their best and enjoy the game," commented Jose Miraflor, vice


*Fig. 1 The limited-edition putter features an additively manufactured 316 stainless steel body with an intricate lattice structure to optimise weight distribution (Courtesy Cobra Golf)*


*Fig. 2 The putter's external surfaces are CNC machined to ensure precise shaping and detail while adding the finishing cosmetic touches (Courtesy Cobra Golf)*


*Fig. 3 Cobra Golf has added King MIM Black wedges to its well-received King MIM line (Courtesy Cobra Golf)*

president of Marketing, Cobra Golf. "To do that, it's critical to use the most effective manufacturing processes to design, develop, and achieve optimal results, and we've certainly done that with this new putter. To continue innovating and transforming the way equipment is manufactured, we worked with HP and Parmatech to take advantage of the benefits of Metal Jet technology."

"During the development of the King Supersport-35 Putter, we saw immediate benefits from this process, including design freedom, rapid design iteration, and high-quality parts that meet our economic demands," he added. 3D printing is accelerating design innovation, and this breakthrough putter will help usher in a new era for the sporting equipment industry at large."

"HP's 3D printing technology allows us to utilise a complex lattice structure to remove weight from the centre of the putter-head and push significant amounts of weight to the perimeter. The result is superior MOI levels and massively increased stability and forgiveness. So not only is the 3D production method more consistent but it also allows us to design products in a new and superior way."

Uday Yadati, Global Head of HP Metal Jet, HP Inc, stated, "The power of personalisation enabled by 3D printing delivers completely reimagined consumer products and experiences. This first of its kind putter is a shining example of the disruptive design and production capabilities of HP Metal Jet 3D printing technology. Cobra's commitment to innovation and competitive excellence combined with the technical expertise and leadership from Parmatech has led to a breakthrough design win for golf fans around the world."

In addition to the additively manufactured design, the King Supersport-35 Putter, which comes in an oversized blade shape, features SIK Golf's Patented Descending Loft technology re-engineered into an aluminium face insert. The company states that this insert design strategically saves weight from the front of the putter to be repositioned heel-toe and tunes the feel to a slightly softer feel than a traditional all-steel SIK putter face. Their signature face design utilises four descending lofts (4°, 3°, 2°, 1°) to ensure the most consistent launch conditions for every putting stroke.

Bryson DeChambeau, SIK Golf partner and Cobra ambassador, reported, "I've had a lot of success over the years with my SIK putter and was really excited to work with Cobra to develop a new way to manufacture equipment and bring this new putter to market."

"HP's Metal Jet technology is an incredibly advanced production method and very exacting, which is pretty critical in golf equipment," he continued. "I think golfers of all levels will benefit from the combination of Cobra's high MOI design and SIK's Descending Loft technology."

**Cobra Golf expands its MIM range with King MIM Black wedges**

Cobra Golf has also reported that it is expanding its family of 'King MIM' wedges, manufactured using Metal Injection Moulding, with the addition of its King MIM Black wedges to the well-received line.

The wedge is produced from 304 stainless steel and, after sintering, robotically polished to exact specifications, eliminating the variability that can come from hand-polishing on a wheel. The end-to-end process is fully automated to deliver consistency from club to club, including on grind shapes and bounce. The King MIM black wedges have a glare-reducing Quench Polish Quench (QPQ) black finish. The club faces and grooves are CNC-milled for maximum surface roughness to deliver the right spin profile, with milling performed in a circular pattern in order to maximise spin on softer shots where the ball won't go as deep into the grooves. The grooves are shaped uniquely to each wedge, with weaker lofts featuring wider, shallower grooves, Grooves become narrower and deeper as loft decreases.

"When we introduced MIM Wedges last year, it marked a steep change in the way wedges were manufactured," stated Tom Olsavsky, vice president of R&D for Cobra Golf. "Since then, we have received requests from better players asking for the type of black finish that is preferred on Tour."

www.cobragolf.com

www.hp.com/go/3Dprinting

## Wall Colmonoy adds Desktop Metal Shop System

Wall Colmonoy Limited (UK), Pontardawe, Wales, UK, the European headquarters of the global powder and components manufacturer Wall Colmonoy, has purchased a Desktop Metal Shop System from UK-based Additive Manufacturing equipment reseller Tri-Tech 3D.

Desktop Metal's Shop System was launched during Formnext 2019. The high-speed, single-pass system was designed to introduce high-quality metal Binder Jetting (BJT) to the market of machine shops and metal fabrication job shops, a global industry estimated to be worth nearly $180 billion.

The Shop System can be used to additively manufacture end-use metal parts for a variety of industries, including manufacturing, tooling, automotive, consumer electronics, and marine, with the quality, surface finish and tolerances needed to co-exist with machining.

Wall Colmonoy is reported to be the first company in the UK to purchase a Desktop Metal Shop System. Having been established as a materials engineering business for over eighty years, the company serves the aerospace, automotive, glass, oil & gas, mining, energy, and other industrial sectors. Its Pontardawe facility recently celebrated its fifty-year anniversary.

The company has seen a surge in requirements from existing and new customers for highly-complex parts and tooling in recent years. With the Shop System, it will use Binder Jetting alongside sophisticated software to maximise its Additive Manufacturing efficiency and effectiveness.

Chris Weirman, Director of Technology at Wall Colmonoy Limited (UK), stated, "We identified the Desktop Metal Shop System as the ideal choice for our first step in the metal AM journey due to its speed, size and flexibility, plus the relationship between Desktop Metal and its UK reseller Tri-Tech 3D. This builds upon our knowledge of polymer 3D printing for complex investment-cast forms."

The Shop System is already said to be allowing Wall Colmonoy to partner with several Additive Manufacturing customers. The company now supports the design, prototype, and product qualification of AM parts for customer-specific requirements, and can also develop solutions to overcome existing technical challenges.

www.desktopmetal.com
www.wallcolmonoy.com
www.tritech3d.co.uk

## Call for Papers for Euro PM2021

The European Powder Metallurgy Association (EPMA) has issued a Call for Papers for its Euro PM2021 Congress & Exhibition, which will take place in Lisbon, Portugal, October 17–20, 2021. The event's Technical Programme Committee invites authors to submit abstracts of papers for presentations in both oral and poster sessions before the deadline of January 20, 2021.

Oral sessions will contain four presentations, with twenty minutes scheduled for each paper. Poster presentations will be in allocated topic zones and will be on display for the duration of the event. Abstracts should be submitted using the EPMA's online submission form, with further information available via the organiser's website.

www.europm2021.com

## Xiris launches XIR-1800 thermal camera

Xiris Automation Inc., Burlington, Ontario, Canada, has launched a new thermal camera designed for metal Additive Manufacturing, the XIR-1800. The new camera uses high dynamic range (HDR) SWIR technology and includes access to WeldStudio™, the company's machine vision and thermal imaging software tool.

This is said to enable users to view clear images of the welding arc, melt pool and base material within metal Additive Manufacturing machines, as well as a 2D temperature map of deposited material, in real-time, helping to control and monitor the metal AM process.

Xiris's thermal imaging tools offer better detection of thermal boundaries in the AM process such as melt pool or weld bead structures, as well as being able to measure the material temperature variations between passes. All thermal video can be recorded for offline review and quality audits. The XIR-1800 is expected to be available to customers from early 2021.

www.xiris.com

*The XIR-1800 thermal camera is designed for metal AM and includes the company's WeldStudio machine vision and thermal imaging software (Courtesy Xiris Automation)*

## Formnext Connect celebrates success as a digital hub for AM

The organisers of Formnext, Mesago Messe Frankfurt GmbH, report that on the first Formnext Connect successfully fulfilled its role as an international digital hub for the AM world, highlighting, even in challenging times, the continuing importance of one of the world's leading exhibitions for the Additive Manufacturing industry.

The digital event, which ran from November 10–12, attracted 203 exhibitors, with about 2,200 representatives, and showcased 1,412 products. Approximately 8,500 active participants from more than a hundred countries used the event's AI-powered matchmaking function, which generated more than 450,000 product and networking recommendations.

*Formnext Connect's programme of stage events and sessions were broadcast online (Courtesy Mesago Messe Frankfurt GmbH)*

In addition, 23,311 new connections were made between attendees and 4,733 business meetings held in the form of video calls. In a programme of 221 lectures and presentations, a range of global experts discussed current and future trends, developments and applications for AM.

"The newly-developed digital format of Formnext Connect has enabled us to meet the demand from the AM community and target industries for dialogue, business, and innovation," commented Sascha F Wenzler, vice president Formnext at Mesago Messe Frankfurt GmbH. "Formnext has thus demonstrated that, even in a purely digital format, it is indispensable as a globally-important catalyst for the technological and economic development of this future-oriented industry."

Accompanying Formnext Connect was the varied programme from the 'Additive Manufacturing Capital Studio', featuring a number of high-profile guests. This was broadcast on the main stage in consideration of different timezones and featured discussion panels among technology experts from the various exhibitors as well as interviews with representatives from various user industries, including automotive, aerospace, construction, mechanical engineering, medicine, and tool and mould-making.

Wenzler believes that the success of the digital format will also play a role in future trade fair formats. "Born out of necessity due to the worldwide corona [COVID-19] restrictions, Formnext Connect has proven itself as a digital platform and will continue to form an important part of future exhibitions," he stated.

Despite this, Wenzler states that he is of the firm belief that the digital format can never make up for the direct contact and personal interaction of a physical event: "That is why we look forward to future editions of Formnext, which we hope will once again be held in person, so that we may bring the vibrant Formnext atmosphere, which we are all familiar from previous years, back to the Frankfurt show floor."

The next edition of Formnext is scheduled to take place in Frankfurt, Germany, from November 16–19, 2021.

www.formnext.com

## Solar Atmospheres and Kittyhawk partner to offer heat treating and HIP

Heat treatment specialist Solar Atmospheres of California, Fontana, California, USA, and Kittyhawk, a Hot Isostatic Pressing (HIP) company headquartered in Garden Grove, California, USA, have announced a strategic partnership for heat treating and HIP services. As many parts require heat treating and HIP, the new partnership is said to allow customers work with two companies that have extensive experience and a strong reputation within the industry.

Solar Atmospheres and Kittyhawk are both Nadcap, ISO9001, and AS9100 certified, and reportedly maintain source approvals for a full line of major aerospace primes.

"The partnership between Solar Atmospheres and Kittyhawk is a natural fit, as both companies are market leaders in their respective industries," stated Brandon Creason, president of Kittyhawk. "This partnership allows the customer to take advantage of Hot Isostatic Pressing and heat treat without having to look further."

"I am very excited about the future and more importantly providing our customers with two of the best options in the service industry," he added.

Derek Dennis, president, Solar Atmospheres of California, commented, "In response to the needs and requirements of our valued customers, Solar Atmospheres is delighted to partner with a high-calibre organisation like Kittyhawk to provide Hot Isostatic Pressing services."

He continued, "Both companies share a strong focus on quality and bringing a valued service to our customers, coupled with a best in the industry level of customer service and responsiveness, and you have a winning partnership for success."

www.solaratm.com
www.kittyhawkinc.com

# Meltio launches new version of its fabrication module Meltio Engine

Metal Additive Manufacturing company Meltio, based in Linares, Spain, and Las Vegas, Nevada, USA, has launched the new version of its Meltio Engine, a fabrication module which enables the Additive Manufacturing of full-density metal parts when integrated with CNC machines, robots, and gantry systems, in a primarily wire-based Directed Energy Deposition (DED) process said to optimise resources and save production costs.

*Meltio has launched the new version of its Meltio Engine fabrication module (Courtesy Meltio)*

According to Meltio, the revamped model is the result of several months of R&D development after the first public presentation of the company's product portfolio at Formnext 2019. The new version is said to offer greater portability and more compact dimensions (94 x 75 x 45 cm), which allow easy integration with most existing compatible systems. The Meltio Engine also includes an onboard computer with integrated touchscreen and GUI for easy operation and monitoring of manufacturing jobs.

The Meltio Engine uses the same proprietary Meltio LMD-Wire + Powder technology used in its compact metal Additive Manufacturing machine, the Meltio M450. The build head uses a high-power multi-laser configuration to deposit layers of metal in wire format, with the added option to work with powder for the creation of special alloys. Additionally, the Meltio Engine can manufacture full-density metal parts with materials such as stainless steel (all common grades), Inconel (718 and 625) and Ti6Al4V (grades 5 and 23). The company explains that many other materials are currently under development at Meltio's R&D centres in the USA and Spain, such as copper, aluminium, molybdenum, tungsten, X9, gold and invar.

Ángel Llavero, Meltio's CEO, stated, "After the launch of the M450, the Meltio Engine moves the Meltio LMD to a new format with which it will solve one of the great historical limitations that Additive Manufacturing had: the ability to manufacture large parts. Now the part size is limited only by the capacity of the robot, the gantry or the CNC in which the Meltio Engine is integrated."

Llavero went on on highlight how the Meltio Engine is designed to manufacture at industrial mass-production levels, to optimise resources, and to allow small, medium and large companies to use the technology to additively manufacture metal parts in the most optimised way. "That was unthinkable until the arrival of Meltio because of costs, difficulty, need for space," he continued. "Is Meltio Additive Manufacturing? Yes, but it offers a completely different metal Additive Manufacturing concept than the one conceived today by the world market."

www.meltio3d.com

# Scandinavian AM project to facilitate regional collaboration

The Danish AM Hub, Copenhagen, Denmark, has joined forces with the Alfred Nobel Science Park, Örebro, Sweden, with the aim of strengthening collaboration between companies in Denmark, Sweden and Norway in their adoption of Additive Manufacturing and other digital production technologies. The project is supported by the EU Initiative Interreg-ETC, and will bring together companies, NGOs, universities, and public bodies in an ecosystem across the Nordic region.

"In the Nordic countries we are good at cooperating, learning from each other and we have several companies, both small and large, that can benefit from exchanging experiences with one another," stated Frank Rosengreen Lorenzen, CEO, Danish AM Hub. "When you look at Denmark, Sweden and Norway, it is clear that we have plenty of large and skilled manufacturing companies who work with 3D print. However, it is a new field and every company has to learn the hard way to be able to produce and actually start saving money, time and resources on this."

Danfoss, headquartered in Nordborg, Denmark, is already involved in the project. Steffen Schmidt, the company's Segment Head & Platform Architect – Additive Manufacturing, stated, "At Danfoss, we have already saved many hundreds of thousands of euros on using 3D printing activities. This is an area we are focusing on, and the development is strong, so we are eager to exchange experiences with our Nordic neighbouring companies, both in terms of technology and competencies."

Saab, headquartered in Stockholm, Sweden, has also joined the project and is reported to be in the process of implementing AM itself. "A closer cooperation between the Nordic countries, where several companies will be able to share their knowledge, might accelerate the use of AM – more competencies will benefit our activities as well. We are pleased to support a category of initiatives like this one," stated Göran Backlund, CTO Saab Dynamics AB, Chair of Saab AM Group.

www.am-hub.dk

# Etteplan launches free cost-estimation tool for metal Additive Manufacturing

Etteplan, Espoo, Finland, has launched a free browser-based tool, Etteplan AMOTool, said to allow companies to quickly calculate costs for the production of parts by metal Additive Manufacturing. Developed by its Additive Manufacturing & Optimisation team, the software has been used in-house for some years. The final online tool was created with support from Business Finland, in collaboration with Etteplan's software unit.

*AMOTool enables estimations of production costs (Courtesy Etteplan)*

"With this tool, our objective is not only to remove a major obstacle, but also to encourage our customers and the entire industry to make use of 3D printing technology and improve the competitiveness of products," stated Riku Riikonen, Etteplan's senior vice president, Engineering Solutions. "The tool makes it possible to compare metal 3D printing with traditional manufacturing methods."

Toni Mattila, Director of Business Finland's Sustainable Manufacturing Finland programme, commented, "Additive Manufacturing methods, such as 3D printing, open up excellent opportunities for companies to improve their cost-effectiveness and competitiveness. Distributed manufacturing increases operational flexibility, which is particularly valuable during exceptional periods like the one we are experiencing now with the coronavirus."

"In addition, AM methods help manufacturing companies improve their material efficiency and sustainability," she continued. "Despite the numerous benefits, however, many companies are still sceptical about the costs involved in using AM. That makes opening up the costs related to AM methods using a calculation service such as Etteplan AMOTool very valuable."

In addition to providing a cost estimate, AMOTool offers an estimation of how design changes might improve the product or component's cost effeciency. The software also estimates whether redesigning is profitable and suitable for metal AM.

"Assessing the cost level of 3D printing is challenging because, with previous methods, a reliable cost estimate is obtained only after the product has already been designed," explained Tero Hämeenaho, Etteplan's AMO Department Manager. "AMOTool solves this nagging problem. Our tool makes it possible to estimate the price of a 3D printed product even before starting an engineering project."

www.etteplan.com

# ESPRIT CAM and Alma CAM develop robotic DED programming

DP Technology, Camarillo, California, USA, developer of the ESPRIT CAM system, has announced a partnership with Alma, headquartered in Saint-Martin-d'Hères, France, a leading CAD/CAM provider for robotics, to create a complete programming solution for robotic Direct Energy Deposition (DED) Additive Manufacturing.

Wire Arc Additive Manufacturing (WAAM) is one of the DED technologies being applied in robot DED to produce the near-net shape preforms with significant cost and lead time reductions, increased material efficiency, and improved component performance, explains the company.

Compared to a machine tool-based DED machine, which can cost up to several million dollars, a robotic DED machine costs significantly less (close to $150,000 to $200,000), states ESPIRIT. Additionally, many companies have existing programmable, industrial robots that can be retrofitted for additive DED applications.

However, in order to program a robot to perform an additive DED task, an engineer needs to determine not only the toolpath of the DED head, but also the robot arm movements to efficiently achieve the ideal toolpath.

This solution allows Alma to use the full ESPRIT DED cycles such as 3x, 4x, and 5x, bringing the software to a new level of support for AM technology. The solution also allows ESPRIT to support industrial robot brands including Yaskawa, ABB, Fanuc, Kuka, and many others. The result of this technology partnership is a complete workflow to provide end users with:

- Dedicated toolpath planning and programming
- Robot programming, simulation, verification, collision detection, and code generation
- Subtractive finishing process planning, simulation, verification, collision detection, and G-code generation

Through industry collaboration with several key customers and research institutions, the company explains that the programming solution has been validated in multiple applications and test cuts, with various robot brands.

www.espritcam.com
www.almacam.com

# NASA's Perseverance rover will carry eleven metal AM parts to Mars

NASA's Perseverance rover, which is scheduled to land on Mars on February 18, 2021, as part of the Mars 2020 mission, will reportedly carry eleven metal additively manufactured parts. The Mars 2020 mission is part of a larger programme that includes missions to the Moon as a way to prepare for human exploration of Mars. Charged with returning astronauts to the Moon by 2024, NASA will establish a sustained human presence on and around the Moon by 2028 through NASA's Artemis lunar exploration plans.

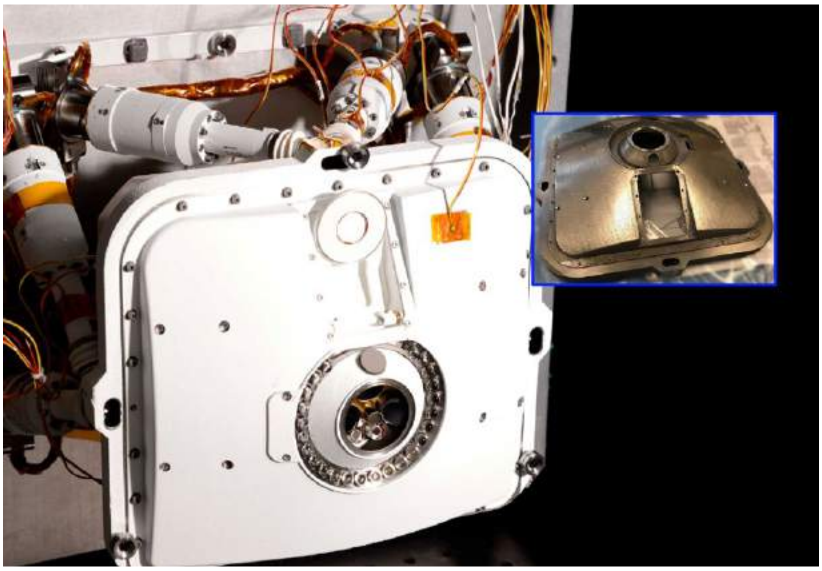
A key objective of Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will characterise the planet's geology and past climate, paving the way for human exploration of Mars, and will be the first mission to collect and cache Martian rock and regolith (broken rock and dust). Andre Pate, the group lead for Additive Manufacturing at NASA's Jet Propulsion Laboratory (JPL) in Southern California, commented, "Flying these parts to Mars is a huge milestone that opens the door a little more for Additive Manufacturing in the space industry."

NASA explains that Curiosity, Perseverance's predecessor, was the first mission to take Additive Manufacturing to Mars when it landed in 2012 with an additively manufactured ceramic part inside the rover's oven-like Sample Analysis at Mars (SAM) instrument. NASA has since continued to test AM for use in spacecraft to ensure the reliability of the parts is well understood.

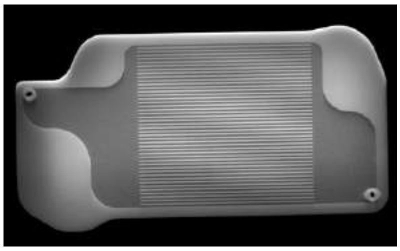
NASA's JPL is managed by Caltech in Pasadena, Southern California, which built and manages operations of the Perseverance and Curiosity rovers.

Of the eleven metal additively manufactured parts travelling to Mars, five are contained within Perseverance's Planetary Instrument for X-ray Lithochemistry (PIXL). This lunchbox-size device is said to help the rover seek out signs of fossilised microbial life by aiming X-ray beams at rock surfaces to analyse them.

PIXL shares space with other tools in the 40 kg rotating turret at the end of the rover's 2 m long robotic arm. To make the instrument as light as possible, the JPL team designed PIXL's two-piece titanium shell, a mounting frame, and two support struts that secure the shell to the end of the arm to be hollow and extremely thin. The parts, which were additively manufactured by Carpenter Additive, are reported to have three or four times less mass than if they'd been produced conventionally.



*Five of the eleven metal AM parts are in Perseverance's Planetary Instrument for X-ray Lithochemistry (PIXL), shown here opening its dust cover during testing at NASA's Jet Propulsion Laboratory (Courtesy NASA/JPL-Caltech)*



*X-ray image of the AM heat exchanger inside Perseverance's Mars Oxygen In-situ Resource Utilization Experiment (Courtesy NASA/JPL-Caltech)*

"In a very real sense, 3D printing made this instrument possible," stated Michael Schein, PIXL's lead mechanical engineer at JPL. "These techniques allowed us to achieve a low-mass and high-precision pointing that could not be made with conventional fabrication."

Perseverance's six other metal additively manufactured parts can be found in an instrument called the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE). This device will test technology that, in the future, could produce industrial quantities of oxygen to create rocket propellant on Mars, helping astronauts launch back to Earth. To create oxygen, MOXIE heats Martian air up to nearly 800°C. Within the device are six heat exchangers – palm-size nickel-alloy plates that protect key parts of the instrument from the effects of high temperatures. NASA explains that while a conventionally machined heat exchanger would need to be made out of two parts and welded together, MOXIE's were each additively manufactured as a single piece.

In order to avoid potential pores or cracks during the Additive Manufacturing process, the plates were treated in a Hot Isostatic Press (HIP). Engineers then used microscopes and mechanical testing to check the microstructure of the exchangers to ensure they were suitable for spaceflight.

https://mars.nasa.gov
www.jpl.nasa.gov

## Valuechain's DNA.am MES adds PrintSyst's AI engine to optimise AM production

DNA.am Ltd, a Valuechain Enterprise Systems business located in Daresbury, UK, and Printsyst, Rishon LeZion, Israel, have completed the integration of PrintSyst's AI engine, the 3DP AI-Perfecter™, into Valuechain's industrial-grade Manufacturing Execution System (MES), DNA.am.

The two companies formed a partnership in 2019 to develop an integrated MES capable of leveraging PrintSyst's AI engine, which enables an automated pre-build workflow and thus assists customers in industries such as aerospace, automotive, and defence to significantly improve their productivity and scale up their AM production. The integrated Valuechain-PrintSyst solution is said to provide state-of-the-art smart automation that learns from previous Additive Manufacturing builds and analyses the intent for which a specific part is going to be used to comply with industry specifications. It then suggests AM parameters that will have the highest probability of right-first-time builds, accurately estimates AM parts costs, recommends the most suitable materials based on AM parts' functional needs and eliminates the need for trial and error.

"Industrial 3D printing has continued to grow over recent months, as companies that initially trialled the technology are looking to scale up," stated Tom Dawes, CEO of Valuechain. "COVID-19 has illustrated the importance of a robust supply chain structure, underpinned by secure collaboration and intelligence. However, many of these companies lack the digital solutions that drive 3D printing productivity while providing a path for an automated, standardised and certifiable digital workflow. Based on our customers' feedback so far, I am confident that our collaboration with PrintSyst will be pivotal in addressing this critical need."

Itamar Yona, PrintSyst's CEO and co-founder, added, "Combining our world-class AI engine and hands-on industry experience, with DNA.am's leading industrial-grade MES, will step change the manual, costly and unscalable 3D printing workflow. We are now able to take into account multiple additional parameters that exist in DNA.am MES and automatically train our engine so we can provide instant, highly-personalised and optimised printing recommendations to our joint customers."

www.DNA.am
https://printsyst.com

## Rapidia launches new rapid cooling furnace

*Rapidia's new rapid cool sintering furnace enables an entire sintering cycle to be completed in about twenty hours (Courtesy Rapidia Inc)*

Sinter-based Additive Manufacturing technology developer Rapidia Inc, based in Vancouver, British Columbia, Canada, has launched a new rapid cooling sintering furnace. The new furnace was developed while the company was in the process of improving the insulation in its existing sintering furnaces, to reduce heat losses and limit skin temperature in AM parts. During this process, the company explains that the detrimental side effect of a lengthy cool down time became apparent. The rapid cooling furnace is said to mitigate this effect.

Rapidia's new furnace is available in the same compact size as the company's earlier furnace designs, sized to fit through an office door and occupy a minimal footprint. In the new model, the need to install a vent to the building exterior has been eliminated by the addition of a high-end activated carbon filter, while the power requirements remain unchanged.

Using the rapid cooling furnace, the entire sintering cycle can reportedly be completed in about twenty hours. As parts produced using Rapidia's Material Extrusion (MEX)-based AM process, which uses water as the binder, do not require a debinding step, it is said that parts can be built and sintered to completion in under twenty-four hours.

www.rapidia.com

## Castor Technologies launches software to identify and optimise components for AM

Castor Technologies Ltd, Tel Aviv, Israel, has launched Castor Enterprise, a proprietary software which is said to enable manufacturers to automatically reduce costs by utilising the benefits of industrial Additive Manufacturing. The company explains that Castor Enterprise is an on-premises solution which automatically identifies cost reduction opportunities out of thousands of parts and assemblies at once, and delivers recommendations for re-designing parts for Additive Manufacturing (DfAM).

The software is said to be based on the feedback derived from 30,000 parts analysed over the last eighteen months by more than eighty companies. Amongst its features are the part consolidation and weight reduction identification capabilities, using a fast Finite Elements Analysis process, states Castor Technologies.

"We have seen our customers' need for a solution that not only reveals the 'low hanging fruits' out of an existing design but also identifies opportunities for Design for AM," commented Omer Blaier, co-founder and CEO of Castor Technologies. "With Castor Enterprise, we now provide a sophisticated tool which identifies those small changes that can have a huge impact on the company's bottom line."

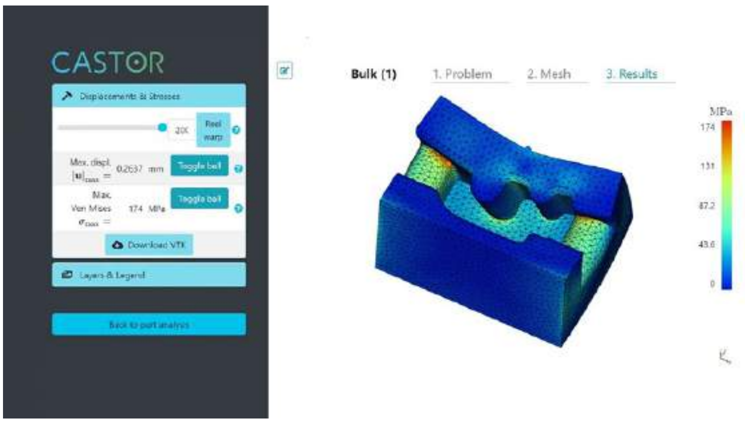
The software is said to be built in a way that allows advanced users to modify almost every default figure it sets, such as customised cost estimation calculations, material properties sensitivity, operational costs from various points of the supply chain, such as inventory, shipment, labour costs, and more. It is PLM/ERP integration-ready and available on-premise, completely offline.

The advanced capabilities of Castor Enterprise are said to be based on four key areas:

- Geometry limitations analysis, based on minimum wall thickness and support material
- Material properties analysis, comparing the AM parts' mechanical properties to traditional manufacturing material properties
- Structural analysis; considering external loads acting upon parts
- Financial break-even point analysis

"By automating the screening process of thousands of parts we save hours of AM professionals' manual work. By quickly providing deep insights that can be translated into actionable decisions, we bring manufacturers closer to maximising the potential profit from 3D printing," Blaier concluded.

www.3dcastor.com




*Castor Technologies has launched Castor Enterprise, its new software for industrial Additive Manufacturing (Courtesy Castor Technologies)*

## Research project to develop ductile iron powder for Additive Manufacturing

A joint research project between Canada's Mohawk College and the University of Guelph is underway to develop a ductile iron powder enabling CGL Manufacturing Inc., a supplier of machined castings, components, and fabrications headquartered in Guelph, Ontario, Canada, to additively manufacture high-quality rapid prototypes for its customers. CGL is seeking a competitive advantage by enabling a faster response to customer's requests for new and redesigned parts, and has selected the combined Additive Manufacturing and materials development expertise at Mohawk College and the University of Guelph.

"A 24-week lead and set up time of the casting process is one of the main challenges CGL faces when a sample part is needed for a new client, or for design revisions of current products," stated Michael Ritchie, president and CEO of CGL Manufacturing Inc. "We want to provide our clients with a high-quality experience, and part of that is reducing production to market time for samples, new products, and design revisions."

*Additively manufactured test coupons of the ductile iron powder (Courtesy Mohawk College)*

The company produces its final parts in 65-45-12 ductile iron, a material known for its strength and durability. While the company plans to continue to use castings to create final parts from this metal, it has identified Powder Bed Fusion AM as a method for producing preliminary parts and prototypes. However, ductile iron is not a material that is commonly used in Additive Manufacturing, and is not commercially available. The joint research project will aim to ensure that the AM parts will have the same chemical composition and mechanical properties as the final casted parts. "This project is an example of a synergetic collaboration and resource integration between industry and academia to develop novel solutions to unique business challenges," Ibrahim Deiab, Professor of Mechanical Engineering at the University of Guelph, commented. "On the Guelph side, the Advanced Manufacturing Lab provides a unique environment to support this type of research, training and education in advanced and sustainable manufacturing technologies."

Jeffrey McIsaac, Dean of Applied Research at Mohawk College, noted, "It's important for the Canadian private sector to compete in a global marketplace. By leveraging academic institutions to help solve key challenges, small- and medium-sized companies grow faster and smarter. Mohawk's Additive Manufacturing expertise will help CGL explore new 3D printing at low risk, and will keep them at the forefront of technology."

The two-year project has received CAN $300,000 of funding from the Natural Science and Engineering Research Council of Canada to support the research through an Innovation Links programme. CGL is also investing CAN $200,000 in the project. CGL will work on this research with Jeff McIsaac, Simon Coulson, and Justin Valenti at Mohawk College's Additive Manufacturing Innovation Centre and Dr Ibrahim Deiab and John Cloutier of the University of Guelph's Advanced Manufacturing Laboratory.

"Our diverse range of capabilities allows us to take on the projects that other firms cannot while providing a level of service unparalleled in our industry. This collaboration with Mohawk and Guelph will provide our clients with an additional reason to rely on Canadian innovation," Ritchie concluded.

www.mohawkcollege.ca
www.uoguelph.ca
www.cglmfg.ca

## Amaero receives Boeing purchase order for metal AM evaluation parts

Amaero International Limited, headquartered in Notting Hill, Victoria, Australia, reports that it has received a purchase order from aerospace manufacturer Boeing for additively manufactured metal evaluation parts.Amaero states that the evaluation parts will be developed and additively manufactured at the company's facilities in El Segundo, California, USA, and Melbourne, Australia.

Barrie Finnin, Amaero CEO, commented, "We are delighted to have received this purchase order from Boeing as it confirms and strengthens Amaero's long term strategic direction. The purpose of Boeing's Global Supply Chain program is to provide access to companies like Amaero to identify opportunities to support global programs within Boeing."

"We have worked closely with Boeing's Global Supply Chain people to unearth a multitude of opportunities within several Boeing programs for Amaero to supply prototypes and production," Finnin continued. "We look forward to working on the evaluation parts in our facilities in Melbourne and El Segundo and continuing to build our relationship."

Boeing is the world's largest aerospace company and leading manufacturer of commercial jetliners, defence, space and security systems, supporting airlines and U.S. and allied government customers in more than 150 countries.

www.amaero.com.au

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# RAM3D collaborates with Sturdy Cycles to produce titanium AM parts

Rapid Advanced Manufacturing Ltd (RAM3D), based in New Zealand, has reported on a recent collaboration with bicycle manufacturer Sturdy Cycles, Somerset, UK, to additively manufacture a number of titanium parts. This is the company's latest partnership in this market, having worked with a number of bespoke bicycle companies for more than six years.

RAM3D explains that it has worked with Tom Sturdy, Director of Sturdy Cycles to produce AM parts for the company's three models which include the Road Race, All Road and XC Race. According to RAM3D, Sturdy is very much involved in the Additive Manufacturing process, advising on any new designs to produce the best outcome for his line of bespoke bikes.

Sturdy used to compete as a professional athlete in triathlons and has a background in Aeronautical Engineering and Sports Biomechanics. After an injury prevented him from continuing as a professional athlete, he decided to focus on design optimisation. Titanium is said to be Sturdy's main choice of metal for his bicycles, as it boasts one of the highest strength to weight ratios of all engineering metals.

With Sturdy's wide range of expertise working in bike shops and R&D, it was a natural progression for him to become involved in frame-building. "There aren't many products that you, as one person, can cover the whole life cycle of. Even with the addition of metal 3D printing, it is still quite technical and challenging.," stated Sturdy. "There is the purist element with titanium, it doesn't need to be painted or finished and for a lot of people, that is quite a big appeal."

www.ram3d.co.nz

www.sturdycycles.co.uk

*RAM3D has additively manufactured titanium parts for Sturdy Cycles bicycles, including its Road Race model (Courtesy RAM3D / Sturdy Cycles)*

# AMUG 2021 moves to Florida

The Additive Manufacturing Users Group (AMUG) has announced new dates and a change of location for its annual AMUG Conference, which was initially set to take place at the Hilton Chicago, Illinois, USA, from March 14–18, 2021. The conference will now take place at the Hilton Orlando, Florida, USA, on the later date of May 2–6, 2021.

"Our goal is to provide an in-person event, in a safe manner, to facilitate the exchange of information in the way that differentiates the AMUG Conference from all others," stated Carl Dekker, AMUG president. "The AMUG Board is committed to planning for an in-person event and will continue to monitor the COVID-19 pandemic and related government restrictions at the federal and local levels. Considering the current and projected circumstances, it was necessary to change the dates of the conference from March to May 2021, and to move the event to Orlando for a larger meeting."

Tom Sorovetz, AMUG Event Manager commented, "The Hilton Orlando offers 249,000 ft$^2$ of meeting space. Even with social distancing protocols in place, this property can accommodate a full-scale AMUG Conference, and it also affords AMUG the opportunity to host outdoor activities."

Dekker noted that over seventy sponsors and 100 exhibitors are supporting the 2021 AMUG Conference by applying the commitments made for the cancelled 2020 event to the coming year. As a socially-distanced conference plan takes shape, AMUG will determine the number of openings for companies to participate. As a result, all new sponsors and exhibitors are being placed on a waitlist.

AMUG has an open call for speakers, and its Agenda Committee is selecting individuals for available speaking slots. Registration for the conference will open on January 6, 2021.

www.amug.com

## Höganäs opens Vacuum Induction Gas Atomiser plant at Laufenburg site

Sweden's Höganäs AB has inaugurated its new Vacuum Induction Gas Atomiser (VIGA) at its site in Laufenburg, Germany, where it produces metal powders for Additive Manufacturing. The company states that the VIGA system, which was commissioned in August after a few turbulent months during the coronavirus (COVID-19) pandemic, represents how new standards for powder quality, as well as for workplace conditions.

"With the VIGA, we are setting new standards on a number of levels," stated Daniel Reimann, Production Manager at the Höganäs Laufenburg site. "On the one hand, we are using it to produce metal powder of even higher quality than before; while, on the other, we are also ensuring workplace conditions of the highest standard."

In addition to powder quality, the working conditions and organisational processes surrounding its production are said to also raise the standards at Höganäs to a new level. "Product quality and workplace quality go hand in hand," continued Reimann. "So, it was important to come up with a solution for the design of workplaces where staff feel comfortable and can concentrate on their tasks. For instance, this includes consideration of the fact that it is more pleasant for staff to monitor the melting and atomisation process from an air-conditioned control room, rather than standing near the intense heat of the crucible."

*The new Vacuum Induction Gas Atomiser (VIGA) at its site in Laufenburg, Germany (Courtesy Höganäs AB)*

According to Höganäs, the Laufenburg plant supplied a considerable proportion of the several hundred tonnes of powder used worldwide for industrial Additive Manufacturing last year, with this quantity expected to increase significantly as demand continues to rise, particularly in the energy, medical and aerospace markets.

Human Gherekhloo, Manager of Applied Technology at the Laufenburg site, commented, "The individual production of high-end components for critical applications is growing rapidly. This not only requires stable production processes, but also places ever-increasing demands on the physical and chemical properties of the raw material."

The company states that the VIGA launch serves as a blueprint for further planned conversion and expansion measures in Laufenburg.

www.hoganas.com

## Altair Material Data Center offers database for AM simulation

Altair, Troy, Michigan, USA, has launched the Altair Material Data Center, a comprehensive material database to enable AM simulation. The application includes accurate data and data lineage for metals, plastics, and composites. Available as a cloud-based standalone system, the company added that it will also be integrated into the Altair Inspire™, Altair SimLab™ and Altair HyperWorks™ interfaces.

Recognising the importance of materials selection for production, Altair has been investing significantly in the area of material modelling for several years and recently acquired M-Base, a leading international supplier of material database and material information systems.

The Altair Material Data Center inludes the M-Base plastic material database, providing comprehensive material information to enable its users to predict and optimise product performance through simulation. Using the centre, users can explore materials and their properties, including structural, fatigue, fluid/thermal and electromagnetic properties, as well as manufacturing process-specific data.

"Altair Material Data Center is yet another compelling solution to help our customers save time, money, and improve product innovation and performance throughout the entire lifecycle of development and manufacturing," stated James R Scapa, founder and Chief Executive Officer, Altair. "We have established strong relationships with material manufacturers and now with the acquisition of M-Base, we've expanded our presence in the plastics industry."

Dr Changwei Lian, Senior Researcher, Baosteel Group Corporation, added, "Baosteel is proud to collaborate with Altair to deeply integrate our material data into the digital development process of automotive industry users while ensuring the data is easily accessible via Altair products and other commonly used CAE software without complex data processing. Having our high-quality material data included in the Altair Material Data Center will provide quick and convenient access to our latest research results and the accurate application data reflecting the performance of Baosteel products."

www.altair.com

## Markforged names new president and Chief Executive Officer

Markforged, Watertown, Massachusetts, USA, has announced the promotion of Shai Terem to president & Chief Executive Officer. Gregory Mark, founder of Markforged, has now transitioned to the role of chairman. The leadership announcements are the results of a planned succession and are said to be designed to position the company for continued success in the next phase of its growth. As CEO, Terem will lead the development and execution of short- and long-term strategies and day-to-day operations, with the aim of positioning Markforged to continue delivering value to its key stakeholders as the company continues to scale.

Since joining Markforged in December 2019 as president and Chief Operating Officer, Terem has reorganised the company to incorporate a channel-first approach while building a strong infrastructure for rapid, efficient and scalable growth. Previously, he served as president of the Americas region at Kornit Digital, a global specialist in 2D digital printing for textiles, and held various product marketing, finance, and operations roles within the AM company Stratasys.

"I have been fortunate to spend the majority of my career in this industry – experience that gives me profound appreciation for the immense value that Markforged brings to organisations around the world," stated Terem. "Our tools are designed to allow manufacturers to go from design to a functional part with unmatched efficiency to truly optimise the supply chain. It is an honour to take the helm of such a pioneering company, and I'm eager to play my part in our mission to reinvent manufacturing."

Gregory Mark stated, "Leading Markforged for the past seven years as Chief Executive Officer has been an amazing journey, and I'm incredibly proud of what we've built. Before Markforged, access to strong 3D printed parts was limited to those who could afford million-dollar machines. Today, we have parts flying in space, and on commercial and military jets; we have hundreds of thousands of parts used by frontline workers to fight COVID. All are printed on a platform that is robust enough for end-use aerospace, and affordable to high schools and colleges. We have democratised metal and carbon fibre 3D printing, and we're just getting started."

In his new role as chairman, Mark will focus on promoting adoption of the company's Additive Manufacturing platform among engineers, designers and manufacturing professionals all over the world.

www.markforged.com

# Moorhuhn Bike wins first prize in purmundus challenge 2020

The winners of the international purmundus challenge 2020, which ran with the theme Geometry and Material in Harmony, were announced in a prize-giving event at Formnext Connect, November 10–12, 2020. First place was awarded to Ralf Holleis of Huhn Cycles for his Moorhuhn Bike, which takes advantage of metal Additive Manufacturing to offer stability and light weight. Second and third places were awarded to polymer AM entries HKK Bionics with the Exomotion Hand One, and Svet Abjo with the Sneaker Zero. The Bolt-It, developed by ETH Zürich, Inspire AG and Gressel, took the prize for Simulation Driven Design.

The finalists in this year's purmundus challenge came from thirteen countries across five continents, with products showcased from China, Germany, the UK, Hong Kong, Israel, Italy, New Zealand, the Netherlands, Nigeria, Austria, Switzerland, Spain, and the United States.

**Moorhuhn Fahrradrahmen, by HUHN cycles and Ralf Holleis**

The Moorhuhn Bike combines the advantages of super-light titanium tubes with additively manufactured lugs. This makes the joints extremely stiff, explained the designers, as they can be designed according to the forces within a bicycle frame in order to distribute them equally. The Moorhuhn joints incorporate an internal lattice structure which supports their very thin walls. The use of AM also makes it possible to produce each frame according to the needs of each individual, so that functions like cable guiding, seat clamps, bearing housings and additional material for welding can be integrated into the design.

"The bicycle industry developed very quickly the last couple years, bikes got lighter and stiffer at the same time," stated the designers. "Those great achievements were mainly possible with a composite material called carbon fibre, but unfortunately producing this material has a very high carbon footprint. In addition, carbon products have a very short product life-cycle as there is a certain safety risk in using second hand or crashed carbon products."

"Sadly, there are nearly no ways to recycle this composite material, so most of the time carbon frames end up in landfill or get burned," they noted. "Metal recycles forever!"

www.huhncycles.com

*The Moorhuhn Bike combines titanium tubes with additively manufactured lugs (Courtesy Huhn Cycles)*

*Bolt-It enables a post-process chain through automated gripping and handling of the AM part (Courtesy ETH Zürich, Inspire AG and Gressel)*

**Bolt-It, by ETH Zürich, Inspire AG and Gressel**

Bolt-It was designed through a research and development collaboration by ETH Zürich, Inspire AG and Gressel. The Bolt-It concept enables a smarter physical and digital post-process chain through automated gripping and handling of the AM part for post-processing. Using this gripping and handling tool, robust machining, with accessibility from five sides, is made possible. A simple torsion removal of the interfaces completes the process.

The two-year project to develop Bolt it was funded by the innosuisse and headed by Julian Ferchow, Research Associate at Inspire AG, ETH Zurich, and Marcel Schlüssel, Head of Technology at Gressel.

www.ethz.ch | www.gressel.ch
www.inspire.ethz.ch
www.purmundus-challenge.com

# Microtrac MRB introduces its new SYNC Analyzer

Microtrac MRB, a leading manufacturer of instruments for particle characterisation, and part of Verder Scientific, a division of Verder Group headquartered in Haan, Germany, has introduced the Microtrac MRB SYNC Analyzer. The new tool reportedly provides traditional users of laser diffraction technology with new capabilities to characterise their materials.

According to the company, the tool's tri-laser technology provides accurate and repeatable laser diffraction information from light detected over 163° of angular scatter. When combined with state-of-the-art camera technology capturing images of the particle stream at the same time, the SYNC Analyzer offers not only size data but also additional information about the shape of the materials and the quality of the dispersion.

In addition, the patented synchronous measurement technology of the SYNC allows users to conduct both a laser diffraction measurement and image analysis on a single sample, in the same sample cell and at the same time.

This is said to make the SYNC Analyzer ideal for both routine quality control and research applications, as it provides valuable information to researchers involved in the development of new materials and processes. The software interface offers both particle size distribution information and a multitude of morphological parameters, and the company's patented BLEND routine allows users to examine materials over a wide size range from 0.01 µm to 4000 µm.

www.microtrac.com
www.verder-scientific.com

*Microtrac MRB SYNC Analyzer has been introduced by Verder Scientific's Microtrac MRB (Courtesy Microtrac MRB/Verder Scientific)*

# 6K Additive expands metal powder production team

6K, a developer of microwave plasma technology for the production of advanced materials, headquartered in North Andover, Massachusetts, USA, and its business division, 6K Additive, has expanded its metal powder production team. The new employees are said to bring extensive knowledge in quality, powder manufacturing and processing, as 6K begins production of its Onyx line of AM powders at its recently commissioned 3,700 m$^2$ (40,000 ft$^2$) lights-out facility. The new team members include:

**George Meng**, Director of Process for Additive Meng joins 6K from GE Aviation where he developed and industrialised a new powder for Plasma Suspension Spray coating, and a new no-line-of-sight thermal spray process for a large critical Ti-based system. Prior to GE, worked at Praxair Surface Technologies, where he was responsible for developing new gas atomised powders.

**John Meyer**, Director of Technology, AM Products Meyer joins 6K from Carpenter Technology Corporation where he was responsible for powder technology and process improvement as Principal Metallurgist. He also managed the Powder Metallurgy (PM) group for its five powder production facilities worldwide including oversight of new product implementation and process technology integration.

**Dave Novotnak**, Production Process Manager, AM Products Novotnak has over thirty years of experience in materials and metallurgical engineering. Prior to joining 6K, Novotnak held the position of Senior Materials Engineer at Carpenter Powder Products having spent twenty years in progressing powder manufacturing processes. He also brings experience in aerospace having spent fourteen years at Pratt & Whitney as Senior Metallurgical Engineer.

**Joe Muha**, Quality Manager, AM Products Muha is a thirty-year veteran in AM powders, having held the position of Principle Powder Metallurgist for Carpenter Powders Products and Quality Engineer. Prior to that, he worked for ATI Powder Metals. Muha also spent fifteen years at Crucible Research where he was responsible for research and QA.

"Adding these experienced leaders to the team underpins our strategy of advancing premium powders in the Additive Manufacturing space," stated Frank Roberts, president of 6K Additive. "Each new member brings deep domain expertise as well as an incredible passion for success, quality and leadership to the team. Their combined 100+ year's expertise in AM powder, materials engineering and metallurgy will allow us to rapidly achieve the quality and production demands brought about by leading organisations in the medical, aerospace and defence markets who drive the application requirements for advanced materials."

www.6Kinc.com

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# RMIT University reports on the success of the 4th International Forum on Additive Manufacturing

*The 4th International Forum on Additive Manufacturing was held digitally by RMIT University on September 9, 2020. In this extended news story for Metal AM, Alex Kingsbury, the university's Additive Manufacturing Industry Fellow & Engagement Lead, and Prof Milan Brandt, Director of the RMIT Centre for Additive Manufacturing report on this first virtual outing of the event.*

Every other year, the Additive Manufacturing folk at RMIT University hold a one-day international forum on AM. This grew somewhat organically through the need to share the latest advancements in industrial AM and reconnect with colleagues abroad. Under usual circumstances the forum is held in a limited capacity venue, and as a result, is an invite-only 'behind closed doors' experience for participants.

The 4th International Forum on Additive Manufacturing was due to be held in Melbourne, Australia, in September of 2020. Like every other event across the globe, it had to be reimagined in the light of the coronavirus (COVID-19) pandemic; while the rest of Australia was faring quite well by September, Melbourne was in the middle of a serious second wave, and, as a result, the members of the RMIT centre were strictly confined to their homes. The conversion to a virtual format meant that for the first time, the once-closely-guarded RMIT AM Forum was available for all to participate.

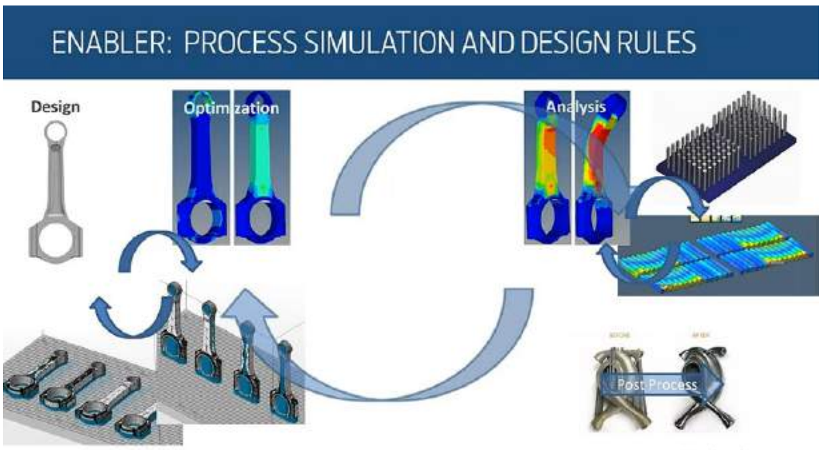
In his welcoming remarks, Professor Milan Brandt, Forum Chair, stated, "The main objective of the Forum was to present an opportunity for Australian companies to further their understanding of the prospects, challenges and opportunities in applying Additive Manufacturing technology." The focus of the AM Forum has always had a commercial bent, with companies given the opportunity to showcase their industrial R&D, present results and highlight case studies.

The Forum was opened by Richard Taube from automaker Ford, with the first keynote presentation covering Ford's Additive Manufacturing roadmap and a discussion of some advanced automotive applications. The afternoon keynote speaker was Professor Christoph Leyens from Fraunhofer Institute for Material and Beam Technology (IWS), who gave a very comprehensive talk on the science and applications of Additive Manufacturing.

Speaking on metal Laser Beam Powder Bed Fusion (PBF-LB), Warwick Downing, RAM3D, gave a pull-no-punches account of running an Additive Manufacturing business in New Zealand. RAM3D is, primarily, a service bureau for the aerospace, defence, and food sectors. Interestingly, they have also built quite a presence in the AM of titanium bicycle parts. Downing took pains to explain the critical role of powder management in the success of high-quality builds, and offered a bold, but substantiated, vision of the future of AM.

Keren Reynolds, BAE Systems, also spoke on PBF-LB, and the current opportunities within BAE for the adoption of AM. Reynolds recently completed a programme of fatigue testing of PBF-LB aluminium for BAE Systems, with a view to developing a framework for the qualification of metal AM within the company. Most recently, BAE has been in the process of designing and setting the requirements for a Hunter-class frigate, so Reynolds was able to outline the potential for AM's application on that platform.

Dr Mike Regan, Director of the HP-NTU Corporate Lab, Singapore, discussed research directions at HP




*The opening keynote presentation was by Ford's Richard Taube and provided an overview of Ford's Additive Manufacturing roadmap. He also discussed the advantages of simulation in the process (Courtesy Ford)*

*Warwick Downing showcased a number of parts being produced at RAM3D (Courtesy RAM3D)*

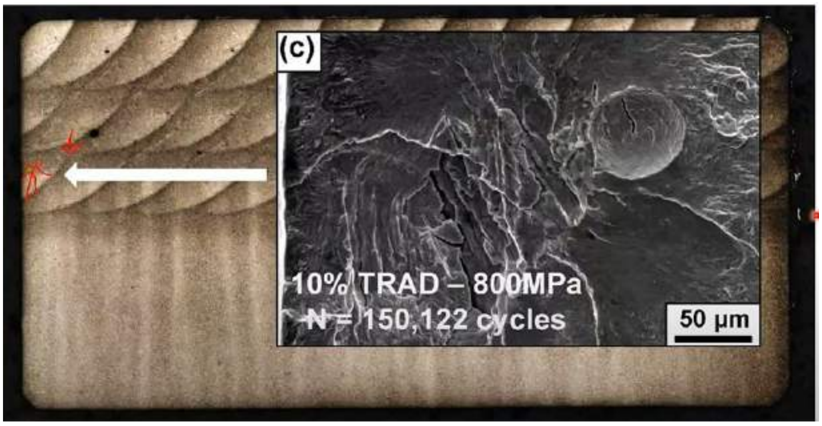
Inc., and how they are informed by global megatrends and customer requirements. In particular, Regan discussed how HP's customers have rapidly innovated this year in response to COVID-19, and how research at HP has shifted to cater to its customers' new needs and requirements as a result.

Two Australian companies were represented at the Forum – both active in large-scale AM. Andrew Sales from AML3D spoke on the progress of the wire-based Directed Energy Deposition (DED) process Wire-Arc Additive Manufacturing (WAAM), and highlighted some research AML3D had carried out into the addition of scandium and zirconium to aluminium alloys. Jeff Lang, Titomic, spoke about the use of another form of DED, cold spray Additive Manufacturing, to create multi-material parts. Cold spray is one of the few technologies that can successfully combine materials with vastly different melting and solidification ranges.

The 'happy hour' slot was delivered by Steve Milanoski from Romar Engineering, who gave the last presentation for the day. Milanoski provided insights into how and why businesses should be using hybrid AM. He developed a deep expertise in hybrid AM during his previous role at SpaceX, and is now bringing this expertise to Romar. In particular, he was able to explain how qualification processes can be shortened using hybrid AM technologies.

A number of RMIT University researchers were also able to provide an update on their industrially-focused projects. Dr Darpan Shidid gave a talk on additively manufactured, load-bearing orthopaedic implants. Dr Alex Medvedev presented on the effects of microstructural changes to titanium alloys on their ballistic performance. Dr Cameron Barr gave a presentation on the fatigue performance of steel repaired using laser-based DED. Bill Lozanovski, a PhD student at RMIT, presented his research thesis on the computational modelling of defects in additively manufactured lattice structures.

*Cold spray can combine materials with vastly different melting and solidification ranges. Here, Titomic's TKF 1000 modular AM system is using Inconel 718, pure titanium and copper to create a hybrid part (Courtesy Titomic)*




*Dr Cameron Barr discussed macrostructure correlation in his presentation on the fatigue performance of steel repaired using DED (Courtesy RMIT University)*

In total, nearly 700 participants from all over the globe registered for the digital event, and, of that number, 85% of those registrants logged in at some point during the day. Activity on social media channels was generated under the hashtag #RCAM2020, and while the event comment box was very active, with an average of one comment per minute, there was also a good parallel conversation happening on Twitter. Given the time differences, North Americans were able to participate during the morning, and Europeans in the afternoon. Maintaining international links and connecting with colleagues and partners from outside of Australia is one of the highlights of the Forum.

Overall, the event was a huge success; the ability to transition to a virtual delivery made it possible for RMIT University to continue to share important industrial advances in AM and hear more on the latest in research and technology. The next forum in two years will hopefully go ahead in person, but the advantages of the virtual delivery were not lost on the organisers, who no doubt look to provide some form of hybrid-style event and get the best of both worlds in future!

All presentations given at the Forum were recorded and are available to watch online here: https://bit.ly/3oCkEGc

www.rmit.edu.au

## Aerospace Hiwing develops high-temperature titanium alloy powder for China's aerospace industry

Aerospace Hiwing (Harbin) Titanium Industrial Co., Ltd (AHTi), Harbin, Heilongjiang, China, a specialist in titanium material R&D and manufacturing, as well as the design, manufacturing and service of high-end titanium alloy products, has developed a high-temperature titanium alloy for use in Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing. AHTI is said to have observed the emerging market for TA32 and the growth of metal AM as an ideal advanced manufacturing solution for high-temperature applications. The company has been a customer of Farsoon Technologies, Changsha, Hunan, China, since 2018, when it invested in Farsoon's PBF-LB machines at its facility for the engineering, process development and rapid prototyping of TA32 alloy components.

With the rapid expansion of the civil aerospace industry in China, the demand for specialised, high-temperature titanium alloys has become a critical challenge for key component development such as aerospace engines and spacecraft. In order to achieve optimised thrust–weight ratio, specialised titanium alloys are increasingly used in parts including engine compressor discs, blades, blisks, rotors, housing and intake pipes.

The need for weight reduction and high performance in these applications place higher demands on the operating temperatures of titanium alloys — other challenges in aerospace component development, including complex structures and faster development iterations, also challenge the established manufacturing process.

TA32 titanium alloy, with the composition Ti-5.5Al-3.5Sn-3Zr-1Mo-0.5Nb-0.7Ta-0.3Si, is a novel α-type high-temperature material developed in China. It offers high tolerance for operating temperatures of up to 550°C, and short-term tolerance up to 600°C, as well as good comprehensive mechanical properties such as tensile, fatigue and creep strength, making it an ideal alternative material for steel or nickel-base superalloy components.

Production of TA32 uses an advanced cold crucible vacuum induction melting and air atomisation technology (VIGA-CC) to produce high-performance powders with high efficiency and a high yield of fine particles. After testing, the TA32 powder is said to offer excellent material properties such as high purity, high sphericity, high fluidity and high bulk density. The physical properties of the material were also tested, revealing a 36 μm median particle size d50, a bulk density of 2.4 g/cm$^3$ and a Hall flow rate of 45 s/50 g – all well suited for the PBF-LB process.

*AHTi developed the titanium powder using Farsoon's FS271 AM machine (Courtesy Farsoon)*

AHTi reportedly took advantage of the robust and open architecture of the Farsoon FS271M machine, including the 'parameter-editor' included in the company's software, to accelerate its material processing development cycles with the development of customised TA32 processing parameters. Using the parameter-editor, AHTi application engineers were also able to carry out a series of tests in which they controlled the laser energy density within the build chamber in order to determine the optimal processing parameters for producing TA32 parts.

Metallographic analysis of the TA32 parts produced using the Farsoon FS271M are said to show a fine crystal grain structure, without defects such as cracks or holes. The mechanical properties of the parts were further tested and shown to offer excellent tensile strength, flexibility and plasticity under high operation temperatures of 500°C, 550°C and 600°C.

www.farsoon.com

## Swiss m4m Center installs CADS Additive's AM-Studio solutions

The Swiss m4m Center, Bettlach, Switzerland, a facility for AM medical applications aiming for ISO 13485 certification, has installed the data preparation and management software AM-Studio by CADS Additive GmbH, Perg, Austria, for the digital mapping of the relevant manufacturing process chain in a PTC Creo® and PTC Windchill® environment.

The manufacturing of medical implants requires a multitude of preparatory and process steps, from the acquisition of patient-specific data using imaging techniques, to the generation of implant geometries and their Additive Manufacturing, up to post-processing and final electroplating. Thus, it is necessary to manage a very large amount of data and map it as efficiently as possible. In addition to the quality management requirements defined in ISO 13485, the installation is said to be focused primarily on establishing a digital twin of the implants to be additively manufactured. This twin will be used in all design and manufacturing steps and form the basis for an efficient and continuous process chain.

www.cads-additive.com
www.swissm4m.ch

# EOS installs two Solukon automated powder removal systems

Solukon Maschinenbau GmbH, Augsburg, Germany, reports that EOS GmbH, Krailling, Germany, has installed two of its SFM-AT800-S automated powder removal systems. Incorporating Solukon's SPR® technology (Smart Powder Recuperation), the systems are said to improve the efficiency of EOS' part-building process chain for application and product development at the company's facilities in Krailling and Maisach, near Munich.

EOS states that, between the two locations, it operates approximately fifty metal Additive Manufacturing machines for testing, application development and the building of demo parts for customers, making it one of the largest operation centres of metal AM machines in the world. With the adoption of the two SFM-AT800-S systems, EOS notes that it has made the process of powder removal more efficient, resulting in cleaner parts at less effort by its operators.

"The most important factor is saving time and labour cost," stated Dr Michael Shellabear, EOS's Director of IP and Technical Services, responsible for the management of the internal AM capabilities at EOS. "Setting the automated system to remove the powder means that the employee is free to perform other tasks while the system is operating. Use of the Solukon system also results in improved cleaning of parts, especially complicated parts with internal channels that trap unfused powder that needs to be removed."

Dominik Hertle, responsible for the Periphery & Automation portfolio of EOS metal systems, commented, "Customers are asking more and more questions about peripheral processes, such as powder removal. As customers increasingly adopt AM for production purposes, post-processing costs become a more important factor in the entire cost of the entire process chain."

"With the adoption of the Solukon systems in our internal operations, we lead by example, demonstrating cutting edge technologies and best manufacturing practices to our customers," he continued.

"Industrialisation is a key trend in the development of the AM segment into a fully mature manufacturing modality, and EOS is committed to lead the industry towards the entrenchment of AM technology as an essential choice for manufacturers. While we continue to focus on our core 3D printing technologies, we encourage and facilitate the development of peripheral processes and automation through collaborations with innovative companies that specialise in these areas, such as the Solukon automated powder removal technology."

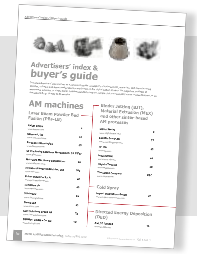
Andreas Hartmann, CEO and co-founder of Solukon, reported, "Our complete line of powder removal and processing systems was developed after listening closely to what users of metal AM systems are telling us. We develop systems for both metal and plastic powders that take the concern out of powder removal. Our automated systems reduce manufacturing costs, while adhering to the highest levels of safety."

Hartmann added, "We are delighted that EOS, a leader in AM, has chosen to express their commitment to the industrialisation of AM through the adoption of our systems in their metal AM manufacturing operations."

www.solukon.de
www.eos.info


*EOS has installed two SFM-AT800-S automated powder removal systems developed by Solukon (Courtesy Solukon Maschinenbau GmbH)*





# Metal Additive Manufacturing and the new Space Race: The inside track with Launcher and AMCM

In October 2020, New York City-based space technology company Launcher started testing its full-sized E-2 liquid rocket engine, designed to deliver the highest performance at the lowest cost for smaller space launch vehicles. That the E-2 features a one metre tall single-piece copper alloy Laser Beam Powder Bed Fusion (PBF-LB) combustion chamber is remarkable. What is even more impressive is the fact that Launcher, a company with less than twenty employees, achieved this in a short time frame and to a relatively modest budget. *Metal AM* magazine's Nick Williams reports on the project and Launcher's close collaboration with specialist PBF-LB machine builder AMCM GmbH.

The first Space Race defined technological progress and human ambition in the mid-20th century, with the launch of Sputnik 1, the first artificial satellite, and the landing of the first humans on the moon with the Apollo 11 mission. The first two decades of the 21st century, however, have already seen radical changes in the space sector. Today, it is private companies which are at the forefront of a new, commercially-driven Space Race, competing in large part to capture a share of the booming demand for orbital launch vehicles for private and state-owned satellite deliveries.

Whilst SpaceX is now a household name with a gravitational pull to rival that of NASA's at the height of the Space Shuttle programme, there are many other companies, large and small, which also have ambitions in this field. What connects all of these privately-owned firms, as well as national and regional state-backed agencies, is the recognition that metal Additive Manufacturing is one of a small number of technological innovations enabling this revolution.

The reason for metal AM's success? It offers the ability to develop and manufacture rocket engines at a fraction of the cost of past technologies, dramatically speeding up development times and leveraging efficiency gains – particularly in terms of combustion efficiency – that would previously have been at prohibitive cost on all but the largest rocket engines. So, what was once only affordable and accessible to super-powers is now being chased by a new generation of private space firms.

One such entrant in this new Space Race is Launcher, a small, but, judging by the talent and experience it has attracted, credible rocket

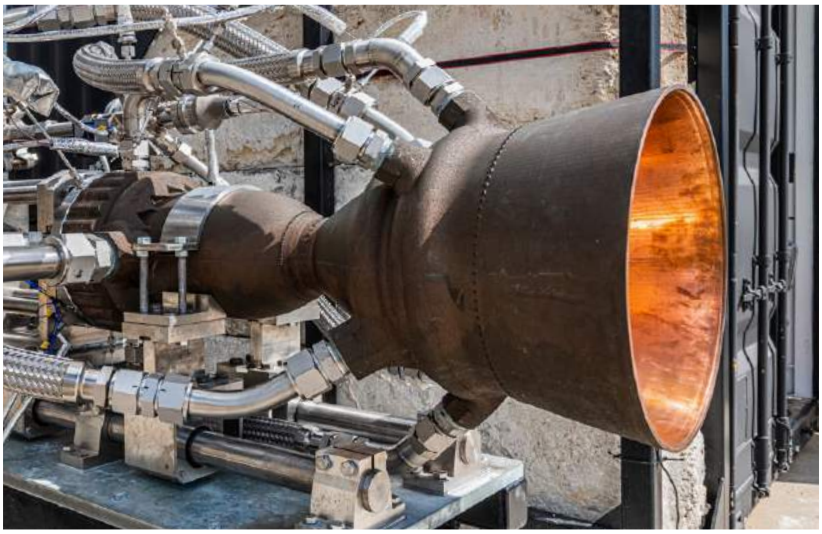


*Fig. 1 Launcher believes that its E-2 engine, here on the test stand at NASA's Stennis Space Center in October 2020, will be the highest-performance, lowest-cost liquid rocket engine for smaller space launch vehicles (Courtesy Launcher/John Kraus)*


*Fig. 2 Members of the Launcher team preparing for the E-2 test fire. Left to right: Andre Ivankovic, Max Haot, Igor Nikishchenko, Ivy Christensen, Viktoria Skachko, Rich Petras and Luis Rodriguez (Courtesy Launcher/John Kraus)*

development company based in New York, USA. Founded by CEO Max Haot, an experienced entrepreneur whose successes include the internet streaming company Livestream, the team at Launcher has made rapid progress over the last two years in designing and testing what it believes will be the highest-performance, lowest-cost liquid rocket engine for smaller space launch vehicles. So far, Launcher has raised $6 million, a relatively modest sum for this sector and the level of the company's ambitions, which includes private funding as well as a $1.5 million Air Force Small Business Innovation Research grant to accelerate development of its E-2 engine.

This article tells the story of Launcher's journey to the point that it has reached today, the development of its E-1 and E-2 engines, its collaboration with AM machine builder AMCM GmbH, and the wider picture of the commercial opportunities in space delivery systems. As well as interviews with Haot, insight is shared by Launcher's Chief Designer, Igor Nikishchenko, and AMCM's Christian Waizenegger.

## The bigger picture of the new Space Race

Explaining the current status of the private space business and its drivers, Haot told *Metal AM* magazine, "Only eleven countries have the technology to deliver satellites to orbit using their own rockets. For a long time, only one private company succeeded in reaching orbit – SpaceX – followed more recently by a second company, Rocket Lab. There's also a third one in China. All companies that have reached orbit have valuations well in excess of $1 billion and, as a result of their success, have access to the capital needed to grow their products and services."

"While there are many other hopeful companies around the world trying to develop orbital launch vehicles, it is clear to us that only a small percentage will succeed. This is true of many industries, and reflects, for example, the early days of the internet. This new Space Race is enabled by the lowering cost of entry to reach orbit – something that has been achieved through innovations such as metal Additive Manufacturing, new electronics, software, etc, combined with a demand for smaller rockets, which are in turn cheaper to develop. While many countries would not, in the past, have attempted a space programme due to its high cost, these new lower barriers to entry are stimulating most countries to seek the development of a domestic small launch vehicle capability – perhaps in part for prestige, but also to be able to independently send their own small satellites to orbit."

Haot believes that the winning formula for small launchers is to focus on the highest performance at the lowest cost – even if it takes a little longer than the competition. "High-performance engines can help us double or triple the payload when compared to a lower-performing rocket of the same size. This is a significant commercial advantage to reduce prices or grow margins."

Explaining just how important efficiency is when it comes to rocket systems for commercial space deliveries, Haot stated, "Since more than 90% of a launch vehicle's mass is propellant, reducing propellant use is the biggest opportunity to reduce vehicle mass and, as a result, increase payload. Payload represents just 1–3% of the vehicle mass, so, by increasing performance, you can double or triple your payload for the same rocket size."

Crucial to both Launcher's business model and the technological challenges it faces is metal Additive Manufacturing. "AM is a key enabler. Launcher could not be testing full-scale, highest-performance combustion chambers with the funding we have raised if AM was not available. The traditional technologies used to manufacture combustion chambers, machining and vacuum brazing, would be out of reach for us," explained Haot. "Since day one, our goal has been to have our first test flight in 2024 and to reach orbit and be profitable in 2026. We hope to reach this objective with less than $50 million invested, which would be a record and breakthrough for the industry and for Launcher."

*Fig. 3 A digital render of the E-2 engine on the Launcher Light launch vehicle for small satellites (Courtesy Launcher)*

## The satellite business

The commercial motivations and opportunities driving the private space businesses primarily exist around the booming satellite business. Since Sputnik 1 in 1957, around 5,000 satellites have been sent to orbit, although only about 2,000 are operational. In the last 18 months alone more than 500 satellites have been sent to orbit as part SpaceX's Starlink system. "We all use satellite infrastructure every day without thinking about it; when we fly, drive, check the weather or use the GPS-enabled navigation in our phones, satellites are playing a key role. Beyond this, imaging and earth observation, earth sciences, high-speed communications, and defence are all enabled by satellites. As well as the race enabled by smaller conventional satellites, new types of low Earth orbiting satellite constellations such as Starlink deliver high speed internet to rural locations. As a result, there is a demand to launch more than 30,000 new satellites in the next five years alone."

Whilst a satellite used to cost a few hundred million dollars to design, build, and launch, now it can be done for a few hundred thousand dollars. "This changes everything," stated Haot, "and entrepreneurs and venture capitalists can, at last, be involved in this industry to bring innovation, competition, and new applications. This is the shift in this historically stagnant industry and it is happening now, and accelerating."

## A mutually beneficial relationship with state agencies

Despite this revolution in the structure of the space industry, a close relationship between established national and international space agencies and the new commercial players is both vital and mutually beneficial, explained Haot. "The United States Air Force, and now the US Space Force, are the biggest buyers and users of satellite launch capabilities in the USA. In addition, their mission is to have access to the best technology in the world. Therefore, investing in R&D and innovation has been the DNA of the Air Force since its inception."

*Fig. 4 A cutaway view of an E-1 thrust chamber prototype showing the types of complex internal cooling channels that can be created by Additive Manufacturing (Courtesy Launcher/ 3T-AM)*

"As part of its plan to have more launch options to buy from, and more competition and innovation – especially in responsive small launch vehicles – the Air Force has been investing in numerous startups. We were selected as part of the first Air Force Space Pitch Day in November 2019 for a $1.5 million contract to further the development of our Launcher E-2 engine. They are boosting and supporting innovation, combining their investment with external investments, with the goal of having more capabilities and options for small satellite launches. Today, our relationship is as the recipient of an R&D award. Tomorrow, our goal is that the Air Force will be one of our largest customers to deploy small satellites. NASA is currently a service provider. We have a Space Act Agreement to leverage the use of its testing facility and teams at NASA Stennis, and we pay for those services."

## The story of the Launcher E-2 engine

At the centre of Launcher's roadmap is its ambitious plan to develop the highest performance, lowest cost liquid rocket engine for smaller launch vehicles. Called the Launcher E-2, it is an additively manufactured, 22,000 lbf thrust, LOX/Kerosene, closed-cycle liquid rocket engine with a booster stage version specific impulse target (the measure of how effectively a rocket uses propellant) of 326s (vac). The oxidiser-rich staged combustion design used offers efficiency gains by not wasting around 5% of propellant on powering the turbopump.

Whilst these engines are set to power Launcher's own Rocket-1 launch vehicle, they will also be available to third parties and, it is hoped, become a crucial propulsion system for a much wider range of launch vehicles. This wider market, combined with what Haot believes will be an expected design lifetime of at least fifteen years, including iterative improvements, means that the rewards for success will be high.

When the team at Launcher specified the E-2 engine and defined its roadmap back in 2017, it initially set the development of the turbopump as its first goal. Laser Beam Powder Bed Fusion (PBF-LB) machines were already available with the necessary build volumes for this application but at the time, explained Haot, no machine was available with the required one metre build height to create the E-2 combustion chamber in one part, and the company estimated that one was unlikely to be available before 2020. "Our competitors chose to print their chambers using existing machines, either by producing smaller engines or producing chambers consisting of three parts or more. This approach, however, reduces combustion/ cooling performance and increases engine weight, as well as increasing costs."

"We had been pushing for a larger AM machine with a number of PBF-LB system developers, but at the time only Germany's AMCM, part of the EOS Group, was ready to take a chance on this format and to align their development activities with our needs. They could see the other applications and the potential breakthrough for other rocket companies, not just Launcher. As a result, the company's machine, the AMCM M4K, became available two years ahead of schedule, allowing us to develop the E-2 combustion chamber at the same time as progressing our turbopump work."

The use of AM resulted in a revolutionary new design for the E-2 engine. Without this technology, Haot explained, a company as small as Launcher would not have been able to manufacture a combustion chamber with such a thrust in this time and with these costs. "Moreover, if traditional technologies such as brazing were used, the characteristics of our chamber,

*Fig. 5 Launcher's Andre Ivankovic helps prepare the E-2 for testing (Courtesy Launcher/John Kraus)*

such as heat transfer parameters and hydraulic loss, would be worse, despite the significantly higher cost of these technologies."

**E-1: the scale prototype and the switch from Inconel to copper alloy**

Development of the full size E-2 engine was preceded by the E-1, a fully-functioning smaller prototype that was used to thoroughly evaluate and test all aspects of the engine's design. Initially, it was planned that the E-1 and E-2 engines would be built from Inconel; however, at an early stage in the project the team discovered the work being done at 3T-RPD, now 3T Additive Manufacturing Ltd., in the UK on the processing of copper alloys by PBF-LB. They approached 3T-AM to exploit the benefits of this material and, as a result, the use of the standard C18150 CuCrZr alloy allowed the engine to benefit from the material's high conductivity and efficient cooling, leading to a longer chamber life and reduced costs when compared to conventional manufacturing methods. The copper part proved to be twenty times more conductive than the comparable Inconel part.

Haot explained, "As part of our pursuit to build the highest-performance AM liquid rocket engines, we were always hoping that one day we would be able to manufacture our chamber in copper alloy rather than Inconel, but had not come across a service provider with this capability. Copper alloy is widely accepted as the highest performance material for cooling liquid rocket engines – Inconel is a compromise. When we heard that 3T-AM was able to do this, we immediately partnered with them and went from quote to successful test fire in less than eight weeks."

> *"...we were always hoping that one day we would be able to manufacture our chamber in copper alloy rather than Inconel... Copper alloy is widely accepted as the highest performance material for cooling liquid rocket engines – Inconel is a compromise."*

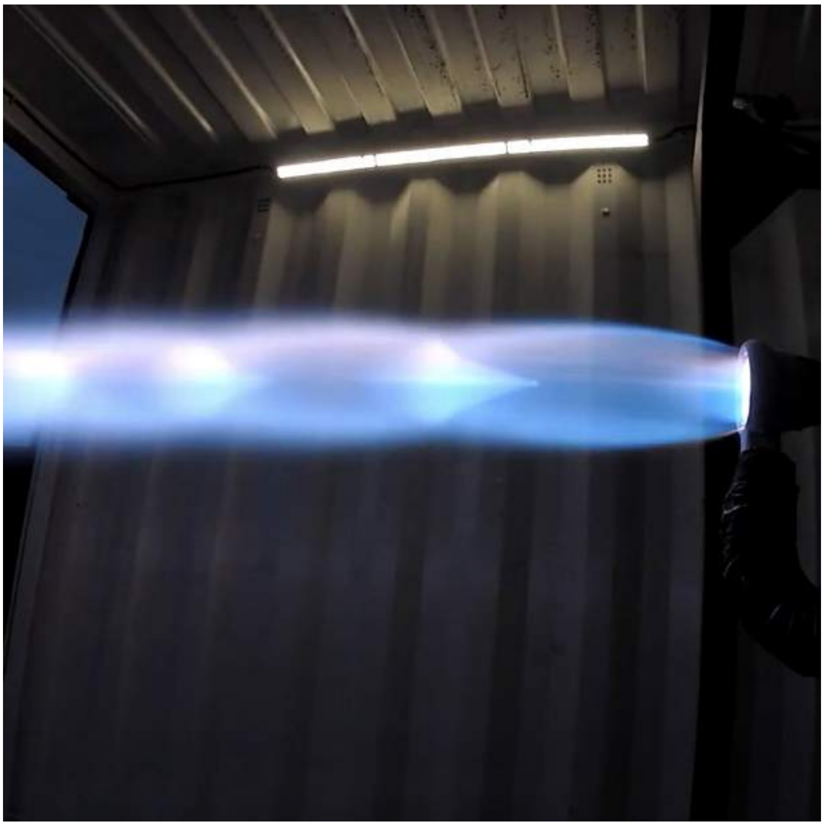


*Fig. 6 Testing the E-1 engine. The blue mach or 'shock' diamond pattern in the supersonic exhaust plume is evidence of the efficiency achieved (Courtesy Launcher)*

*Fig. 7 The E-2 engine combustion chamber after heat treatment and Hot Isostatic Pressing (HIP) on a Quintus Technologies HIP system at Accurate Brazing Corp's Greenville, South Carolina, facility (Courtesy Launcher)*

**Going big: moving from the E-1 to the E-2**

Launcher's engine development programme has relied on the ability to 'scale up' the engine, from the smaller E-1 to the full size E-2 that we see today. Commenting on the challenges that this scaling up presented, Haot stated, "With the same operating parameters such as fuel, pressure, mixture ratio, etc, it is easier to provide cooling of a large combustion chamber. Thus, we were comfortable about the strategy of moving from the E-1 to E-2. Larger internal cooling channels are also easier to build and to clean of powder. On the other hand, for a larger combustion chamber, it is more difficult to build walls and manifolds with the necessary strength; in addition, large chamber volumes can lead to high-frequency combustion instabilities, a process that can cause overheating and destruction of the chamber. Thus, it is not possible to simply enlarge the combustion chamber dimensions in scale and hope that it will work. However, thanks to our experience and a world-class design team, Launcher can handle these kinds of challenges easily."

Crucial to this stage of the project was the development of process parameters for the production of a metre high CuCrZr combustion chamber on the newly developed AMCM M4K machine. AMCM's Christian Waizenegger explained, "The development of process parameters for CuCrZr was one of the key elements for the success of this project. This development needed to take into account all the post-processing steps and ensure that the required material quality was still met. The materials and process development department of EOS in Finland played a key role in this aspect. They have decades of expertise and access to dedicated materials that allows them to develop the optimal process chain. The process development was achieved using a two-phase approach. First the processes were developed on an AMCM M290 1 kW, a system with similar laser and optics configuration to the M4K-1, but with the advantage

*Fig. 8 Launcher E-2's first ignition and test (Courtesy Launcher/John Kraus)*

of offering an easier operation throughout a development project. In the second phase, the process was ported onto the M4K-1 and first samples produced in order to confirm material quality. Heat treatment was also a key factor in the project's success. This process step was an integral part of the application's development and without this holistic approach to both the build process and subsequent heat treatment, the project would probably not have been successful."

The final heat treatment and Hot Isostatic Pressing (HIP) cycle for the E-2 has been custom developed by Launcher to reach its specific material property goals. Haot stated, "Our design and the pace of process innovation within our team are the proprietary aspects of our products. We hope, however, that many propulsion companies choose this material and machine platform to ensure its long-term support and advancement. Our strategy is to ensure that our AM machine, process/parameters and material are supported by a supply chain with multiple customers and service bureau vendors offering the printer and material."

**Test firing the E-1 and E-2**

Test firing of various prototypes of the E-1 engine took place in 2018 and 2019 and included investigating the performance of different build parameters such as powder layer thickness, and, as a result, build speed and build cost. These tests demonstrated that the E-1 engine design achieved 98%+ C*.

As can be seen in Fig. 6, the blue mach or 'shock' diamond pattern in the supersonic exhaust plume is evidence of the efficiency achieved in the E-1. "All Kerosene engines typically have a yellow plume due to fuel film cooling or low combustion efficiency, which means unburnt fuel leaves the combustion chamber and combusts outside the nozzle, thereby creating a yellow plume/flame. Because of our liquid oxygen cooling and high combustion efficiency of greater than 98%, you only see a blue plume, which relates to the combustion products (water, CO, $CO_2$). Most, if not all, of the yellow-burning kerosene is combusted inside the chamber. As a result, this blue plume is a confirmation of the unique efficiency of E-1."

The first E-2 test campaign took place in October at NASA's Stennis Space Center in Mississippi. In this campaign, three test fires were performed. The first two tests used an uncooled copper replica of the combustion chamber to reduce risk and fully evaluate the additively manufactured injector's performance. Both tests were successful and confirmed the performance of the AM injector, the test stand equipment, and the avionics systems.

The first test firing with the fully assembled AM combustion chamber was partially successful, however it had to be terminated because of

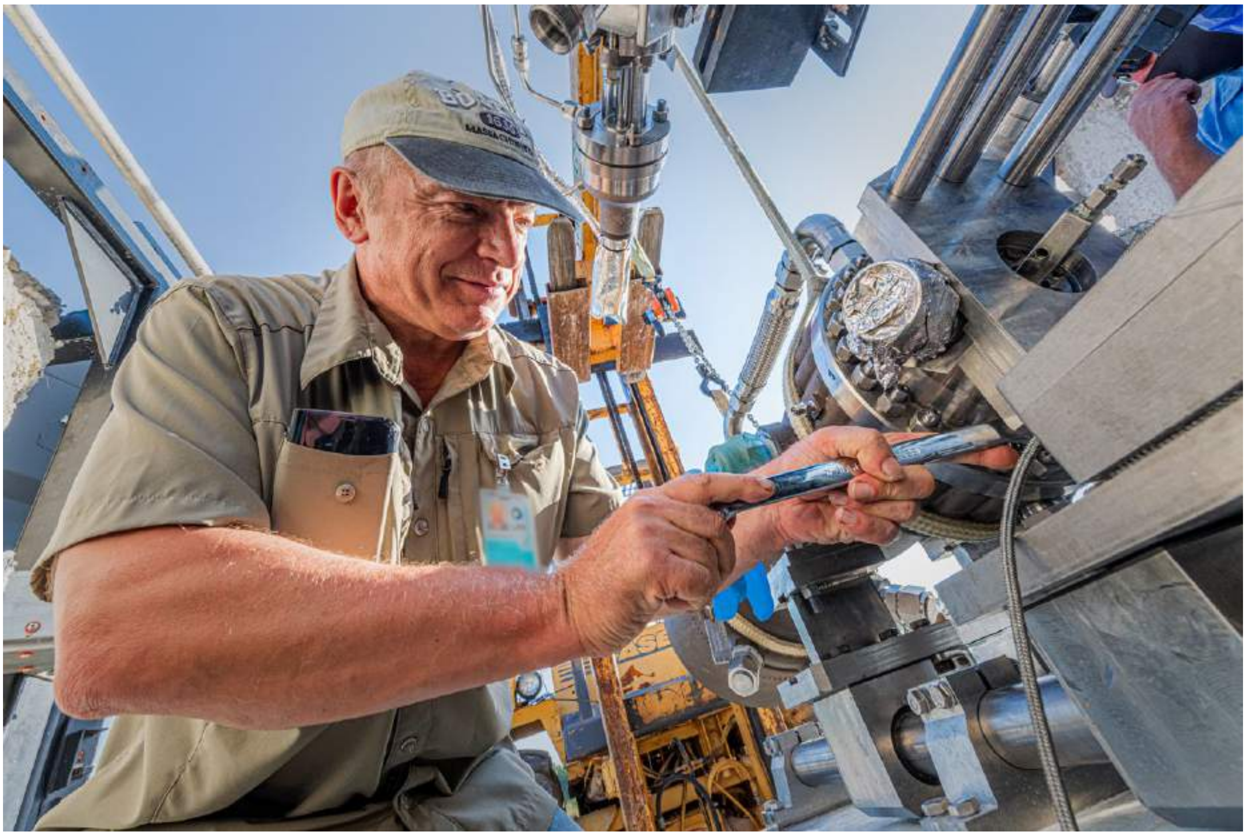


Fig. 9 Launcher's Chief Designer, Igor Nikishchenko, preparing the E-2 for test firing (Courtesy Launcher/John Kraus)

areas of restricted flow in some of the cooling channels. "Now that our Launcher E-2 engine test stand is built and ready to go – reaching test four with a new chamber in March 2021 will be about 5% of the cost and effort that it took to reach test number one," commented Haot.

Whilst the combustion chambers are the 'star of the show' when it comes to the application of AM in rocket systems, it is by no means the only AM application. There is, however, a recognition that there needs to be a solid case for the move to Additive Manufacturing. "AM will be used where it makes sense for us. For the engine, this includes most parts of our pumps, turbine, and some valve components. In terms of structures such as tanks, we believe that the traditional manufacturing techniques available are lower cost and higher quality than some of the 3D printed vehicle tank attempts you might see; we are therefore not seeking to use AM for that."

## The rocket scientist's perspective: Launcher's Chief Designer, Igor Nikishchenko

Many of the world's highest performance booster liquid rocket engines were designed in the 1980s by teams based in Russia and Ukraine. The results of these achievements by scientists and engineers in what was then the Soviet Union remain unrivalled and are still in production to this day, notably in the form of NPO Energomash's RD-180, still used for the first stage of America's Atlas V rocket.

In 2018, Launcher tapped into this rich heritage with the appointment of Ukrainian rocket scientist Igor Nikishchenko as its Chief Designer. Based at Launcher's New York City headquarters, Nikishchenko has over thirty years of experience in high-performance liquid rocket engine development. He was Deputy Chief Designer in the Liquid Propulsion Department at Yuzhnoye, the Ukrainian state-owned company that designed the Zenit launch vehicle, as well as the RD-8 oxidiser-rich staged combustion liquid rocket engine. Yuzhnoye is also the designer and subcontractor for the first stage of the Northrop Grumman Antares launch vehicle. More recently, he worked in Italy for Avio, a key contractor for the European Space Agency's Ariane and Vega launchers.

During his career, Nikishchenko has been involved in the design and development of propulsion systems for various launch vehicles, including hypergolic gas generator cycle engines and LOX/Kerosene Ox-rich staged combustion cycle booster engines with thrust levels ranging from 4,500 lbf to 270,000 lbf.

With the Launcher engine, the challenge he faced was delivering the efficiency of engines such as the RD-180 in a much smaller form factor. Commenting on the target of reaching as close to maximum theoretical efficiency as possible, Nikishchenko told *Metal AM* magazine, "Thanks to Additive Manufacturing, optimally-shaped cooling channels, which combine high heat transfer with low hydraulic losses, can be created in the combustion chamber. The creation of such channels using traditional technologies would result in very high costs for machining and subsequent brazing. So with AM, we needed to first create an optimum 3D model as our target. To estimate combustion efficiency in rocket engines, the efficiency factor C* is used. This coefficient for the E-2 engine should reach 0.98, which is close to the theoretical limit value of 1.0. Of course, such efficiency is not something incredible and has already been achieved in some modern rocket engines, for example, the RD-180. But it should be remembered that the E-2 engine is much smaller, and the efficiency of smaller engines is usually lower, C* =0.93–0.95. And besides, it must be a very low cost engine."

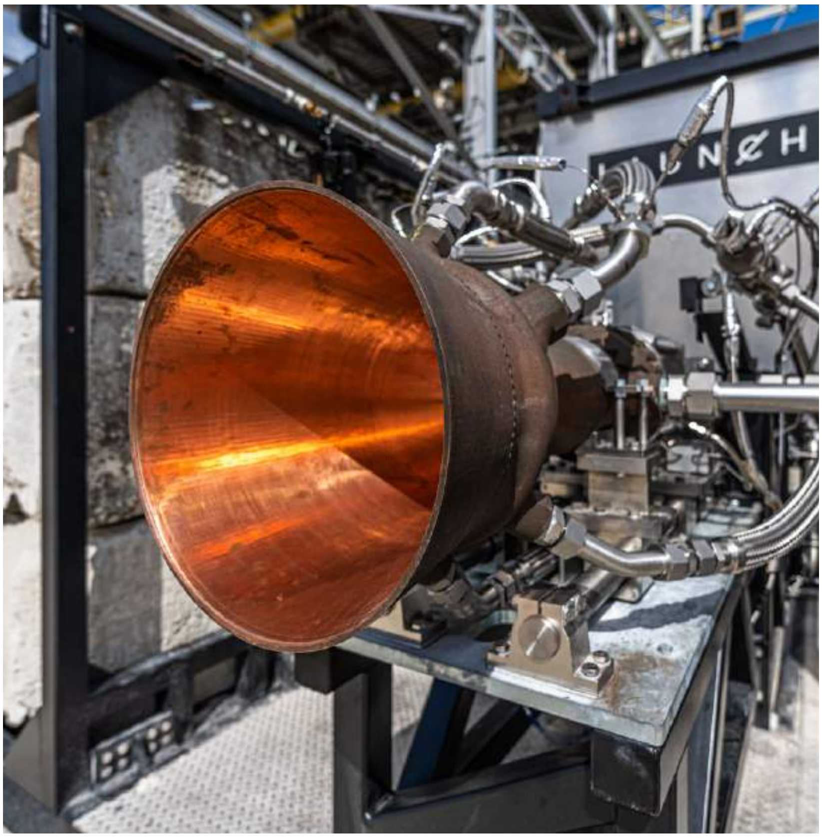


*Fig. 10 View showing the internal surface of the E-2 combustion chamber (Courtesy Launcher/John Kraus)*

**Embracing new technologies: opportunities and approaches**

Nikishchenko continued, "As mentioned, one of the most challenging tasks in the development of rocket engines is the production of combustion chambers with narrow, complex-shaped channels used for cooling. The mechanical processing of such channels, and especially their subsequent enclosure, is a difficult technical challenge. For many years I thought about the possibility of a cheaper solution and then, just a few years ago, the opportunity to solve this problem appeared – Additive Manufacturing. Unfortunately, so far only relatively small combustion chambers can be manufactured using AM, and the choice of materials is also limited - until only recently, copper alloys could not be easily processed by AM. Therefore, I am very pleased that it was Launcher who contributed to the creation of the world's largest AM machine capable of processing copper alloys, the AMCM M4K. Using it, we have made the largest copper-alloy combustion chamber, which will also be the most efficient of the additively manufactured chambers."

When considering whether rocket designers are inherently conservative or adventurous, and how AM fits between these positions, Nikishchenko stated, "I would say yes and no. In the early design phase, vehicle designers are often very adventurous – they have to be, because there may appear to be no way to overcome a problem and create a solution. In a rocket, heat capable of melting the most resistant of refractory metals is separated from the cold of space by a 1/25 inch thick copper wall. The only reason why the wall doesn't melt instantly is because heat is absorbed on one side faster than it is supplied on the other one. Imagine that you are sitting in a bottomless boat and draining the water faster than it flows."

"But once the solution to a problem is achieved – and usually this requires a lot of money and time – rocket scientists become very conservative, because the performance of an engine has been achieved with great difficulty, but can often then be destroyed as a result of a completely minor change; one which, at first glance, should not affect anything. So, I think most of the traditional rocket engine manufacturers will proceed with some caution when introducing AM into the production of these engines."

**A history of metal powder-based parts in rocket engines**

Nikishchenko commented, however, that whilst a new technology such as AM may be greeted by some with a level of caution – as is the case with all innovation – it can also be regarded as an evolution of Powder Metallurgy (PM) -based processes that have been successfully used by rocket designers for decades. "This is the destiny of any innovation: at the beginning no one understands why this is necessary, and, after a few years, no one can imagine

*Fig. 11 A control room at NASA's Stennis Space Center during E-2 testing (Courtesy Launcher/John Kraus)*

the modern world without it. As for Additive Manufacturing, what could be seen as the precursor of this technology has been used for rocket engines for several decades before the invention of what we today also call 3D printing. The Soviet RD-170 engine pump impellers were manufactured using the near net-shape Powder Metallurgy process of Hot Isostatic Pressing. Whilst this is not AM as we know it today, it is nonetheless, in the broadest sense, an 'additive' rather than 'subtractive' manufacturing process. In this process, the metal powder is not fused with a laser, but loaded into a special container that is prepared to the required shape. This is then subjected to high pressure and heat – so Hot Isostatic Pressing – to densify it, and then the container is removed. The laser now eliminates the need for this container, but HIP – as a heat treatment process rather than as a forming technology in its own right – is still needed today to remove any residual porosity from AM parts. So, space vehicle designers knew about the capabilities of metal powders and applied PM technologies long before the current more widespread use of AM."

**Opportunities expected and unexpected**

When it comes to application development by AM, the technology offers some well-understood advantages: namely, design freedom to achieve unique shapes (including internal channels, etc), speed of manufacture for larger and more complex items compared to conventional technologies, and the ability to consolidate multiple components into one part. Commenting on how each of these benefits has been leveraged by Launcher, Nikishchenko stated, "All of the AM technology advantages you listed have been applied to the design of the E-2 combustion chamber. It contains both shaped internal channels and manifolds that, otherwise, would be fabricated as separate components and added by welding. It should be noted that even the perceived weak points of AM technology, such as high surface roughness, played a positive role in the design of the combustion chamber: a rough surface in channels can significantly increase the heat transfer to the cooling liquid and, therefore, in some conventionally manufactured engines, combustion chamber channels are processed in a special way to obtain artificial roughness. In our case, we got this improvement for free. And of course, no traditional technology, containing numerous stages of stamping, machining, brazing, welding and then again machining, would have allowed a practically finished combustion chamber to be created from scratch in two weeks, even if we assume that we would have all the machines necessary for this."

**New alloys for AM**

In many applications for AM, the use of a standard alloy as used in general manufacturing has proven to be highly successful; however, it is anticipated that new alloys custom-designed for AM will bring further advantages in the future. "We are now at the very beginning of the triumphant progress of AM technology. Therefore, attempts are mainly made to use previously-developed alloys that have proven themselves well in traditional manufacturing methods. At Launcher, for example, we were one of the first to use a CuCrZr alloy for additively manufacturing combustion chambers. In the future, I do not exclude the creation of alloys specifically designed for AM which will allow either increased freedom in the build process, for example by eliminating support when printing overhanging elements, or improved the strength of materials by, for example, reducing porosity," stated Nikishchenko.

**AM's contribution in context**

Commenting on his experience of rocket systems development and putting AM's role into context, Nikishchenko told *Metal AM*, "I want to say that the new generation of launch vehicles, or rather, companies involved in their development, are appearing not only thanks to AM. Many industrial advances, such as miniaturised electronics, semiconductor lasers, the Global Positioning System [GPS], increased demand for satellite launches and satellites, have driven this. In addition, lightweight and reliable control and orientation systems, and composite materials for lightweight tanks, have been created. After all, the success of SpaceX inspired many. AM is significant, but not the main source of new opportunities in the space industry."

## AMCM: the machine builder's perspective

As with so many application success stories in metal Additive Manufacturing, they arise as a result of close collaboration between a machine builder and its customer. The story of Launcher and AMCM is no exception and the results of such collaborations can bring rewards for all parties. In the case of AMCM, the reward has been the ability to launch to the open market the AMCM M 4K-4 machine after development testing on a very challenging application.

As AMCM's full name (Additive Manufacturing Customized Machines) suggests, the company specialises in the customisation of PBF-LB systems from EOS GmbH for special applications. When Launcher decided to partner with AMCM GmbH, it was on the back of a promise to deliver the necessary one metre build height required for the E-2's combustion chamber. AMCM's Christian Waizenegger told *Metal AM* magazine, "Back in 2018, Max contacted us with the request for a large-scale AM system capable of printing a complete combustion chamber. At that point in time, neither a system of this size, nor a process for the CuCrZr material that would later be selected, existed. We saw it as a challenging project, but had the feeling that Max and his team were the ideal partners to go through such a journey with."

"We started developing a large-scale printer – the M4K – based on the existing EOS M 400 platform. The goal was to modify the machine to allow for build jobs of up to 450 x 450 x 1000 mm (x, y, z), with as few changes as possible so that the machine could still build parts that were developed on the original M 400 system. We then also developed the needed processes for CuCrZr in close collaboration with our colleagues from EOS Finland."

Process development was initially started on the AMCM M290 1 kW, a modified EOS M290 with a single 1 kW laser, and the first small-scale samples were produced to check material quality, to optimise process productivity and to align with post-

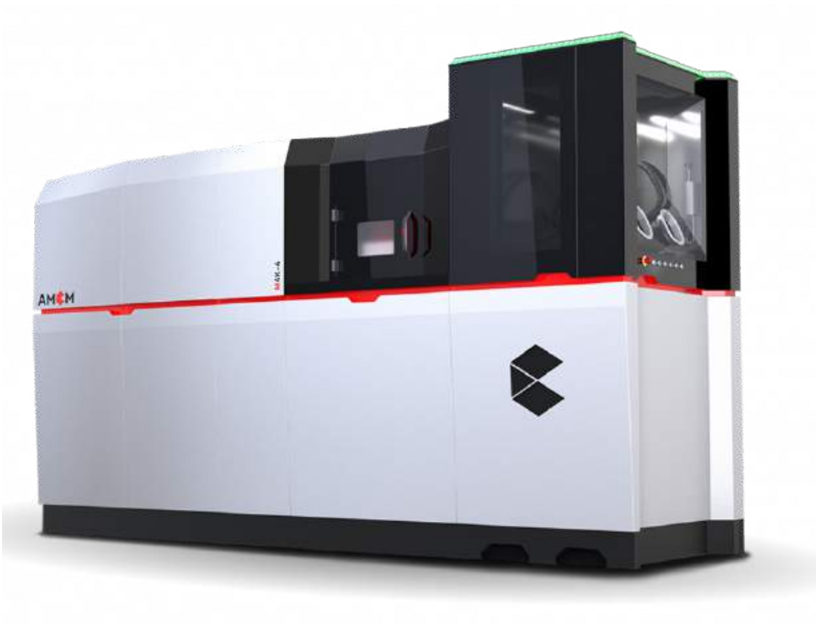



*Fig. 12 AMCM's large-scale PBF-LB machine, the M4K, is based on the EOS M 400 platform but allows for builds of up to 450 x 450 x 1000 mm (x, y, z) (Courtesy AMCM GmbH)*

*Fig. 13 Digital render of Launcher Light. The company's goal is to have its first test flight in 2024 and to reach orbit and be profitable in 2026 (Courtesy Launcher)*

processing steps."Once the first M4K prototype was available, we transferred the process onto the system and produced the first real-size parts to allow Max and his team to perform further tests and optimisations on the design of the combustion chamber. Finally, we produced the real combustion chambers that Launcher used for its tests."

Whilst built on the proven EOS M 400 platform, the AMCM M4K's custom features include a more robust frame design, a new filter system (RFS 2.0), and optional soft recoater. The AMCM M 4K can produce parts from a wide range of materials, including aluminium (AlSi10Mg), nickel alloy (IN718) and copper alloy (CuCr1Zr).

**Productivity and build time**

Commenting on the challenges of productivity and cost when it comes to an application such as the E-2's combustion chamber, Waizenegger stated, "Productivity is key to this application. Surprisingly, the main reason is not only the cost per part – something that everyone needs to be as low as possible – but also the fact that so many of these rocket engines will be needed in the future. Thus, a technology is needed that allows us to cover the client's needs in terms of number of combustion chambers produced over a period with the lowest investment in terms of number of AM systems required."

"The build time of the E-2 combustion chamber is approximately ten days when built on a single 1 kW system (M4K-1). Considering the very large size of the part and the amount of material that is melted, this is a very high level of productivity. During process development our focus was on delivering the highest productivity possible at the required final density. Productivity could be even further improved by using a multiple-laser system such as the M4K-4 with 4 x 1 kW lasers; however this has not yet been tested with Launcher. We have to always remember, however, the fact that a combustion chamber built using the conventional technologies requires several months and the combination of multiple processes to be completed. In this sense, the AM technology used to produce the E-2 combustion chamber is already miles ahead of the conventional path. That is without considering the amazing improvements, in terms of combustion efficiency, that can be reached with AM designs."

**Unique challenges**

Commenting on the most significant challenges from a machine builder's perspective when developing such a large application, Waizenegger stated, "The time frame of this project – only ten months from start to first prototypes – was one of the most challenging constraints for this project. We needed to ensure we kept up with the ambitious rhythm set by Launcher but, at the same time, deliver the expected quality. We therefore put a lot of effort into identifying upfront all the major elements needed for success, in order to avoid multiple system design loops. At the same time, we decided to build a 'Minimum Viable Product' as a first step, to then design the final system. This was the best compromise to accelerate the project but keep the needed quality constraints. A further challenge was the handling of very big loads of powder – easily 1.5 tonnes – in the build chamber. Ensuring a stable and precise z-position of the build plate, even under such high loads, required a dedicated system design. The robust and welded M4K frame and body is designed to handle such high loads without any compromise."

**Process stability and the wider AM workflow**

The need for process stability on such large, high-value applications is, in many aspects, much greater than on smaller items, where a build time might be in hours rather than a week or more. Waizenegger stated, "Worst case would be a job interruption right before the end of the build, after several days of manufacturing. Process and machine reliability is key to avoid such situations. Our system is based on the EOS M 400, a system that has proven to be very reliable over several years. We took care to change as few elements related to the process as possible. The build chamber itself is 98% identical to the M 400 and the processes from the M 400 can all be ported to the M4K. Whenever possible, the necessary additional modules were chosen from the EOS portfolio – this is the case, for example, for the filter units on the M4K. Doing so allowed us to rely on proven elements that are known to be stable and to perform under very demanding conditions."

"Special care has also been given to powder management, as a job interruption due to powder short feed would ruin the entire build job. The sieving and conveying of large amounts of powder over several days without interruption is a requirement, and the solution must also be adapted to the exact scenario found at a customer's facility – for example gravity feed or conveyor feed, batch processing or continuous processing." AMCM stated that it worked with German metal powder handling specialist Volkmann GmbH to design and deliver solutions compatible with the M4K systems.

None of the above work, however, can deliver success if the part being built hasn't been design-optimised for AM. "Design for AM is key to avoid job crashes. We therefore simulated the designs from Launcher and built critical sections of the design to validate those simulations. Through iterative design loops we optimised the application's design, together with the team from Launcher, to ensure that it conformed to the requirements of PBF-LB production," stated Waizenegger.

The availability of peripheral devices that are suited to handle such part sizes is crucial to an application's success and, commented Waizenegger, should not be taken as a given. As well as working with Volkmann GmbH for the powder sieving and conveying solution, AMCM worked with Solukon Maschinenbau GmbH, also based in Germany. Solukon provided the depowdering solution needed to operate in conjunction with the M4K.

## Conclusion

There is no doubt that the space sector will become an ever more important market for metal Additive Manufacturing and, as with the 20th century's Space Race, technologies developed on the journey will quickly feed through to more everyday applications. The cooperation between Launcher and AMCM is a good illustration of this and the resulting developments in both materials and process technologies will no doubt enable a further widening of AM's application portfolio.

Whilst the development of combustion chambers by AM is by no means unique, what this story illustrates very well is how AM has helped to open up a sector such as the space industry not only to private enterprise, but to small organisations as well as the industry's giants. Development time has been dramatically reduced, as have the costs and manufacturing time needed for each combustion chamber – all whilst delivering exceptional levels of performance.

Haot concluded, "Working with AMCM has been incredible, with delivery ahead of schedule and expectations met every step of the way. They've demonstrated extreme flexibility to our adapting needs and requirements. When we started the project, our first contract specified Inconel 718, but after great results with CuCrZr with our subscale E-1 engine, AMCM saw the benefits and potential and agreed to switch the project and contract to CuCrZr, even if it meant more investment in parameter and material development."

"We were also very lucky not to be working with a team customising a machine blindly, but with a team that developed the product they are customising – the EOS M 400 - and have access to the design and source code to make the necessary modifications. This gave us a lot of confidence that they would be able to make it happen."

"The key to this project's success to date has been the close cooperation between the Launcher team and the AMCM/EOS team," stated Waizenegger. "Together, we jointly defined the required outcomes of the project and communicated openly about project risks and mitigation actions, so as to ensure that all parties have realistic expectations of the timeline and results of the project. Crucially, all parties stayed as flexible as possible when it came to changes that were needed to ensure success – because at the end, we can only be successful together."

## Contact and further information

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# Falcontech: The journey from materials engineering to large-scale metal Additive Manufacturing

China's Falcontech Co. Ltd. is well on the way to completing its first 'Super AM factory', designed to house fifty metal Additive Manufacturing machines supplied by its partner, Farsoon Technologies. Whilst the wider story may take in the dramatic rise of Additive Manufacturing in China over the last decade, at the heart of this ambitious project's success is the story of a successful partnership between an AM technology supplier and its customer. In this article, Chenlu Fang, Global Marketing Manager of Farsoon Technologies, interviews Shen Yulan, General Manager of Falcontech, and Li Wei, its Sales Director, to tell the story of the company's rise, its ambitions and the partners' close collaboration.

In June 2020, Falcontech, a leading supplier of additively manufactured parts to China's aerospace industry, released plans for its 'Super AM Factory' model, designed to house a targeted fifty metal Additive Manufacturing machines, most of them large-format platforms. By the end of October 2020, the facility had received its twenty-fourth metal AM machine from Farsoon Technologies, China's leading Laser Beam Powder Bed Fusion (PBF-LB) machine manufacturer, thus fulfilling its 2020 expansion plans ahead of schedule.

To put the scale of this achievement into context, compared to the rapidly expanding metal AM market that can be seen in China today, in the early 2010s even the term Additive Manufacturing remained a deep mystery for most of the market. Plastic AM methods such as polymer Powder Bed Fusion, Material Extrusion (MEX) and Vat Photopolymerisation (VPP) had all achieved some level of acknowledgement and application within rapid prototyping and the consumer products market, but metal PBF-LB technology in China remained at a very early stage in terms of material, machines, processing and production.

Around this time, the demand for lean manufacturing, especially in the civil aerospace and medical industries, started to emerge in China. The development of key components requiring more complex structures, fully customised solutions, and faster 'design-to-manufacturing' iterations, challenged established manufacturing processes such as casting.

While metal AM remained a novel technology in China, Shen Yulan, founder and General Manager of Falcontech (Fig. 1, left), observed this emerging market as an ideal advanced manufacturing solution for high-value-added applications.

*Fig. 1 Shen Yulan, founder and General Manager of Falcontech (left) and Wei Li, the company's Sales Director (right)*

Fig. 2 Falcontech's Super AM Factory, which currently houses twenty-four Farsoon metal AM machines (Courtesy Falcontech)

## Breaking new ground: the move into metal AM

With a background in the automotive industry and in metal alloys, Shen had developed an intimate knowledge of a fully developed manufacturing chain and the lean profit margins which went along with such a mature industry. Being one of the main shareholders of Yinbang Clad Material Co., Ltd, Shen had continuously explored new advanced technologies and markets with the potential to impact the future of manufacturing. After seeing metal Additive Manufacturing becoming widely used in Europe and America, Shen felt confident in introducing and driving the adoption of metal AM in the Chinese market.

Established in August 2012, Falcontech is located in Wuxi City, near Shanghai. Situated in the Yangtze Delta location, one of the most developed industrial regions in China, home to a large pool of talent, Falcontech was able to form a technical team with a solid background in metallurgy, material production, and Additive Manufacturing, with a clear vision of establishing an industrial-level metal PBF-LB ecosystem to offer innovative solutions for the key aerospace and medical sectors.

*"Falcontech has a clear vision of a technical roadmap focusing on metal Additive Manufacturing, including material processing, part production and post-processing."*

In order to offer high-quality components and solutions for the aerospace and medical industries, as well as other industries such as shipping, chemical production, and automotive, Falcontech set up a comprehensive, closed-loop technical roadmap with the early establishment of three main business units: Metal Powders, Metal Additive Solutions, and Advanced Manufacturing, in order to offer its customers metal powder development and production, application engineering, parts production, material processing, post-processing, inspection and standardisation.

Wei Li, the company's Sales Director (Fig. 1, right), stated, "Falcontech has a clear vision of a technical roadmap focusing on metal Additive Manufacturing, including material processing, part production and post-processing. For manufacturing systems, including material production lines and Additive Manufacturing systems, we chose to partner with the industry leaders. We believe that combining our expertise and knowledge through a professional partnership is the best strategy to offer the high-quality solutions to the industrial additive market."

## In Additive Manufacturing, material is king

The first element of the metal Additive Manufacturing value chain is the material used to produce parts. Before 2012, the availability of specific-grade, high-end metal powder in China was heavily dominated by various international brands from Canada and Germany. However, due to import regulations, the purchase of specialised grades of metal powder from outside China could not meet the needs of process development and large-scale parts production.

Falcontech realised early on the need for a sufficient supply of consistent, aerospace-grade material as key to the production of high-performance end-use components for civil aircraft. In September 2012, the company invested in an advanced Electrode Induction Melting Gas Atomisation (EIGA) material production line dedicated to titanium alloy powder development and production under an inert atmosphere (Figs. 3 and 4). The smelting process is carried out without a crucible, with the metal stream controlled by high-speed inert flow to break the bonding force between the liquid metal atoms and achieve atomisation.

Taking titanium alloy as an example, with intensive formula optimisation and process development, Falcontech has been able to produce Civil Aviation Administration of China (CAAC) -certified, aerospace grade titanium powder with excellent repeatability, purity, sphericity and flowability, well-suited for industry applications in Additive Manufacturing, Hot Isostatic Pressing (HIP), Metal Injection Moulding (MIM) and surface coating.

By closely working with leaders in both industry and research, Falcontech's metal powders have been tried and tested both in China and globally. With an annual yield of ninety tons, Falcontech's titanium powder stands out for its quality, and has a significant market share in the industry.

Today, Falcontech offers a total of twenty-four grades of titanium, nickel-base, cobalt chromium, aluminium and steel alloys in a variety of particle sizes.

*Fig. 3 Falcontech's titanium powder EIGA production line (Courtesy Falcontech)*

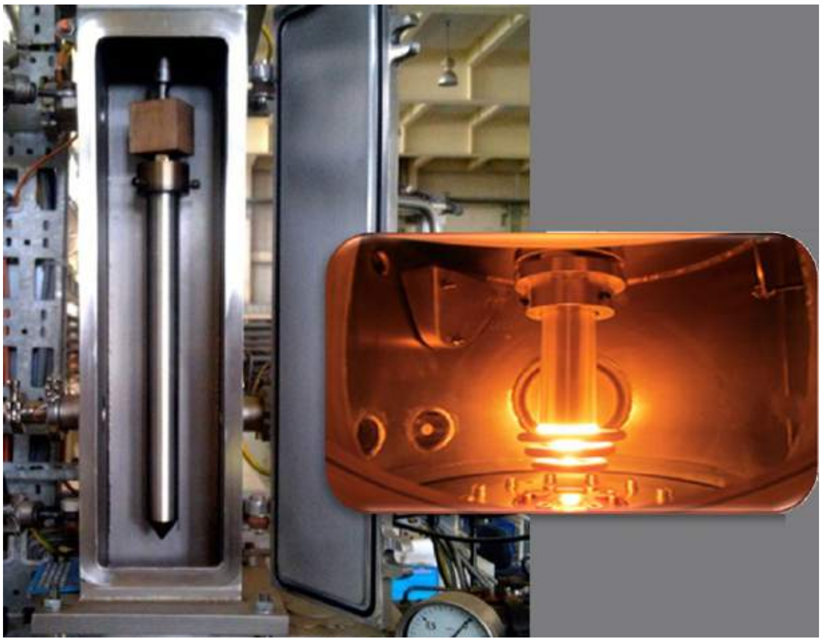

*Fig. 4 Detail of Falcontech's EIGA atomisation plant (Courtesy Falcontech)*

## Entering China's civil aerospace market

As an early adopter of metal Additive Manufacturing in China, Falcontech has been witness to the rise of the country's civil aerospace

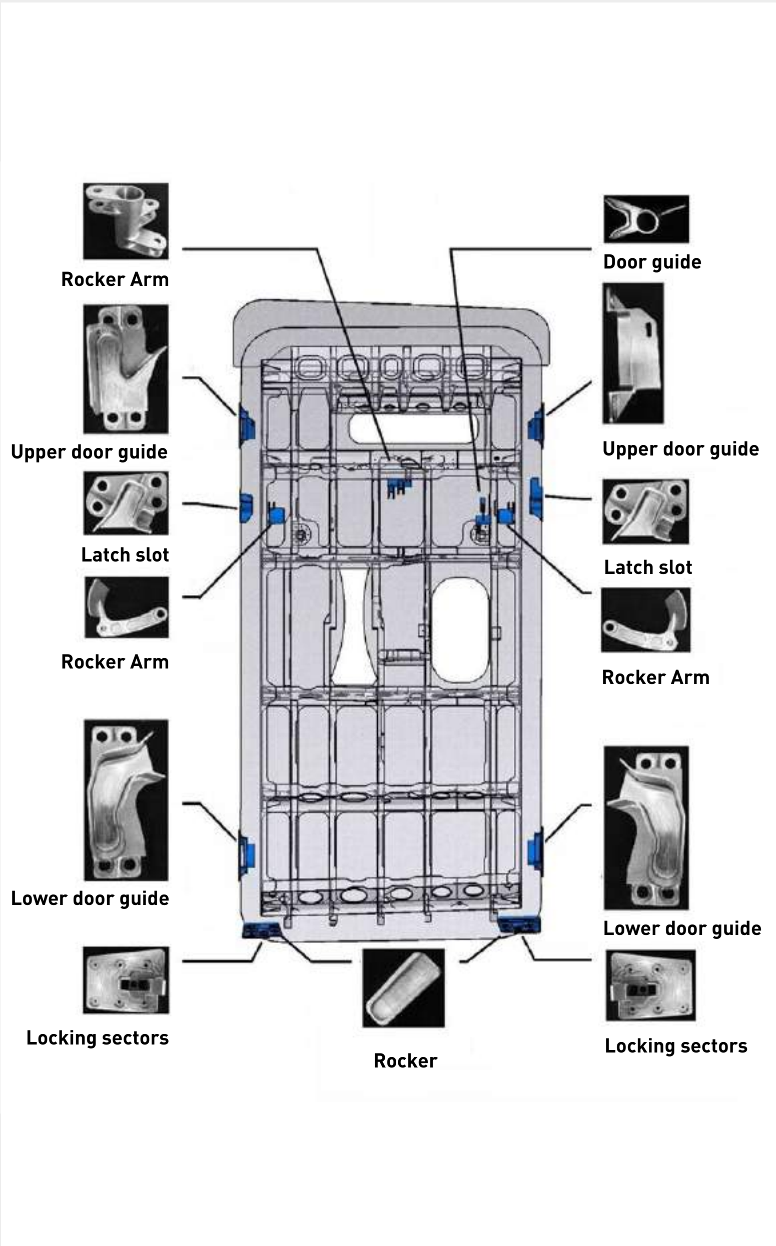


*Fig. 5 COMAC-approved Falcontech-produced titanium parts installed on the cabin door of the C919. (Courtesy COMAC, Falcontech)*

industry, as well as the growth of its manufacturing ecosystem. In 2013, the company established a long-term partnership with COMAC, the leading civil aerospace manufacturer in China, when the companies agreed a collaboration project on the metal Additive Manufacturing of titanium components for use on the C919 aircraft. The COMAC C919 is a narrow-body twinjet airliner capable of carrying up to 168 passengers. This collaboration accelerated Falcontech's establishment of manufacturing methods able to meet the standards required in the aerospace industry, for both material and part production.

"Standards are the key to pushing an advanced technology into a successful commercial product," stated Shen. "Industry standards in the aerospace sector will best ensure the consistency, repeatability, and reliability of the production quality." Falcontech therefore invested heavily and consistently in large-scale aerospace-grade titanium material testing, Additive Manufacturing process development, part production, and post-processing studies, building up a quality control database according to the certification of airworthiness. In 2014, the company received AS9100C & ISO 9001:2008 aerospace industry certification.

After two years of intensive collaboration and development, the COMAC project reached its successful conclusion in 2015, by which point twenty-eight metal AM parts had been approved by COMAC and installed for operation on the C919. Falcontech was the first company to supply metal additively manufactured parts for a civil airliner in China. As a leading metal Additive Manufacturing service provider, the company also became a qualified part supplier to COMAC, and still supplies parts to six C919 jets today (Fig. 5).

"Metal Additive Manufacturing has shown the potential to transform the design-prototyping process in the aerospace industry," explained Shen. "Take the aerospace engine as an example; production of each component by traditional manufac-

*Fig. 6 Falcontech's AM production floor, with Farsoon metal AM machines, including FS421M, FS301M and FS271M (Courtesy Falcontech)*

turing takes more than ten processes and six-to-twenty-four months due to their complicated structures. Additive Manufacturing is able to simplify the manufacturing process and accelerate part iteration by three-to-four times. Now, we are able to produce a brand-new engine prototype within three years, compared to the ten-to-fifteen years taken by traditional processes."

## The bigger picture

Falcontech is now looking to the bigger picture of true industrial manufacturing. Following its success on the C919 project, it entered into small-batch production of metal AM parts for COMAC, and – to meet the estimated aircraft orders it could expect from the company – began to expand its capacity for part production, heat treatment, post-processing and advanced inspection.

"We set up a phased technology and marketing plan at Falcontech to achieve our goal of metal additive industrialisation," Shen noted. "In the first five years, 2012–2016, we focused on material and technology research for metal Additive Manufacturing – we heavily invested in a number of international industrial metal 3D printing brands for this process. We carried out a number of tasks, including metal material formulation development and series production and material process engineering, testing our material on various metal platforms to ensure repeatable performance with multiple international brands of metal additive systems on the market. Also, from the very beginning, we started the process of material certification towards targeted industries and applications."

In addition, the company continued to expand its services and markets into the medical and automotive sectors. By working closely with industrial partners, Falcontech also acquired ISO13485 certification in the medical sector.

"Interestingly enough, by the end of 2016, the global additive market also accelerated, with GE and Siemens entering the game," noted Li. "These changes also convinced us it was right to walk the line towards industrialising Additive Manufacturing production. This is when the idea of the Super AM Factory came into focus for our next 2017–2021 five-year development phase."

## Towards a Super AM Factory

"In order to have a better understanding of industrial AM and better prepare ourselves for building a Super AM Factory, during 2017 and 2018, our core team arranged multiple tours for market research, technical training and institutional exchange around the globe; expanding our team of experts from technology, sales and production sectors. Also, we kept investing in more value-added specific industry applications to develop deeper knowhow in the industry," said Shen.

The target of the Super AM Factory envisioned by Falcontech was to scale up metal Additive Manufacturing productivity,

*Fig. 7 Multiple FS621M system installed at Falcontech Super AM Factory (Courtesy Falcontech)*

differentiated service capacity (such as large-format part fabrication), a streamlined industrial workflow, and – most of all – to achieve a truly economical manufacturing cost. With more than seven years' experience in operating metal AM machines from various international brands, Falcontech understood that better cost-performance was the key to expanding the technology's applications. This goal could only be achieved by working with a local manufacturing partner.

"This partnership required a much higher level of technical collaboration, a customised build platform, a higher degree of flexibility in parameter control, an established process database of various material degrees for quality control, and a lower cost of machine ownership and operation. In order to achieve this goal, we had to find a strong partner in the industry," Shen explained.

After over a year in evaluation, Falcontech entered into a long-term partnership with Changsha, Hunan-based machine maker Farsoon Technologies, making a significant investment in a number of the company's metal AM machines.

"We had a clear-thinking process when choosing the partner," explained Shen. "Firstly, we were looking for a strong leader in industrial AM with full competence of machine development and manufacturing that would be able to offer quality products and solutions. Second, the company must have the capability for technology innovation, based on a profound industry knowhow, in order to be able to develop customised solutions that could support our industrial-scale production and differentiated service capacity."

"Finally, based on our wide range of applications and industrial manufacturing capacity, we needed a high level of technical support and fast-response service to ensure high machine uptime and achieve an economic manufacturing cost," he continued. "We were very lucky to find Farsoon as the right partner that can meet all our needs."

As of October 2020, Falcontech has purchased twenty-four Farsoon metal AM machines. With its enhanced manufacturing capacity for series production, Falcontech has firmly established itself as a leading aerospace manufacturing service provider in both China and the global market.

## Innovators in AM growing together

"As our partnership developed, I found out that Falcontech and Farsoon are similar in many ways," said Li. "Both companies are professional in their technology, while all have truly open mindsets to collaborate and grow together. Both of our R&D teams can work innovatively towards a technical solution in various contexts, e.g. machine adaption, software integration, parameter development and productivity optimisation; this allows us to respond quickly to market needs. We are seeing more benefits and added value brought by Farsoon's open-minded, in-depth partnership, compared to the more conservative, less operationally flexible and slower technical solution iterations working with international brands."

Through the joint efforts taken by Farsoon's metal application team and Falcontech, significant technical progress has been made, with the companies achieving optimal productivity, part wall structures as thin as 0.5 mm, improved dimensional accuracy ± 0.5 mm/800 mm, improved build surface roughness of Ra 6.3, and higher metallurgical quality for parts produced on Farsoon AM machines.

Thanks to the 'open for industry' philosophy of Farsoon's machines, Falcontech is able to operate with a higher degree of flexibility in parameter setting and future material development, which has contributed to a total of twenty material processing parameters for aerospace applications, including multiple types and grades of titanium alloys, aluminium alloys and nickel-base superalloys. Farsoon's application team also assisted Falcontech with the establishment of a processing database for aerospace materials, for future development and manufacturing quality control.

"The openness of Farsoon's manufacturing platform is important for us in both material development and industrial scale production," explained Li. "Our material team can have better flexibility exploring different parameter combinations of laser power, scanning path, layer thickness and scanning speed; this is especially valuable when it comes to specialised superalloy materials development for high-end applications. During large-volume series production, we can optimise the build speed by choosing a variety of layer thicknesses to improve the production yield. In comparison with a closed additive system, Farsoon's open platform will offer more benefits in the long run, allowing more possibilities for specialised material and application development without any major technical restrictions. It also encourages increasing technical exploration and software integrations for a more connected manufacturing ecosystem."


*Fig. 8 Farsoon FS421M systems installed at Falcontech (Courtesy Falcontech)*

As leading companies in China's AM industry, Falcontech and Farsoon also shared the responsibility to further push for advanced materials and bring a technical AM solution to the manufacturing market. As Li explained, "Farsoon is a true partner for us rather than simply a machine supplier. With invaluable support from Farsoon we are able to further explore a number of key applications and educate the potential markets about the advantages of Additive Manufacturing; all these cannot be achieved without an open mind."

## Enhanced productivity through large-format machines

Of the twenty-four Farsoon metal AM machines Falcontech has purchased to date, twenty-two are large-format Farsoon FS621M (Fig. 7) and FS421M (Fig. 8) machines. These have build volumes of 620 x 620 x 1100 mm and 425 × 425 × 420 mm respectively.

Introduced to the Chinese market in early 2020, the FS621M machine is one outcome of Farsoon and Falcontech's collaboration. The customised large-format machine offers an industry-leading build envelope, extended build chamber volume and maximum productivity per laser. Addressing the challenges facing metal AM, such as productivity, build size constraints, powder management, process control and factory layout, Farsoon developed the FS621M by co-innovating with the Falcontech team to understand the needs of their AM factory. With one of the largest PBF-LB build volumes on the market, the systems are opening new possibilities for metal production which could not previously have been achieved for industries such as aerospace, oil and gas, and many others.


*Fig. 9 Oversized aluminium alloy engine component (590 x 590 x 98 mm) produced on an FS621M (Courtesy Falcontech)*

As of today, the installation base of the FS621M system at Falcontech has reached a total of four systems and these are used for large-volume parts fabrication and batch production. An increasing number of processing parameters have also been developed with Falcontech to process a wide range of powders, including titanium alloys, aluminium alloys, nickel-base superalloys and stainless steels.

The FS421M system is the first metal AM solution to be released under Farsoon's Continuous Additive Manufacturing Solution (CAMS) concept. With productive multi-laser solutions and continuous production capability, the FS421M has achieved accumulative sales of more than thirty systems globally. "We have seen exceptional performance and stability in the Farsoon FS421M metal system via multiple series production jobs since installation," stated Li. "We are thrilled by the high-quality parts manufactured taking advantage of the benefits from Farsoon AM. With the increasing demand of manufacturing orders, we will further expand our production capacity and improve turnaround time for parts delivery with more Farsoon metal systems."

*"We have seen exceptional performance and stability in the Farsoon FS421M metal system via multiple series production jobs since installation..."*

## Technical support and customer service for engineering excellence

With the increasing demand for metal AM component production in the civil aerospace market, the Falcontech team has been met with engineering challenges from a wide range of specific applications. Titanium alloys represent an important application material for key aerospace components, but with the high level of internal stresses generated during the build process, titanium alloys, especially TA15 parts, tend to show internal defects such as cracks and porosity, resulting in part failure during functional testing for mechanical properties. This risk becomes even more challenging when it comes to larger part fabrication. Previously, although the Falcontech team had made significant investments into finding a solution to ensure the mechanical properties of larger TA15 parts, the company was only able to successfully build small- to medium-sized parts, due to its limited ability to customise processing parameters.

Now, with the availability of Farsoon's open AM machines, the company's engineers have been able to greatly improve their ability to customise a wide range of processing parameters for this material, especially in terms of gas flow and laser power. With the help of Farsoon's application team, Falcontech was also able to explore the combination of heat treatment and specific processing solutions. Within a short span of time, Falcontech is now able to successfully produce oversized TA15 parts on both FS421M and FS301M machines, with excellent mechanical performance and improved productivity.

As the machine installation base has reached twenty-four systems total, Falcontech has also received more projects and is now running to almost its full manufacturing capacity. Farsoon's service team has offered tailored customer-centric training and service plans throughout. During the beta-testing phase of the four installed FS621Ms, the company assigned a dedicated engineer at Falcontech's facility for training staff and ensuring machine uptime. Farsoon also set up an on-site inventory at Falcontech's Super AM Factory, equipped with important consumable machine parts.

"We are impressed by the professionalism, efficiency and creativity of Farsoon's technical support and service force," commented Li. "Farsoon has shown a real customer-centric mindset and understands the critical points of a service bureau. Innovative service plans like on-site inventory have improved our operational management, and minimise the machine downtime from parts ordering, payment and shipping."

## Understanding the emerging Chinese and global market

Despite the influence of the coronavirus (COVID-19) during 2020, Falcontech has seen signs of strong growth in industrial metal AM, and more opportunities opening up in China. Besides the emerging Chinese civil aerospace industry, the aviation sector also calls increasingly for development and prototyping parts for manned aerial vehicles, satellites and space vehicles. These advanced aerospace applications usually feature complex design geometries, making metal AM a well-suited manufacturing alternative.

"We have seen an increasing number of industry giants from traditional manufacturing, including the automotive, machinery, heavy industry, shipping and moulding industries in China, starting their evaluation and layout to implement metal Additive Manufacturing," Li explained. Starting from last year, a variety of metal AM technologies in China have received increasing capital investment and funding from the market to support R&D and accelerate the industry's development.

"As for the global market," Li adds, "we have also observed a similar trend around larger-format production systems, especially with tall vertical height, multi-laser systems for increased productivity, and specialised high-temperature alloy materials."

With the establishment of the Super AM Factory, Falcontech can offer the combined manufacturing capacity of over twenty medium- to large-format machines to manufacture large parts in relatively high volumes. Li stated, "We are confident in offering an advanced metal laser sintering [PBF-LB] solution, from quality materials to processing development, series production, post processing and inspection services, to global partners."

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# Strategies for advancing the automation of metal Additive Manufacturing

In the early days of metal Additive Manufacturing process development, automation was off the radar of machine manufacturers. Technologies created for rapid prototyping simply had no need for it and, until the last decade, few truly anticipated the pace at which Laser Beam Powder Bed Fusion and Binder Jetting have evolved in the race towards the series production of metal parts. In this article, Joseph Kowen reports on how the industry has addressed the challenges of automation so far, and what developments we can expect in the near future.

Consider this: at Formnext Connect in November 2020, and in the weeks leading up to the event, the Additive Manufacturing industry saw a stream of announcements on the subject of AM part processing, including collaborations and product launches on what could more broadly be described as industrial automation in AM. Siemens, Grenzebach, Ossberger and AZO presented a case study on reducing cost per part through automation in the processing of polymer parts made on EOS machines. HP announced a new post-processing solution for its Jet Fusion 5200 system with AM Solutions. AM Flow, a Dutch startup, raised $4 million in Series A funding to develop end-to-end solutions for AM automation, also mainly for polymer parts, while Solukon launched the SFP 770 automated unpacking system for polymer parts. PostProcess Technologies, meanwhile, announced the development of a patent-pending Variable Acoustic Displacement (VAD) technology for automated polymer powder removal. This is only a partial listing of some of the developments the industry saw in 2020.

What is common to these announcements is that they all involve the automation of stages of the workflow for producing polymer parts. Less widespread during the conference were announcements on innovations and developments in the field of automation for metal AM part production. One news release that might be the exception is Siemens' collaboration with Sintavia on software automation. It seems that in metal AM, industrialisation and automation is a much harder nut to crack.

*Fig. 1 In contrast to metal AM, a number of post-processing solutions for polymer-based AM parts were announced at Formnext Connect, such as this automatic unpacking station from AM Solutions for the HP Jet Fusion 5200 Series (Courtesy AM Solutions / Rösler Oberflächentechnik GmbH)*

  

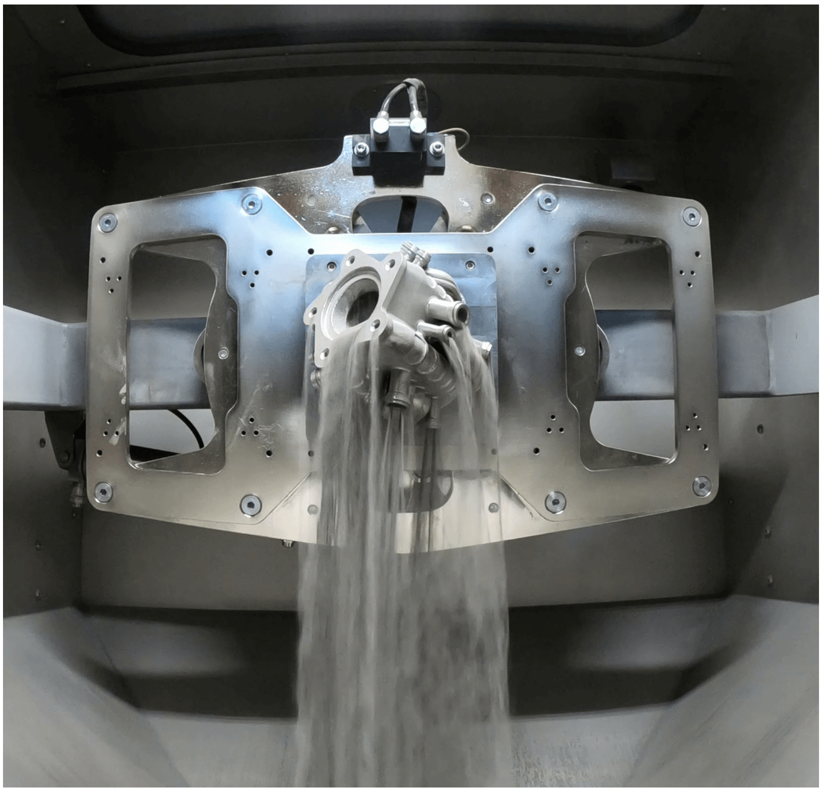

*Fig. 2 Depowdering solutions for complex AM parts, such as the SFM-AT800-S machine from Solukon, have made an important contribution to addressing the challenges in automation, but they are just one piece of the puzzle (Courtesy Solukon Maschinenbau GmbH)*

This article will catalogue what has been done to advance the automation of metal AM part production, and aims to shed light on what is still missing in the automation picture. We will try to ascertain why this is so, why automation in metal AM is still so elusive, and we'll report on what some voices in the metal AM industry are saying about automation and how they see its future path. In so doing, we will take a high-altitude view of automation in metal AM. We will not look into the intricacies of individual processes that form part of the automation process chain, such as depowdering or support removal; rather, we will look at the overall automation flow, or, more precisely, the processes and systems that connect the various stations that parts need to traverse on their path from feedstock to functional use, or – in the case of most common metal AM processes – from powder to production part.

Beyond our description of the various issues faced by metal AM automation and their status, we hope that the thoughts and ideas raised here will assist in stimulating broader discussion on the issue and sensitising both the industry and its consumers to the possibilities – and challenges – of automation and industrialisation in metal AM.

## No time for automation?

As rapid prototyping technologies developed into Additive Manufacturing solutions, the focus of the industry and its systems providers was squarely on the AM processes themselves. The challenge of producing accurate, repeatable and functional parts, metal or polymer, required a focused technical and intellectual effort. Success was measured by the part itself, so little effort was devoted to the manufacturing context in which individual parts miraculously materialised out of a vat or powder bed. The broader environment and post-processes were left to the customers themselves.

One of the results of this focus was high part cost, as shall be seen. High cost meant that potential uses of metal AM as a production tool were limited to applications that were less cost-sensitive, or where the geometrical advantages of the part made a strong case for using AM, notwithstanding the cost.

The software that serves as a backbone for any attempt at automation has made significant strides in recent years. Tools for processing data, build setup, workflow management and other functions have begun appearing on the market with increasing frequency. The subject of software automation is a topic that deserves dedicated attention, and for this reason is not covered here. It might be said that in the evolution of metal AM, the central nervous system of any automation – the software – has developed, but the body has yet to coalesce around it in any meaningful way.

In the development of metal AM until now, automation was at best an afterthought and, at worst, completely neglected, as machine manufacturers threw most of their resources at the AM process itself.

## Metal AM machines – Where is the need?

The numbers of machines sold into the market give some perspective on the stage of development of the metal AM segment. The *Wohlers Report 2020* estimated that 2,327 metal Additive Manufacturing machines were sold in 2019. This number includes machines from all of the metal AM technologies: Powder Bed Fusion (PBF), Binder Jetting (BJT), Metal Material Extrusion (MEX), and Directed Energy Deposition (DED). The *Ampower Report 2020* estimates that about 78% of metal AM machines sold in 2019 were either Laser (PBF-LB) or Electron Beam Powder Bed Fusion (PBF-EB) machines, of

  

*Fig. 3 The promise of high-capacity industrially focused metal Binder Jetting systems such as the Production system from Desktop Metal has served to highlight the potential of the process for mass production. However, the current reality of manually depowdering builds in such systems is a challenge that needs to be urgently addressed before Binder Jetting can be a true industrial-scale technology (Courtesy Desktop Metal)*

which more than 90% were PBF-LB. Historically, PBF-LB's share of the metal AM systems market has been even higher. The *Ampower Report* estimates that the installed base of all PBF systems is 9,111 machines, or 88% of the installed base of all metal systems from all technologies. It is estimated that of all the PBF systems, PBF-EB only accounts for approximately 500 units, or a little more than 5%.

Given the state of the market now, or, more precisely, where the machines are located, automation is a key issue for PBF. Due to the dominance of PBF-LB over PBF-EB, from a practical point of view, the former is where any consideration of automation must lie. That said, PBF-LB systems are not standardised. While the basic PBF-LB process is similar regardless of the manufacturer, the mechanical design and layout of the machines produced differs. Since there are more than sixty manufacturers of such systems worldwide, there is great variability within the overall PBF-LB market.

But what of technologies poised for future growth? Binder Jetting is a technology where automation could, arguably, play a bigger role. There are only a handful of companies with offerings in the metal BJT space, and their total installed base is a little over 200 machines, according to the *Ampower Report*. This is a very small footprint, amounting to only about 2% of all metal systems worldwide. However, BJT is a developing area, with large players such as HP and GE, and well-funded startups such as Desktop Metal, making serious movements into this space.

These technologies add to the systems that metal BJT pioneer ExOne has been commercialising for a number of years. The promise of BJT as a future technology for metal AM lies in its cost structure, which offers the possibility to address markets where PBF-LB is not economically feasible. It is here that automation has an important role to play; the lower cost of parts opens up higher quantity applications, such as some automobile applications. Larger quantities make investment in automated processes more attractive. Symbiotically, automation could, therefore, play an important role in the speed of development and penetration of BJT into production applications. The discussion on automation in BJT is based not on its current significance in the AM industry, but on its future.

Another metal technology that should be mentioned is the Material Extrusion of metal filament, also known as Fused Filament Fabrication (FFF) or metal Fused Deposition Modelling (FDM). There has been some development in this segment over the past few years, particularly with machine makers such as Desktop Metal and Markforged, and material suppliers such as BASF. While, theoretically, this technology should also be a candidate for

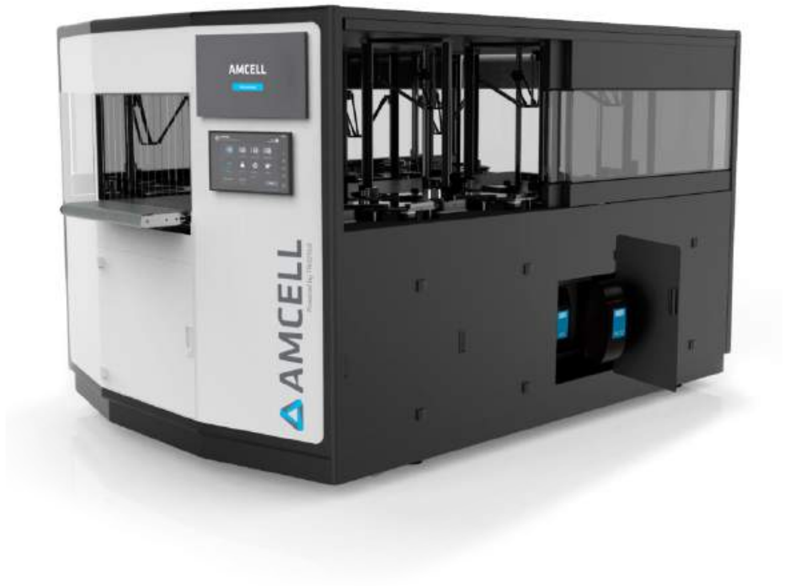


*Fig. 4 Triditive is developing its automated platform, AMCELL, in which a number of filament extrusion heads produce parts simultaneously and finished parts are automatically extracted from the machine on a conveyor system for debinding and sintering (Courtesy Triditive)*

automation, MEX is a vector-based AM process that is slow and has other disadvantages compared to PBF and BJT, such as lack of feature resolution. It is best suited to low-batch production. Since the process is not based on powder, many of the headaches associated with powder handling and removal are avoided.

A Spanish company called Triditive is developing an automated system called AMCELL in which a number of extrusion heads produce parts simultaneously and finished parts are automatically extracted from the machine on a conveyor system. It is a platform worthy of note for its dedication to automation, but as a low-batch solution it occupies a place only on the periphery of metal AM.

## The process steps

It is worth laying out clearly the process steps of PBF-LB and BJT in order to understand exactly where automation could play a constructive role in making these AM processes more efficient. At the end of the day, an investment in automation must make business sense, so operators of metal AM facilities will, by necessity, need to calculate their savings and return of investment on any automation system.

The term 'post-processing' is used frequently in connection with AM. We will use the more generic terms 'automation' or 'process automation' to describe how the part gets from AM machine to final product, which will also generally include steps that would commonly and accurately be called post-processing. Examples of post-processing would be heat treatment, polishing and shot peening.

It is worth pointing out that each different application, whether for the automotive, aerospace or medical industry, is going to face specific challenges, and this will affect the fine details of any automation solution. The analysis laid out here will, by necessity, be based only on the generic aspects of production process automation.

PBF-LB contains the following main process steps:

- Build process >>
- Cooling >>
- Unpacking and depowdering >>
- Heat treatment and cooling >>
- Cut from build plate >>
- Support removal >>
- Optional: Hot Isostatic Pressing (HIP) >>
- Surface treatment, depending on application (grinding, polishing, shot peening, milling) >>
- Transferring or shipping for final use

BJT includes the following steps:

- Build process >>
- Placement in curing oven for hardening green parts, depending on process variant >>
- Depowdering >>
- Preparation for debinding and sintering >>
- Debinding and sintering >>
- Optional: HIP >>
- Surface treatment, depending on application (grinding, polishing, shot peening, milling) >>
- Transferring or shipping for final use

The more of these processes that are able to be connected through automation, the better the process and the lower the cost. Practically speaking, the AM automation that we are talking about relates to the earlier stages in the process chain. Once parts are on their way towards surface treatment and finishing, traditional automation processes can be applied, and this ceases to be an AM-exclusive issue.

Metal powder is the starting point in both BJT and PBF-LB. Powder is generally a headache in metal AM, and it needs to be managed. All powders pose health and safety risks. Reactive powders, such as titanium and aluminium, also risk ignition and explosion if not handled under


*Fig. 5 As a collaboration between Premium AEROTEC, Daimler and EOS, NextGenAM was envisioned as a way to demonstrate the feasibility of an automated production cell for metal AM part production. A production unit was built at Premium AEROTEC's technology centre in Varel, Germany*

inert conditions, or if particulates are allowed to build up in the factory environment.

A second common element is heat. PBF-LB is a hot build process, and parts are hot to handle and need to be cooled. They generally also require heat treatment. BJT is a cold process to start with, but requires curing and sintering in the downstream.

Automation of the BJT workflow faces a unique challenge not present for PBF-LB. Additively manufactured green parts produced by BJT can be fragile depending on their dimensions, which could make handling them with automatic systems problematic. Automation experts believe that solutions can be found that will handle these parts with the care that is needed to avoid breakage and failed builds. Changes to the design of the part or layout of the parts in the build box could also mitigate losses due to the indelicate handling of green parts.

The makeup of the build could also be a factor. If the build comprises a wide variety of parts, this makes part handling more complicated compared to a build in which all of the parts are identical and arranged in an organised and repeatable way in the build volume. Finally, green part strength may also be enhanced in the future through the development of stronger binders. BJT machine providers are all aware of the value of improving the strength of green parts and the benefits that this would bring for automation.

## Factories of the future

Over the past number of years, many of the leading PBF-LB suppliers have presented concepts illustrating how they see the AM 'factory of the future'. Many have published artistic renderings of these concepts. As far as such factories being built for metal AM, very few of them have so far made it off the drawing board. Here are two that did, as well as a machine manufacturer that has given such significant thought to automation as to be worthy of mention.

**NextGenAM**

In 2017, three companies got together to establish the NextGenAM project. A collaboration between Premium AEROTEC, Daimler and EOS, NextGenAM was envisioned as a way to demonstrate the feasibility of an automated production cell for metal AM part production in the aerospace and automotive industries. Its members represented some of the most highly regarded names in their industries, each with its own particular commitment to metal AM. Through the project, an automated unit for building aluminium parts was built at Premium AEROTEC's technology centre in Varel, Germany.

The genesis of the project was not just a desire to demonstrate the technical prowess and industry leadership of its partners, though that may have been one of the motivating factors. An earlier study by the three companies had found that up to 70% of the total cost of an AM part could be attributed to the pre- and post-processing costs; this included downstream processes such as build removal from the machine, build plate transfer, powder removal, support removal and other processes that in many cases required substantial manual labour. With such a high overhead, the companies figured, the total costs of metal AM would remain high, and would discourage all but the highest value or geometrically complex applications. While some costs could be mitigated by smart design with the specific idiosyncrasies of AM processes in mind, using

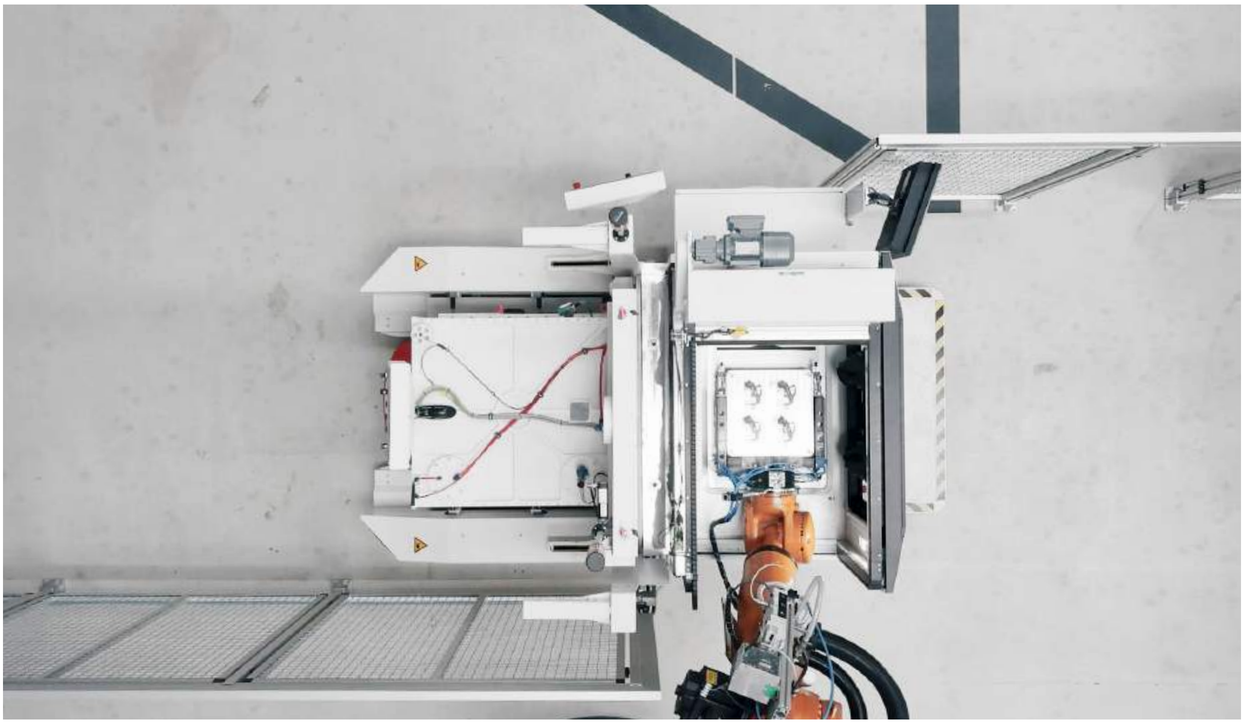

*Fig. 6 An overhead view of the NextGenAM production cell at Premium AEROTEC's technology centre in Varel, Germany*

what is referred to as Design for AM (DfAM), they realised that some of the manufacturing process could be streamlined. NextGenAM set out to build a pilot to prove that AM could be made cheaper.

*"NextGenAM concluded in May 2019. Its findings suggest that for some parts the manufacturing cost could be reduced by up to 50% using the automated production line, compared to currently available metal AM systems."*

To design and build the automated processes for the project, the members of NextGenAM turned to Grenzebach Maschinenbau GmbH, a company based in Asbach-Bäumenheim/Hamlar, Germany. Grenzebach specialises in automation systems and possesses a wide range of automation tools and technologies, having extensive experience in their implementation for a variety of industrial applications. Grenzebach supplied the automated guided vehicles (AGVs), mechanical design of the automation interfaces, as well as fleet management software for controlling the automation system for transferring, loading and unloading build boxes. As a result of its involvement in NextGenAM, Grenzebach has designated AM as one of its focus markets, and it aims to provide solutions in both metal and polymer AM based on its learning and experience in the AM area.

The NextGenAM project concluded in May 2019. Its findings suggest that for some parts the manufacturing cost could be reduced by up to 50% using the automated production line, compared to currently available metal AM systems. The collaborators were quoted as saying that the AM production line was automated from beginning to end, meaning that no manual work was required at any stage of the process, from data preparation and central powder supply through to the AM build process itself, and including heat treatment, quality assurance and separation of the components from the build platform.

Dr Adrian Keppler, then EOS CEO, stated during the project, "The NextGenAM project has provided a very tangible demonstration of how industrial 3D printing can be used cost-effectively in series production as part of an automated process chain. In combination with the possibilities for digitalisation as used here, the pilot plant represents nothing less than a milestone along the way to digital manufacturing."

Jasmin Eichler, Head of Research Future Technologies at Daimler AG, offered this insight: "With this collaborative pre-development

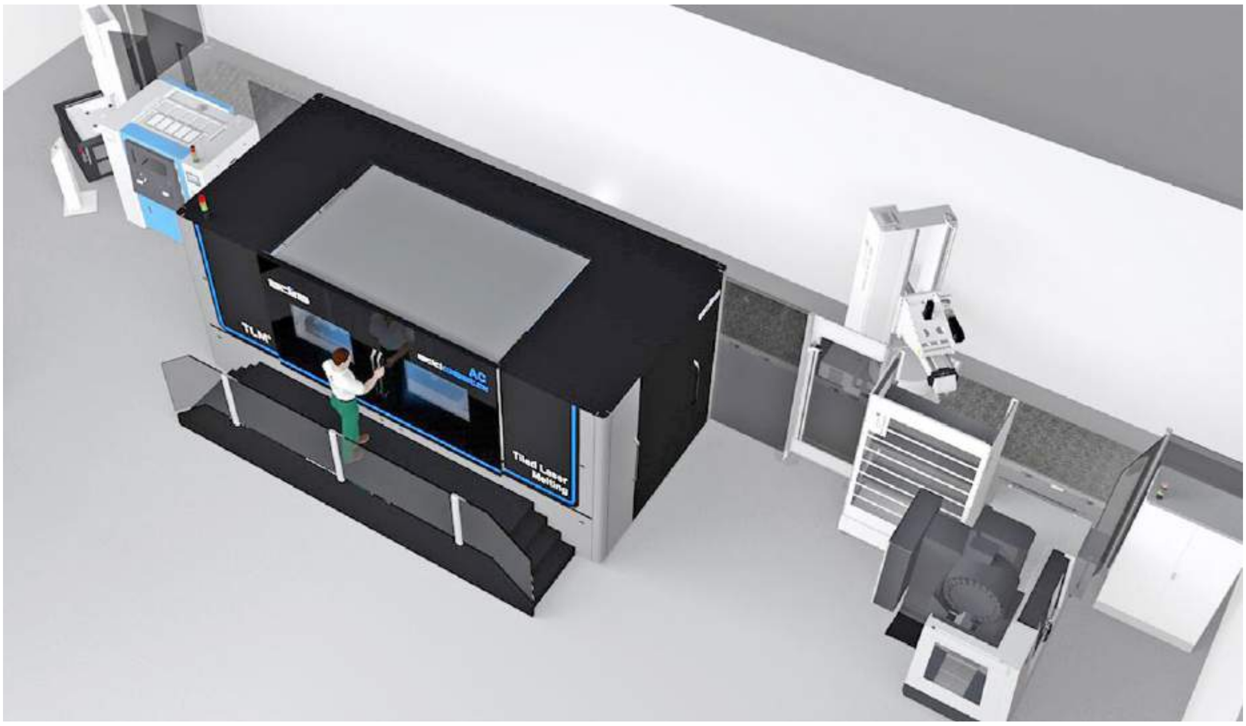

*Fig. 7 The Hyprocell project was established in 2017 with the objective of developing and demonstrating a multiprocess production cell concept. The AM part of the pilot was built at Poly-Shape's facility in Marseille, France, and featured a large PBF-LB machine (AddCreator, Adira); a depowdering system (SFM-AT800, Solukon); and a milling centre (Haas 3-axis VF-2). Movement of build trays between stations was performed by an Erowa ERD 500 robot*

project, we are taking a significant step towards achieving cost-effectiveness in metal 3D printing throughout the process chain. The project lays the cornerstone for the future realisation of larger quantities in the automotive series production process."

With the curtain having come down on this project, industry sources note that a real project based on the pilot has yet to be implemented elsewhere. There are a number of possible reasons for this, but the two main ones – related to each other – are cost and the need to modify or add hardware to facilitate the automated work flow.

**Hyprocell**

The Hyprocell project was established in 2017, with the objective of developing and demonstrating a multiprocess production cell concept, employing laser-based manufacturing, and implementing the concept in a real environment (pilot facilities) by manufacturing real parts in order to measure the benefits. The project was funded by The European Union (EU)'s Horizon 2020 programme and managed by Lortek, a private Spanish manufacturing research organisation. The target industrial sectors for the project were power generation, aerospace and general manufacturing.

The AM part of the pilot was built at Poly-Shape's facility in Marseille, France. Poly-Shape was later acquired by French system manufacturer AddUp in 2018. The pilot included the following operating stations: A large PBF-LB machine (AddCreator, from Portuguese machine maker Adira); a depowdering system (SFM-AT800, from German depowdering specialist Solukon); and a milling centre (Haas 3-axis VF-2). Movement of build trays between the different stations was performed by a robot (Erowa ERD 500).

The workflow is as follows: The robot transfers the produced part inside a specially designed dustbox to a dedicated depowdering station. Any remaining powder is removed from the part and safely captured, thus diminishing release of powder into the factory environment. The part is then transferred by the robot to a milling centre in order to bring the part's surface to the required quality. The dimensional accuracy of the part is controlled by a measuring machine performing automated 3D scanning. The part handling system is connected to a robotic storage and loading station for loading and extracting the finished parts using a pallet system. The pallets are stored in a rack magazine.

Juan Carlos Pereira Falcón, a Senior Researcher in metal Additive Manufacturing at Lortek and leader of the Hyprocell project, stated that the team was pleased with the findings of the pilot and with the integration of its various elements, especially the flexibility available to integrate existing machines into the system in a modular way. On the down side, the expense of the system, especially with the use of a very large PBF-LB machine with a long build cycle, meant that they


*Fig. 8 The MetalFAB1 PBF-LB machine from Additive Industries has automation as part of its basic design concept, with connected modular units that include build 'cores', a powder removal unit, a heat treatment unit and a part removal module (Courtesy Additive Industries)*

were unable to find a use case that made economic sense. It would have been better, he added, to have a number of smaller systems being serviced by the single robot and depowdering system.

**MetalFAB1, Additive Industries**

One PBF-LB supplier has made automation part of its basic design concept. Dutch company Additive Industries, Eindhoven, includes automated features as modules within its system offering, the MetalFAB1. The basic system includes a bulk powder removal device, although it lacks the ability to remove powder trapped inside internal channels. In late 2017, the company launched an optional in-line product removal module that cuts the built part off the base plate and prepares the plate for the next build. Using the MetalFAB1, build plates are automatically loaded from a storage unit, and an exchange module allows the removal of finished plates from the system. The system is expandable and can include multiple 'cores' or build units. An integrated heat treatment unit is also available.

In November 2020, the company announced the MetalFAB-600, its latest system, due for commercial release in 2021. Not much is known about the MetalFAB-600 at this stage, but according to the company, the new model builds upon the knowledge and experience gained with the MetalFAB1 in terms of robustness and the automation of key production processes. The company claims that this automation will include a focus on powder handling, alignment and calibration.

## Visions for the future

A number of metal AM machine providers have committed to automation at one level or another, though at this stage mostly verbally. A number of cases are discussed here. They represent a sampling, and by no means an exhaustive list, of everything that metal AM companies are doing in the area of automation, but they are illustrative of a desire within the industry to tackle the issue.

With the exception of the two pilots that have already been described, there are not many examples of automated systems that have been put into practice. Some customers have invested in parts of the process, such as depowdering systems, but these tasks are in most cases not connected to either upstream or downstream steps.

**GE Additive**

GE's newest systems, including the GE Additive Concept Laser M LINE, are automated in terms of the loading and unloading of the build module. This enables faster changeover times, which maximises machine up time. Maybe more importantly, it eliminates operator exposure to powder and makes operation safer.

The key hurdles that GE Additive sees in the workflow that require mitigation in any automated system are: the manipulation and storage of all the relevant files and data, in significant amounts, and from different tools; powder handling from receipt through to recycling, where there are often differing reuse strategies, and questions about what percentage of virgin powder to add into the mix; and depowdering and support removal, which pose many challenges. These are important process steps that automated systems will need to address.

Chris Schuppe, General Manager, Engineering & Technology at GE Additive explained the company's view of automation: "Automation will ultimately drive costs down for the overall process, which should improve the business case, and that will ultimately lead to further adoption and higher volume applications."

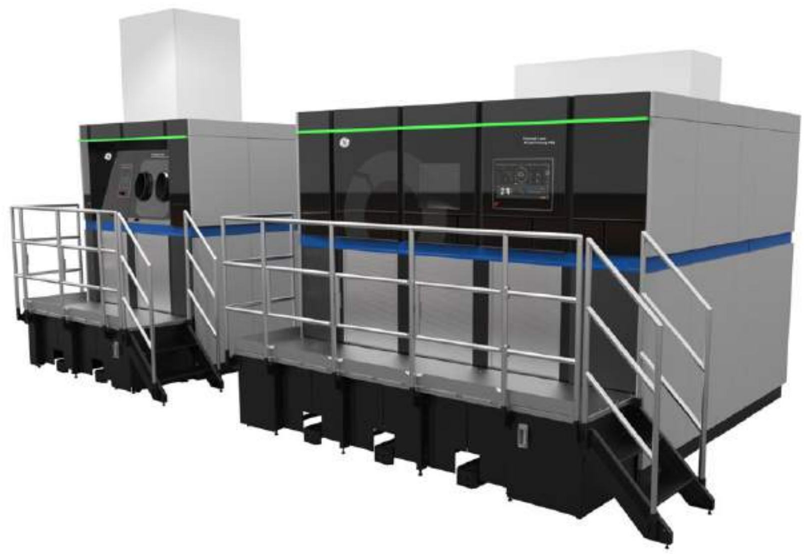

*Fig. 9 GE's newest systems, including the GE Additive Concept Laser M LINE, are automated in terms of the loading and unloading of the build module (Courtesy GE Additive)*

**Farsoon Technologies**

Farsoon Technologies is a Chinese company with roots in the early days of the development of laser sintering in the US. It initially focused on polymers, but has moved into metal AM in the past few years. The company made headlines recently when it announced a deal with Chinese aerospace company Falcontech for the supply of fifty metal AM machines, as part of an investment that is covered in more detail elsewhere in this issue.

The company has a clear vision for how it sees automation in the future of metal AM. Don Xu, Global Business Group Director, explained that machine manufacturers will have to work much more closely with their customers to customise their machines to fit in with the customer's production line and application requirements. Standard machines have been sold off the shelf to date, but that will have to change in order to get maximum value for the technology, and this applies to automation as well.

In fact, Farsoon has worked with Falcontech to customise aspects of the machines it is supplying, especially with regards to powder supply and recycling. As a supplier of both metal and polymer PBF machines, it was interesting to hear that Xu believes that metal part production may be easier to automate than the production of polymer parts, since metal parts are stronger.

*"As a supplier of both metal and polymer PBF machines, it was interesting to hear that Xu believes that metal part production may be easier to automate than the production of polymer parts, since metal parts are stronger."*

Automation is squarely on the company's radar and is a key direction for the future, although it is not quite ready yet. Xu emphasises that no one company will be able to address the automation challenge: it will have to be a collaboration between the customer, the AM machine supplier and automation specialists. Today, the focus is on automation of the powder supply, but in the future, the automated transfer of parts will also be accomplished. It was with automation in mind that the company partnered recently with Siemens, in order to be better prepared for the challenges ahead.

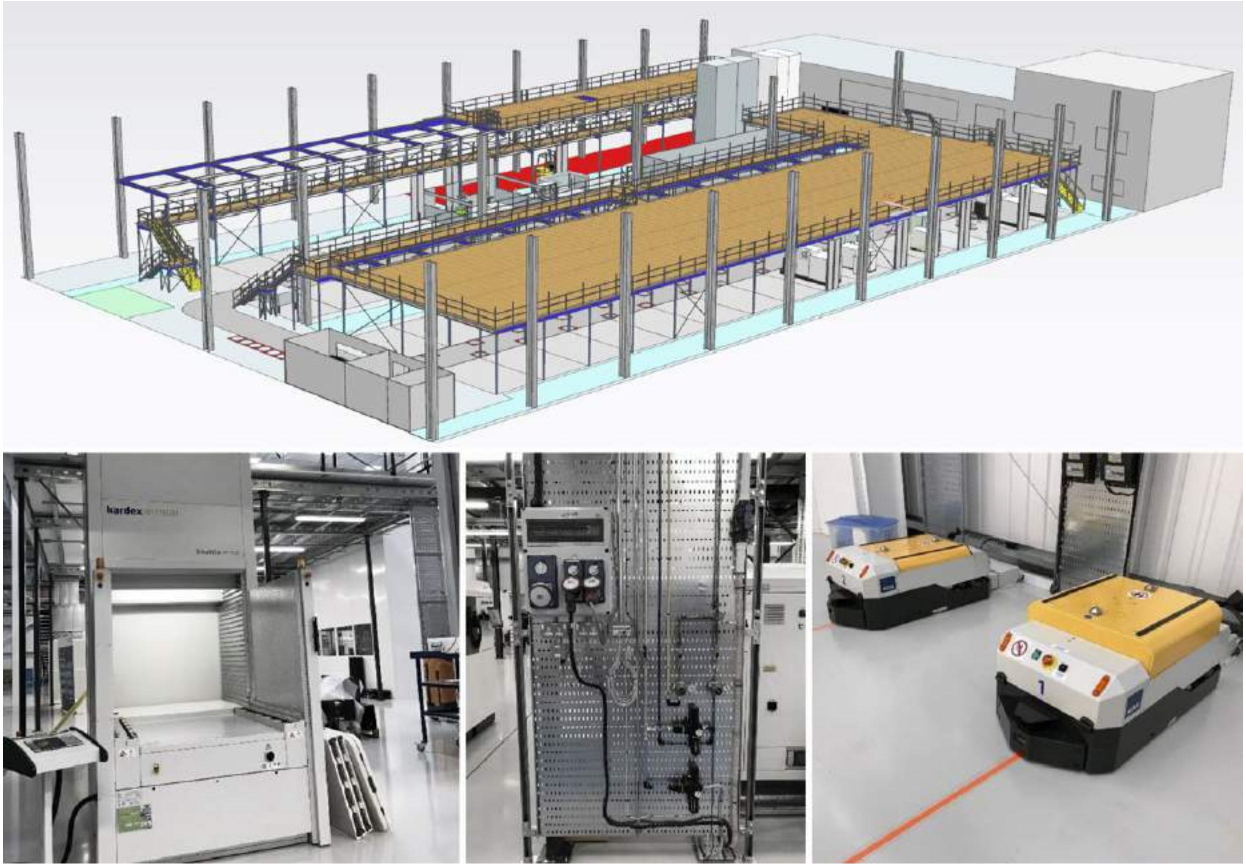

*Fig. 10 Creating an effective factory layout for series PBF-LB production at Materials Solutions, as featured in Metal Additive Manufacturing magazine, Vol. 5 No. 4, Winter 2019 p. 146 (Courtesy Materials Solutions)*

**Materials Solutions (a Siemens business)**

Materials Solutions is a leading AM service provider that specialises in metal AM and addresses the aerospace, automotive, tooling and power generation segments. In 2016, Siemens acquired a majority interest in the company, and, in 2019, acquired the balance to make it a wholly-owned subsidiary. Siemens adopted the strategy of industrialising PBF-LB at the facility. To pursue this objective, a €30 million investment was made into the company, involving a move to a new 4,500 m$^2$ production facility outside Worcester, UK.

The target is to have up to fifty AM machines, a digitalised production facility and production and post-processing capabilities under one roof. The facility is one of the largest metal AM facilities in the industry, and its layout was planned for maximising the automation of high-value processes, whether currently implemented or intended for implementation in the future. A circuit-style layout has been developed at the facility for uninterrupted end-to-end production flow, and AGV's are employed to move products or materials around the facility. Build box loading and offloading is still performed manually.

The facility was designed with a centralised powder supply and deploys a number of Solukon powder removal systems. Heat treatment is provided by third party sub-contractors off site.

**GF Machining Solutions and 3D Systems**

GF Machining Solutions, a unit of Swiss company Georg Fischer SA, partnered with 3D Systems in August 2018 to advanced manufacturing solutions for AM. The partnership paired an established machine manufacturer providing industrialised solutions with a provider of PBF-LB systems. The first fruit of this collaboration involved integrating a System 3R Delphin chuck, produced by GF Machining Solutions, into the DMP Factory 500 PBF-LB system, produced by 3D Systems. This allows the operator to seamlessly move the build plate, which sits on-top of the chuck, from the metal additive machine onto downstream stations for further processing. This saves time in clamping and making dedicated tooling after the part has been separated from the build plate. This modest step in integrating systems paves the way for further automation in the future. More details about this collaboration are reported elsewhere in this issue of *Metal AM.*

**The ExOne Company**

A pioneer in BJT technology, ExOne launched two new metal AM machines in 2019. The build volume of the larger machine, the X1 160Pro, is 800 x 500 x 400 mm, making it a large-volume platform intended for industrial applications. With a volume of 160 l, the weight of the build box can exceed 700 kg when fully loaded, making the logistics of moving it from station to station in the manufacturing process a challenge.

In September 2020, the company announced that the machine would be supplied with either a standard conveyance system, or with the X1D1 automated guided vehicle. This AGV can support multiple machines, reducing the total footprint of the system and simplifying movements between processes.

For many years, ExOne focused solely on the delivery of AM machines. With the announcement of the X1D1, the company is consciously signalling the move of its new BJT systems into real production environments for customers. John Hartner, ExOne CEO, explained that the company is shifting some attention to the need for automation so that it can help customers take full advantage of a smart digital manufacturing system. Depowdering parts has become a key area of focus for the company, as this is where the bulk of labour cost is expended. The company also sees opportunities to speed up the entire process by improving efficiency in this area.

The vision of the company is to surround the relatively simple build process with technology to make it continuous, hands-free and even smarter. It views BJT automation as a way to lower costs, drawing even more customers to this technology and sustainable manufacturing solution.

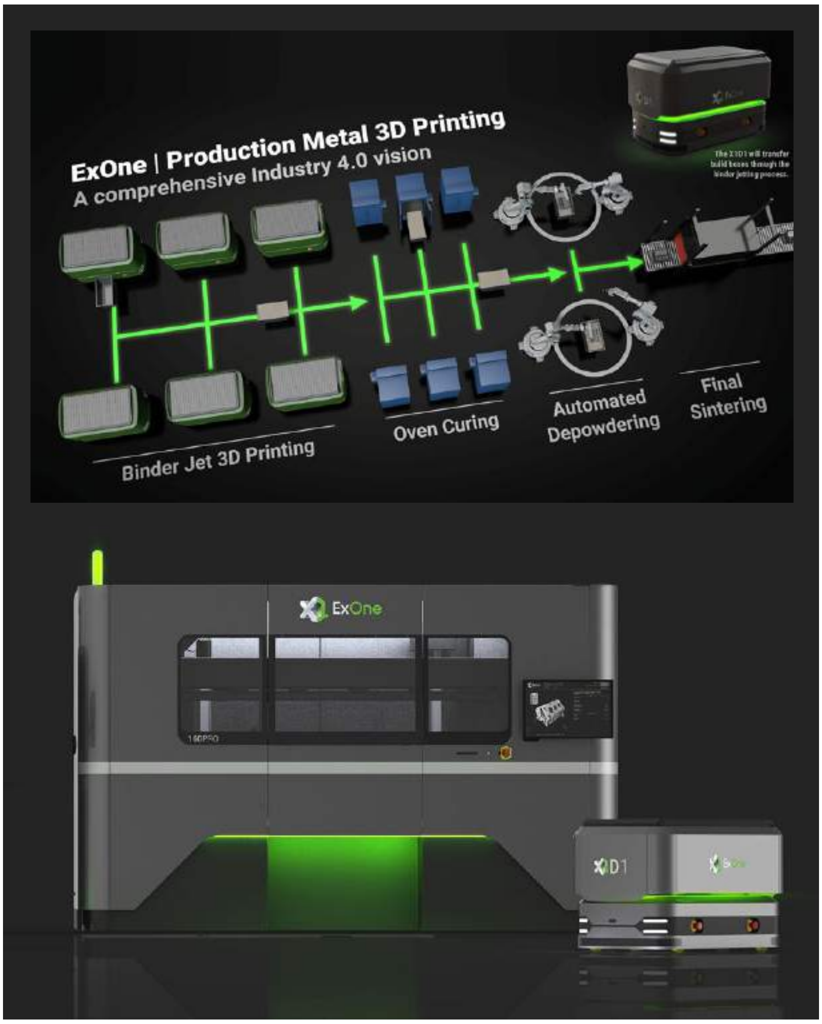


*Fig. 11 With the announcement of the X1D1 automated guided vehicle, the company is consciously signalling the move of its new BJT systems into real production environments for customers (Courtesy The ExOne Company)*

**Indo-MIM**

Bengaluru, India-based Indo-US MIM Tec. Pvt. Ltd. is the largest manufacturer of metal injection moulded (MIM) parts for the aerospace, automotive and other industries, and operates manufacturing facilities in Bengaluru and in San Antonio, Texas, USA. In May 2019 the company entered into a strategic partnership with Desktop Metal, under which it has deployed a Desktop Metal Production System at its San Antonio facility, and plans to add a Shop System in the near future.

Of interest to the AM world is the fact that Indo-MIM, as a leading MIM supplier, is already engaged in the downstream sintering of MIM parts. The deployment of BJT technology simply adds an alternative source of green parts in the upstream stages. So it is particularly interesting to understand its vision for automation, since it understands very well how automation of the process can result in cost-efficient production.

Jag Holla, Senior VP Marketing of Indo-MIM's US operations, explained that the company views BJT as being in its infancy, but predicted that within the next two years it would mature considerably. He noted that automation would be required if the process were to grow into production scale.

Indo-MIM is satisfied with the strength of the green parts, which are at least as strong as the MIM parts that they are familiar with, if not stronger. Holla foresees that it will not be a problem to automate the unpacking stage using existing robotic technologies. Currently, depowdering is a manual process that takes up to three hours. If the machine were to run in low labour-cost locations, manual processes are not an issue, but in high cost locations the manual depowdering process becomes expensive. Holla estimates that this process can be reduced to about thirty minutes if automated, and envisages that powder removal will be achieved through the fluidisation of the unbound powder, making it easier to process additively manufactured parts.

For unpacking technology to make sense it should be applied to a facility running multiple machines, and currently there is not enough demand for the kind of parts where BJT makes sense. Generally, MIM is cheaper for larger quantities of parts, though Holla expects this will change as knowledge about DfAM expands among customers and build speed increases.

## What has been learned?

There are a number of takeaways or insights from our brief and anecdotal dive into the world of automation. Here is a summary:

**Some machines just aren't designed for automation**

Automation of the current installed base of PBF-LB will, in many cases, be a challenge, and will be costly, given that the machines were not designed with access to automated solutions in mind. New machines will emerge with greater levels of automation built in, or with an architecture that enables them to be connected to an automated environment with greater ease than is currently the case.

**Fragmentation is an obstacle to automation**

The existence of more than sixty suppliers of PBF-LB systems means that the market is quite fragmented, with great variability in the interfaces that would need to be developed for automation to work at the mechanical and process level.

**We need to look beyond powder**

Current industrialisation efforts that have actually been implemented relate mainly to the automatic supply and recycling of powder, but not generally to the processing of as-built parts themselves.

**Binder Jetting offers both the greatest possibilities and challenges**

Metal BJT technologies, a relative latecomer to the metal AM party, offer greater possibilities for the development of sensible automation systems, which also happen to make more sense for the production quantities that BJT is planning to offer. The impending entry into the BJT market of HP and GE Additive will add fuel to this trend, and it will be interesting to see how these companies address the automation issue.

One of the challenges to automation in BJT relates to the handling of green parts. This will have to be resolved, through mechanical means and/or by part design. Improvements in the chemistry of the binders may bring more robustness when using robotic handling, but it appears not to be a make or break challenge to the automation of BJT. What also needs to be considered is that many of the MIM producers who are driving the industrialisation of metal BJT are already masters of automation, with robotic pick and place systems used in the industry to remove parts from the injection moulding tools and correctly place on trays for debinding and sintering.

**Machine makers should focus on their core technology**

AM machine manufacturers, whether PBF-LB or BJT, should continue to focus on their core processes. Automation solutions should be provided by companies that specialise in automation, equipped with the experience and the tools to meet the needs of specific customers and unique applications.

**Automation must make business sense**

Automation must make business sense by facilitating the lowering of per-part costs, and will not be justified in many cases. Automation can also positively impact intangibles in an AM operation, such as health and safety concerns related to operating powder-based technologies, but business cases cannot rely only on soft factors, however important they may be to the overall risk of the business.

## In conclusion

Automation and part cost reduction will expand the applications for which AM makes sense. Many machine suppliers realise this, but to date, few have implemented practical automation solutions, either directly or through specialist automation providers.

The argument that automation does not make sense because there are not enough applications that need it will reach an inflection point. Machine providers will start to see automation as a way to increase the number of applications that can feasibly make use of AM, which in turn will fuel the development of automation systems.

As with many technological innovations, the early movers and risk takers willing to bet on automation in AM will reap the rewards, as their experience with the nuances of the AM process chain will turn into a competitive advantage.

## Author

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# Machine Learning and Additive Manufacturing: What does the future hold?

As industry marches toward automation, networked communication and robotics, Additive Manufacturing has a unique advantage. No other production technology has been designed, from its inception, to enable connectivity and communication; AM machines around the world are already producing more build data than any other manufacturing technology. If used properly, this data will provide the foundation for the development of Machine Learning tools that can improve and industrialise the AM process at nearly every point in the workflow. In this article, Chelsea Cummings and John Barnes, from The Barnes Global Advisors, discuss the present and future of Machine Learning in AM.

Manufacturing is on an accelerating march towards automation, networked communication, and robotics. The internet collapses great geographical distances so that immense amounts of data created through manufacturing processes can be shared easily and quickly. This assemblage of different disciplines then feeds into what is called Industry 4.0 – the Fourth Industrial Revolution, which picks up from the Digital Revolution (Industry 3.0) that gave us the unimaginable computing power we rely on today. With Industry 4.0, anything that generates signals or data can be connected to the internet, making that item more efficient or more useful to more people. Generating data is only useful to a society if we can balance the quantity of data created with the ability to turn it into usable, actionable information.

Additive Manufacturing, having been born with the internet, has always enjoyed the connectivity and communication potential that its manufacturing brethren did not have. AM, being a digital process, can generate terabytes of data during a build. The value of AM lies in the design of performance-optimised components that can only be built with AM technology. By enabling components which would usually be made of multiple parts to be produced in one piece, AM also contributes to the minimisation of assembly and with it, touch labour. With Artificial Intelligence (AI) and Machine Learning (ML), this data or digital input can then be used to optimise the physical output. We hope this translates to increased productivity, higher yield and the ability to close the loop on quality control rather than relying on costly 'after the fact' inspection processes.

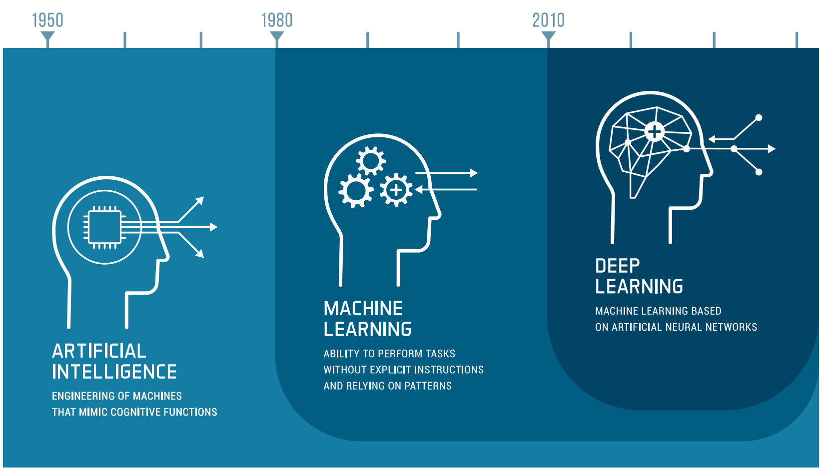


*Fig. 1 The evolution of AI and ML over the decades*

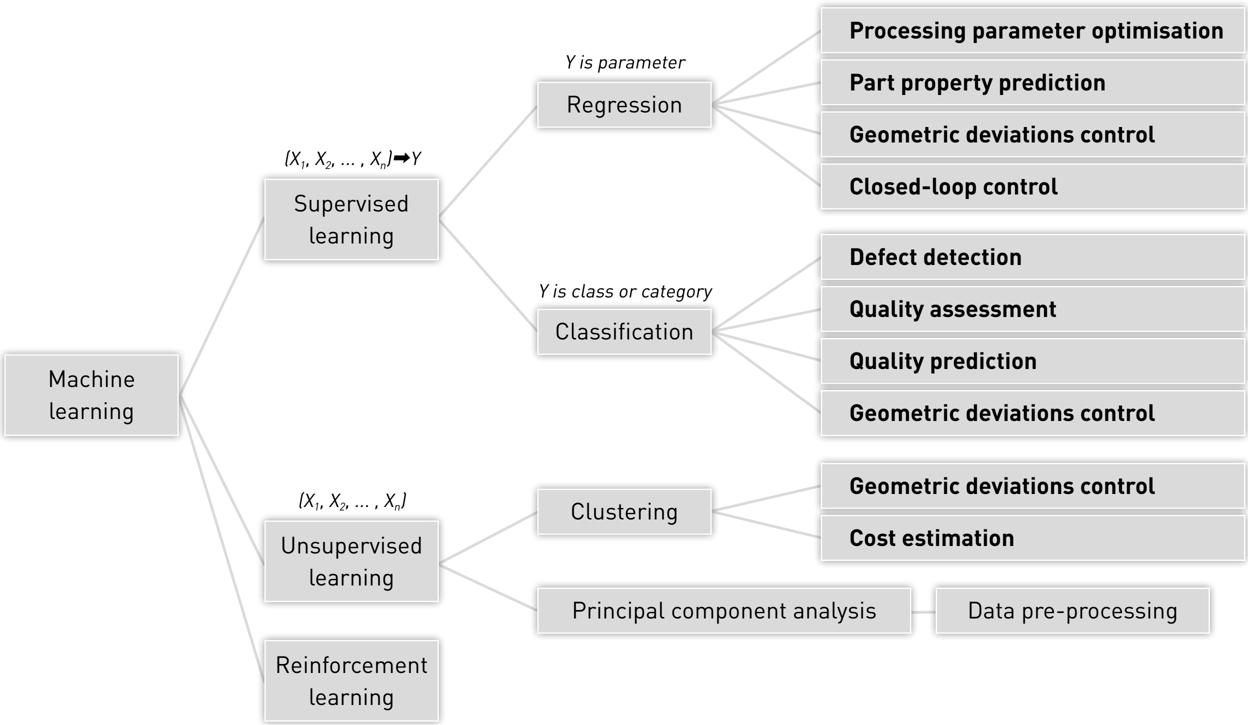


*Fig. 2 CCDC Army Research Laboratory Cooperative Research and Development Agreement 19-013-001 created a useful diagram to categorise ML approaches in use today*

## What is Artificial Intelligence and what's possible?

Broadly, one can think of AI as the ability to replace human intelligence in decisions or actions. AI is thought to be an aspirational target, in that the definition may change over time as we learn what is truly possible.

AI dates back to 1955, when it was founded as an academic discipline. Since its inception, it has been associated with reasoning, knowledge representation, learning, perception and natural language processing. Initially being applied to game playing techniques, like having computers beat humans at checkers, AI saw a leap in capability with the rapid improvement of semiconductors and transistors that afforded the computational power and speed to tackle large datasets. In the 1990s, AI was used for data mining, logistics, and scenarios which were complex, had a lot of data and some prescribed relationships. We're going to review Machine Learning, which is a subset of AI.

There are many current examples of how AI has impacted both our daily lives and the field of Additive Manufacturing. Our desire is to focus on ML specifically, illustrate where ML is in use in AM and provide a perspective of where we think it could go — or, perhaps, where we wish it would go — to improve the field of AM from a user's point of view. Today, ML is being integrated into various different facets of AM. It is employed to improve parameter development so that we get to an optimised result faster than our preferred Design of Experiments; it is being coupled with multi-spectral data to learn and predict quality outcomes so that we can improve throughput and productivity on the printers; and it is being developed into other products on the drawing board to make build-time estimations better, speed up design iterations, explore trade space for cost and weight performance and improve our ability to impact part performance by examining the powder.

## What is Machine Learning in comparison to AI?

ML is a subset of AI. As described by Carnegie Mellon University Professor, Dr Manuela Veloso, Machine Learning "is a fascinating field of Artificial Intelligence research and practice where we investigate how computer agents can improve their perception, cognition, and action with experience. Machine Learning is about machines improving from data, knowledge, experience, and interaction."

Specifically, in this article, we are going to address the concept of improving a machine's performance from data, knowledge, experience and interaction. It is the ability to handle large amounts of data with modern computational power that enables this. When we add the ability to leverage experience and interaction between datasets or actions and consequences, is when things get really interesting. Data exists all around us today, as we have migrated from analogue systems to digital systems. This data could be health data, weather data – or in our case, build performance data, inspection data and mechanical performance data. The key is being able to turn the massive amount of data generated into useful information to improve the machine's performance.

Dr Tom Mitchel, Professor at Carnegie Mellon University, frames the opportunity from the computer perspective: "How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?"

Next to the data sets involved, the ability to leverage experience to automatically improve algorithms is key to appreciating Machine Learning. Take, for example, the case of hurricane forecasting: these forecasts save millions of dollars by limiting evacuation areas, but in the early stages of predicting the track of a storm, models sometimes predict tracks that do not coincide with the actual track that the storm eventually follows. Hurricane forecasters effectively use data assimilation to constantly update their model predictions and uncertainties. As data is assimilated over time, the uncertainties decrease because the period of prediction (i.e., extrapolation) becomes shorter as a hurricane nears the region of interest (i.e., the location where it will make landfall).

There are four broad types of learning [1]:

**Supervised Learning**

Algorithms try to model relationship and dependencies between the target prediction output and input pairs. The labelled input (e.g., a vector) is paired with an output value (e.g., a signal). The benefit here is that we could predict an output with new data because we've formed a relationship that affords us the ability to predict the output for unseen situations.

**Unsupervised Learning**

Algorithms are trained for pattern detection and descriptive modelling. Labels are not attached to the data, so the model trains simply on the raw data. In this approach, the methods employed can be principal component and cluster analysis, which groups the unlabelled data and looks for commonality.

*Fig. 3 The image on the top shows the scan of a measured layer, with support material (white) and the actual part (red), which trains the algorithm to make adjustments and improve. The final part is shown below (Courtesy Inkbit)*

**Semi-supervised Learning**

Algorithms are a hybrid of the prior two. Sometimes, all of the data does not have labels, though some may [2]. Labelling of the data would be exhaustive, so in this form the model is built acknowledging that some relationships are known (labelled), but allows for others to be unknown. The unlabelled data still carries useful information about the group.

**Reinforcement Learning**

Algorithms continuously learn from the environment with iteration. By using observations from interactions with the environment, the computer gets smarter each time it is given a risk vs reward proposition. Here, the algorithm works similarly to a game, where the goal is to win but the environment causes the experience to change with time over a near-infinite possible number of combinations.

Further detailed in Fig. 2 [3], the algorithmic learning types' applications start to take shape. With the flowchart approach, we can perhaps infer what basic method is potentially being used to achieve the ML innovations that we are seeing today, and those that are on the horizon tomorrow.

Clustering appears more than once in the following examples, perhaps indicating this as one of the most suitable approaches for ML development in AM. To further define clustering, it is considered unsupervised because it automatically groups data based on similarities that appear naturally within the data. The data is not labelled such that data point A belongs in so-called Group 1 or data point B belongs in Group 2; a cluster is formed by data points very alike each other and very unlike other data points. The label of a given cluster or group is, however, up to


*Fig. 4 Screenshot of the Senvol ML software interface. The parallel coordinate plot on the right shows the range of laser power, scan speed and hatch spacing an AM user should use if they would like to make stainless steel 316L coupons with 50% probability that UTS is 720 MPa or greater and 50% probability that yield strength is 560 MPa or greater*

the user to understand, define, and assign actionable meaning to [4].

The intent here is to describe how ML is contributing to Additive Manufacturing today and suggest where it could go. Our approach is from a user's perspective. For a more detailed, technical explanation of ML in AM, refer to the journal articles by Meng, Williams, Jarosinski *et al.* [5] and by Johnson, Vulmiri, Zhang, Brice *et al.* [6], as we intend this article to be focused on the holistic and commercial advantages of ML in AM. As ML is better understood by more people, we seek to understand what it could do from a uniquely AM-focused perspective, and how it could help the industry to further industrialise, safer and faster.

## Machine Learning in AM today: The current state

ML is already present in AM product development, but the integrations have not yet been fully realised. We are seeing data, which may be from traditional sources, or multidimensional data, that advises algorithms that can notify users of improvement opportunities. From powder feedstocks, to materials design, through to the AM machine in the form of parameters and ultimately with parts, ML is now firmly a part of the growth of AM. The learning types' data inputs could be in the form of images, chemistries, sensor data, mechanical property data and volumetric information, such as Computed Tomography (CT). Ultimately, we can combine volumetric information and characteristic descriptive data to predict an outcome. In this article, we'll examine different facets of AM to describe ML in use today and what is on the horizon.

### Machines

Inkbit is a new entrant to the AM space, having emerged out of Massachusetts Institute of Technology (MIT) in 2017. Its process is most closely related to Material Jetting, in that it forms a bonded layer by jetting resins with different properties, for example elastomers. The company uses a proprietary 3D scanning system to generate a topographical map of each layer after deposition (Fig. 3). From this data-rich map, it can observe and detect any discrepancy from the expected geometry.

Inkbit uses ML through a neural network of different image processing algorithms. The CAD file that is supplied is 'unknown', meaning that the company does not immediately know how the file needs to be altered so that the additively manufactured part matches requirements. Using a form of unsupervised ML, the company can correct the deviations in subsequent layers. This data then trains the ML algorithm so that the machine can learn the properties of each material and anticipate its behaviour. Given (Fig. 2), we might expect a clustering type of approach to yield a specialised type of geometric deviation control in this case.

  

**Materials & processes**

When speaking of big data, it should be made clear that it is useless unless fed into a big analysis. ML is, necessarily, the key factor in making sense of such large data sets. AM machines generate a large amount and variety of data types during each and every build. Autonomous regression modelling is needed to put data that is dynamically changing or has a kinetic component to it to use. Perhaps one of the greatest opportunities to put ML to work within the AM industry is in correlating materials with specific parameter sets to achieve a known, good material output and thereby qualify a fixed process. Working real-time data analyses for such large datasets by hand is tedious and can be subjective. Letting computers do it in the background will get the industry much farther faster, yielding more accurate results.

Senvol is answering the call for an autonomous characterisation workflow of AM processes and materials with its proprietary data-driven ML software. Agnostic to machine, material, and process, the software is being used to support the characterisation of AM processes and materials, optimise process parameters, predict material properties and support quality assurance. For example, utilising predictors – common parameters such as power, scan speed and hatch spacing – users can correlate the probability of meeting desired mechanical properties that are isolated from geometric effects. Fig. 4 is a visualisation of this feature. By this ML approach diagram, we might infer a number of regression vectors are being used to indicate the outputs.

**Design**

Once a process is established for a given material, suitable applications for AM production are chosen. A fixed parameter set may have proven that it produces good material, but yield is still highly dependent on design. Adapting or modifying a design for a given parameter set is one step, but optimising the design to leverage all of the advantages of AM is a wholly unique effort. The latest products in software development look to consider both.

Already widely recognised as a major digital innovation in AM, generative design has changed how we explore design spaces and optimise structures. To date, generative design has mostly been used to optimise for load path where strength and stiffness dominate. It can also be used for scenarios looking to optimise for thermal or vibration. ParaMatters' CogniCAD software, for example, can optimise and structurally analyse its own output for stress, vibration or thermal cases. Not only does it effectively produce topology-optimised structures for AM processes (Fig. 5), it can also create optimised outputs for casting and CNC applications. ParaMatters uses ML primarily in two different areas: first in the generative design process, which uses gradient-based optimisation methods that employ neural network training of the software, and second, in the design of support structures, which is optimised with unsupervised clustering algorithms.

**Quality assurance**

AM processes generate a lot of data, but little is truly monitored in a real-time sense. Reviewing build logs and layer camera images can assist in saving time and money by catching defects created during the build before they move downstream and more value is added. Monash University spin out Additive Assurance has taken up the challenge to make more use of the data while it is being generated, in a product it calls AMiRIS.

Additive Assurance's patent-pending process uses a suite of optical sensors, mounted external to the powder bed Additive Manufacturing machine to gather micron-level detail. It observes the build process in near-infrared and

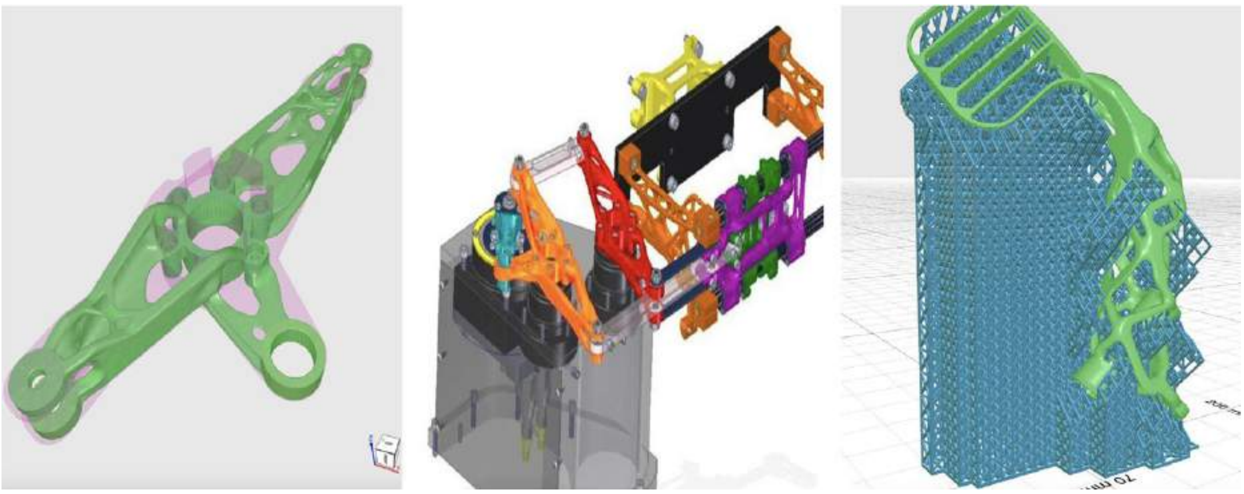

*Fig. 5 CogniCAD stages of optimisation and analysis. First optimised is the part's geometry which is analysed individually and then within its greater assembly, next support structures are applied and optimised for a given build approach*

*Fig. 6 Additive Assurance AMiRIS, external quality module*

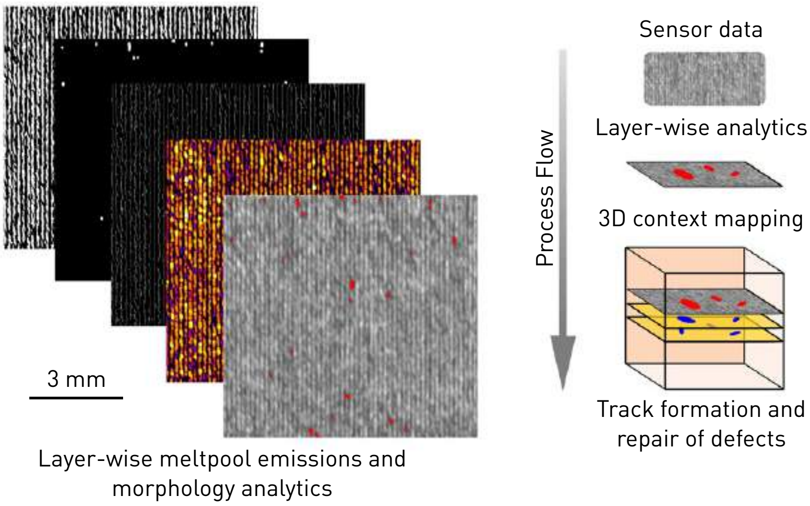

*Fig. 7 Additive Assurance AMiRIS, external quality module*

converts that data into insight on the health of the build (Figs. 6, 7). The company employs a deep learning algorithm which has been trained to look for events that lead to problems or possibly even failed builds. When the sensors pick up an anomaly, AMiRIS assigns it to one of the following categories:

1. This situation results in scrap – AMiRIS can act to terminate the build
2. The anomaly is suspect - AMiRIS asks a human to intervene
3. A scenario that will right itself and requires no human intervention.

As a quality assurance tool, the algorithm has been trained initially via data from a variety of parts, machines and sources, and continues to learn. It can look for laser scan errors, geometric variances, recoater errors, lack of fusion and over-melting. When allowed to connect to the internet, the sensor package will gain the benefit of 'the wisdom of crowds' by learning from other machines that are connected.

Even if operating remotely, the algorithm will continue to learn, just at a slower pace. The data is converted into information via 2D and 3D process maps which characterise 1) Defect Type, 2) Anomalies and 3) Machine Errors. Additive Assurance likes to render this as a simple equation: Melt pool emissions + melt pool morphology + over multiple layers + machine learning = quality assurance production.

## Machine Learning for AM tomorrow

**Super powder approach**

Srujana Rao Yarasi is a PhD student at Carnegie Mellon University and, along with her supervisors, Prof Elizabeth Holm and Prof Tony Rollett, is working on a new method, combining input data to study what they call the 'super powder approach' (Fig. 8). To the layman, this means they are taking immense datasets to create a model of models. When successful, they could predict a powder's ability to spread, for example, in various machines with any recoater system by imaging the powder. Comparing the data to a 'standard' powder could also mean faster qualification times and more flexibility for the AM machine user to buy feedstock materials.

Large datasets, in this instance, are SEM images of powder particles used to quantify morphology in order to link size, sphericity, surface texture and more to the powder's flowability properties.

Data also takes on another form that could aid powder characterisation: Computed Tomography scans of powder particles as a means of predicting porosity. This form of unsupervised learning is new, as it combines Computer Vision and ML algorithms to use vectors versus discrete points. As Yarasi put it, "With this method, we intend to get any powder to perform its best." CT files are routinely described in terabytes, so are very data rich and thus best suited for autonomous algorithmic computing. Again, we see unsupervised learning employing clustering to employ geometric deviations control, as seen in (Fig. 8).

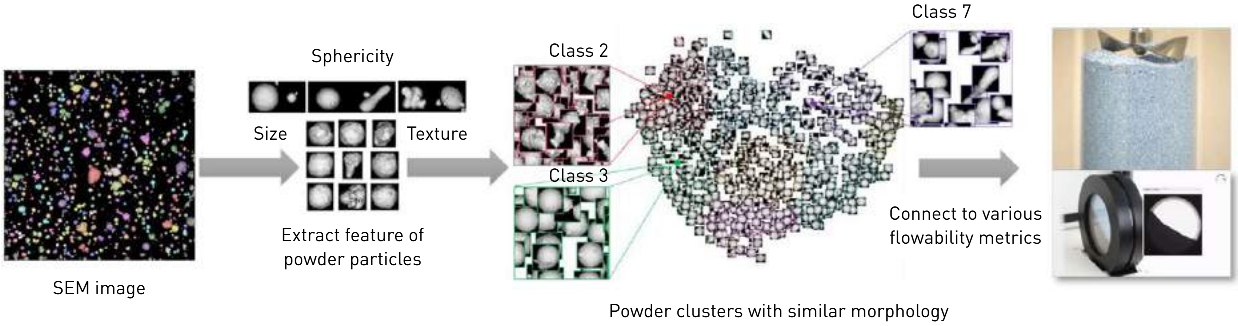


*Fig. 8 Super Powder Approach visualisation*

**Simulation**
Similar to CMU's Super Powder Approach, startup Exlattice is attempting to take a hybrid approach with ML. Its goal is to speed up the process of simulating the build and associated processes, and it is doing it by coupling physics-based modelling, i.e. Finite Element Analysis (FEA) with ML. Simulating the Additive Manufacturing process has proven to be a challenge given the computing processing time required to crunch through the dynamics of the process in any kind of meaningful accuracy.

*"3YOURMIND plans to employ ML through its Machine Connectivity feature, which leverages OPC/UA's Umati data model to achieve a digital connection between AM machines and their existing Manufacturing Execution Systems."*

Process simulation is used as a tool to avoid expensive build failures caused by overheating, large deformation, and residual stress, and it's not unusual for a simulation-based FEA to take a day to run, or longer.

The Exlattice hybrid approach finds a particular way of integrating ML models with traditional FEA which could translate into greater simulation speed improvement potential. The consequence to model complexity and accuracy will be key. The company is developing simulation engines based on the hybrid ML + physics model for metal Powder Bed Fusion (PBF), Binder Jetting (BJT), sintering of green parts, and other AM processes.

In this approach, ML via semi-supervised learning also allows a unique interface to continuously feed in data from experiments, daily operation, and potentially in-situ monitoring. ML with these data can help improve the physics part of the model, making it increasingly more accurate and faster to set up for users, which is another advantage compared to the traditional simulation tools. While not annotated in Fig. 2, we can surmise that semi-supervised learning is perhaps combining clustering of failures to liken to labelled defect classifications.

**Value proposition**
Another aspiration of ML in AM would be the ability to liken process data to a given part's value proposition. Correct application identification in AM is essential to the industrialisation of the technology. To decision-making executives in any organisation, the critical component of any project investment is its value proposition, AM being no exception. For this reason, the selection of parts to which AM should be applied must be carried out accurately and efficiently; there is only so much tolerance for force-fit endeavours.

ML developers in AM understand that the best advisor to that selection is the process itself, in terms of producibility and affordability. AM workflow software developer, 3YOURMIND, recognises this and has developed a solution that rapidly selects parts for further review by applications engineers to determine if they are suitable projects for the technology. 3YOURMIND plans to employ ML through its Machine Connectivity feature, which leverages OPC/UA's Umati data model to achieve a digital connection between AM machines and their existing Manufacturing Execution Systems (MES). This will be the vehicle by which the company grows ML capabilities to further advance its existing products, such as the application selection solution. It can be imagined that supervised classification and unsupervised clustering could be utilised to employ geometric deviation control in conjunction with cost estimation, as per Fig. 2.

**Safety**
An indirect application of ML in AM is in the field of safety. Today, we employ cameras and other detection devices for safety and security monitoring, but this approach is not truly effective in preventative safety, only offering event data after the fact. Be Global Safety (BGS) has employed ML to train its algorithm to spot unsafe situations

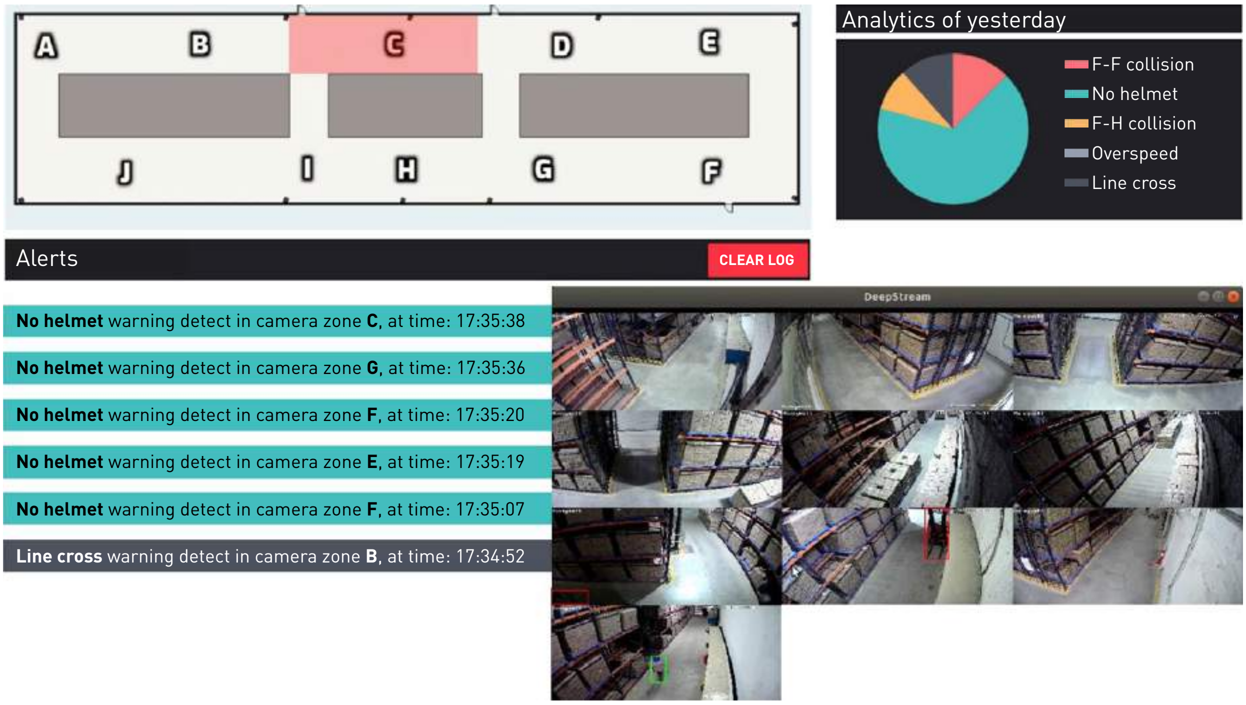


*Fig. 9 This image shows the dashboard of the BGS tool, where we can see the area where there is a non-compliance which puts out an alert in real time*

and make instant notifications for human intervention. To do this, the company employs deep learning technology, a form of supervised learning.

BGS digitises the environment, including health and safety considerations, in manufacturing. It is effectively a real-time safety solution that can be trained to assist in complying with local, national, and international safety standards. The use of ML allows digitisation of current safety operations, but in the process also creates a tool for virtual safety audits (Fig. 9). Updates can then be incorporated instantly to advise human observers as new threats emerge. In line with today's coronavirus (COVID-19) safety measures, for example, wearing a face mask would be important, and compliance can be measured quickly. As BGS puts it, "These digital updates to safety standards, machine specifications and required training are of great importance to advanced manufacturing technologies like Additive Manufacturing, where the technologies continue to evolve at a breakneck pace."

**Design**

Finally, ML can fully close the data feedback loop by influencing new designs to be fully adapted to the AM process, as well as fully leverage its benefits. With poorly-adapted design arguably being the Achilles's Heel of this technology, it is becoming an increasingly important requirement that the manufacturing process begins not at the part build, but at part design. This will be achieved by harmonising several ML approaches' results to feed back into step zero of manufacturing operations: Design.

Materials, process and simulation data that advise producibility, thereby value proposition, could ideally be likened to specific features that comprise a mechanical design engineer's toolbox. Quality monitoring could mature from simple pass or fail metrics to a dynamic rating that indicates the best inputs to achieve the best outputs. Indicators sophisticated enough for design advisory will likely require all the types of output vectors, intelligently weighed to properly serve the described purpose.

## Summary of benefits for tomorrow

We see the ultimate benefit of Machine Learning in AM as the reduction of guess work for more data-based decision making. The current approach for most companies is a lengthy confidence-building process with static data points, which is not only costly, but tedious and difficult. AM is complex and multi-disciplinary, and humans can have difficulty taking in many data fields coupled with time, temperature, movement, and materials kinetics. ML will utilise the copious amounts of data generated during the AM process for training the algorithm in real time. We see the main benefit of this as increased confidence, which then manifests in programme savings which will speed up the industrialisation of the technology.

As we have described, ML is used in the workflow preceding and following the build event. Before building, it is present in design and process robustness analysis. Following the build process, it is employed in the product to ensure that what was made meets the product requirements. ML is also making our industry safer in the manufacturing environment. Successfully understanding links between outputs and inputs, those links are fed back into the workflow, satisfying continuous improvement – while often still manual, there is opportunity for automation in this area forthcoming.

Continuous improvement is a tenant of Six Sigma, a popular tool used in manufacturing to reduce defects. It applies mainly to operations that are repetitive, because it needs statistically significant populations of data to feed it. Just as these data points are somewhat static, ML enables us to capture significantly more data, perhaps in multidimensional form, which gives a much richer description in order to enable algorithms to continuously improve. Continuous improvement is a key facet of manufacturing, and ML is bringing the tools to make AM improve continuously.

## Conclusion

It is obvious that AI has come a lot farther than a single input achieving a single output, but it is going to take ever greater employment of ML to further AI in AM in terms of achieving entirely optimal output. We must now connect many input variables to widely variable outputs. An almost entirely digital process, AM is one of the most suitable technologies for ML to evolve. In AM exists a situation in which data can be autonomously mined and analysed in the background; humans can then have time to consider actions that require implicit understanding, which computers can only emulate.

It is interesting to see that ML is in use not only to help us make things faster, but also to help us learn things faster. The algorithm's ability to take in so much data enables humans to explore more trade space faster – or to decide not to explore space that is unlikely to be fruitful. Once learnt, the continual introduction of new data allows the algorithm to get smarter, facilitating better and more consistent output.

As technology seems to be getting continually 'smarter', it is, in fact, only as smart as we tell it to be. The algorithms we write, even if unsupervised, ultimately require us to assign meaning to the results they present us. We are excited to see this is apparent today within AM machines themselves, such as in Inkbit's neural network of topography scans; in process and material characterisations, per Senvol's innovation; in ParaMatters' unsupervised clustering ML that aids generative design; and in Additive Assurance's in-situ anomaly detection.

Tomorrow's ML solutions promise rapid powder inspection via CMU's Super Powder Approach, intelligent value proposition analysis per 3YOURMIND's research, an advanced outlook for ensuring safety compliance by Be Global Safety, and, ideally, the development of fully considerate designs of process constraints and performance enhancements unique only to AM technology.

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## References

[1] https://medium.com/towards-artificial-intelligence/differences-between-ai-and-machine-learning-and-why-it-matters-1255b182fc6

[2] https://towardsdatascience.com/types-of-machine-learning-algorithms-you-should-know-953a08248861

[3] CCDC Army Research Laboratory Cooperative Research and Development Agreement 19-013-001

[4] https://hub.packtpub.com/introduction-clustering-and-unsupervised-learning/

[5] Machine Learning in Additive Manufacturing: A Review, Lingbin Meng, Brandon McWilliams, William Jarosinski, Hye-Yeong Park, Yeon-Gil Jung, Jehyun Lee, and Jing Zhang, *JOM*, Vol. 72, No. 6, 2020

[6] Johnson, N. S., P. S. Vulimiri, A. C. To, X. Zhang, C. A. Brice, B. B. Kappes and A. P. Stebner (2020). "Invited Review: Machine Learning for Materials Developments in Metals Additive Manufacturing." *Additive Manufacturing*: 101641, https://doi.org/10.1016/j.addma.2020.101641.

  

# System 3R: Bridging critical gaps in the Additive Manufacturing workflow to enable serial production

In conventional subtractive manufacturing process chains, components move efficiently throughout a production chain using pallets and standard referencing and clamping systems, enabling parts to be automatically processed by a variety of technologies as they move through a facility. GF Machining Solutions' System 3R division has leveraged its expertise in this area to create a tooling solution tailored to Laser Beam Powder Bed Fusion (PBF-LB) production. As Dogan Basic, Product Manager AM, explains, this optimises workflow, increasing the potential for AM automation and, as a result, for successful series production.

In the world of machine tools, and within industrial processes linked to machining and automation, it is common to encounter pallet handling. This process allows a pallet, on top of which the final application has been fixed, to move efficiently throughout a production chain using standard referencing and clamping systems.

In industry, an infinite number of different products can be manufactured with a wide variety of machines and solutions – thus, tooling flexibility is essential. Key benefits of pallet handling are reduced machine setup times, constant repeatability of work cycles, and reduced machine downtime due to human error.

Now well established in an ever expanding range of industrial fields, metal Additive Manufacturing, and specifically Laser Beam Powder Bed Fusion (PBF-LB), is advancing as a viable technology for serial production. This brings new challenges, such as the need for greater integration with other technologies in the manufacturing production chain and increased automation. In order to achieve high quality and productivity in serial production, manufacturers must ensure the highest levels of process repeatability and reliability.

Unfortunately, even those AM manufacturers which have integrated AM automation technology to the most advanced levels currently available often still use manual processes for some post-finishing operations, whether due to the absence of tooling or the use of equipment that has not been sufficiently adapted for AM process automation. This creates a wide range of constraints that can negatively impact the cost-effectiveness of metal AM.

*Fig. 1 An AMcarrier and BuildPals inside a DMP Flex 350 PBF-LB machine (Courtesy System 3R)*

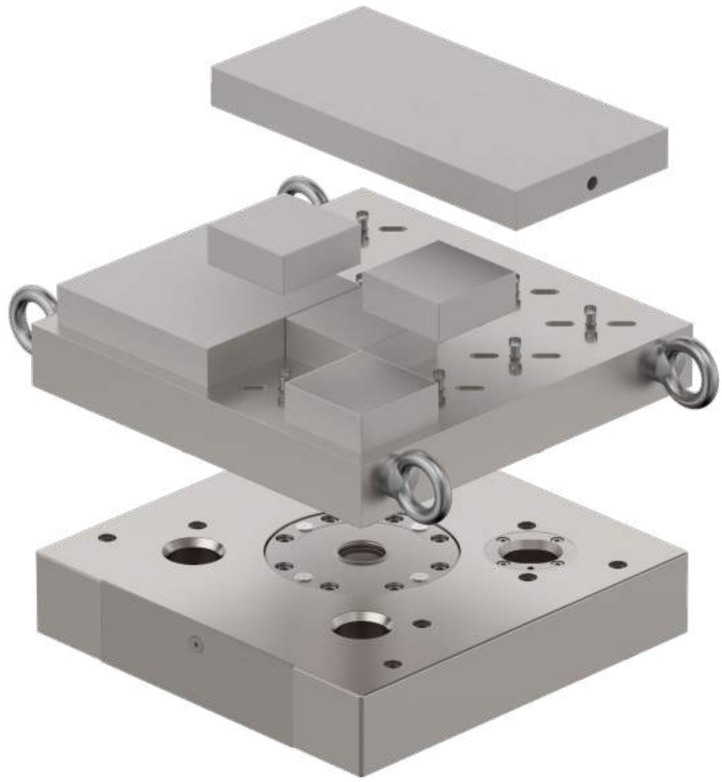

*Fig. 2 An exploded view of the System 3R Tooling solutions for AM. From bottom to top: the Delphin TableTop Chuck, the AMCarrier, and BuildPals of various sizes (Courtesy System 3R)*

These complications begin with the setup inside the Additive Manufacturing machine, where the absence of tooling necessitates manual build plate attachment and levelling. Dismantling the build plate can also be tricky because of the unscrewing operation inside a powder environment.

Yet the real issues come into focus during the post-processing stage: AM parts are often produced with lightweight and bionic geometries, making handling and clamping a very complex procedure. These shapes require the production of dedicated fixtures, as they generally cannot be mounted directly into a vice or other standard clamping tool.

In order to enable the automation of AM part finishing, it is therefore advantageous to keep the part linked to an individual, easy-to-clamp pallet which enables pallet-handling automation. Only once most processing operations are complete is the part separated from the pallet. This provides the added value of facilitating part referencing across the complete process chain.

Without tooling solutions designed for AM workflows, the advanced design and production possibilities for series production offered by technologies such as PBF-LB may remain out of reach.

## AM tooling solutions from System 3R

GF Machining Solutions, which includes milling, tooling and AM technology in its broad portfolio of manufacturing technologies, has partnered with manufacturers to develop complete, end-to-end AM workflows for serial part production. This includes the use of products that it has developed through its System 3R tooling business, which draws on the brand's long experience in the development of advanced pallet and automation systems for industry.

Through its collaboration with several Additive Manufacturing machine makers, System 3R has developed a complete AM tooling portfolio that enables users to avoid the problems that can arise when tooling is not optimised for AM. These solutions are designed to handle production across the entire AM workflow by addressing challenges that are specific to AM parts production, and deliver the necessary repeatability for serial production, even under the harshest conditions.

With these solutions in place, high temperatures, powder-filled environments and potential build plate deformations no longer pose a barrier to effective pallet handling and the efficient production of the highest-quality parts. The System 3R tooling portfolio consists of several individual components, each of which has been fully optimised for its use case to allow manufacturers easy access to the advantages of AM.

These solutions also serve as the hardware that links together GF Machining Solutions' full AM workflow, showcased with 3D Systems in the DMP Flex 350 and the DMP Factory 500 machines.

**The Delphin TableTop Chuck**

Designed for use within the build chamber of the DMP Flex 350, the Delphin TableTop Chuck was developed to enable an operator to set up build plates within one minute (See Fig. 1 and 2, where the TableTop Chuck is the lowest component in the system). A protective cover keeps screws clean for ease of use, while a direct interface with System 3R's build plate solution, the BuildPal, minimises the tooling height to enable the largest possible build area.

Much of the ease of setup comes from the use of simple drawbars, designed to enable zero-point clamping. The hole pattern enables a wide range of configurations, but the most important benefit is the ability to maintain very precise positioning. Furthermore, by acting as the central point for holding build plates or System 3R's AMCarrier system, any stresses produced during the build process are kept from influencing the machine table.

**AMCarrier**

The heart of the System 3R AM tooling system is the AMCarrier (Fig. 3, lowest component), which links the chucks and the build plates (or BuildPal, visible with parts attached in Fig. 3). Its pin grooves allow build plates to be mounted to the AMCarrier in a number of positions, as well as being an effective system for clamping preforms to carry out hybrid part production. Unlike a simple pallet, however, the AMCarrier is designed specifically to work in concert with the System 3R BuildPal, the AM tooling portfolio's build plate, to compensate for deformation caused during the build process.

A patented elastic solution creates a semi-rigid work environment that can adjust throughout the build process. This significantly extends the life of the build plates and prevents issues that can require longer refurbishing processes.

The AMCarrier also acts as the workholding solution for the AgieCharmilles CUT AM 500 wire-cutting Electrical Discharge Machining (EDM) machine. Following post-processing, the AMCarrier unit can be fitted onto the CUT AM 500's tilting table, which flips the parts 180° to separate them from the build plates (Fig. 4). This separation process creates a fine, EDM-finished surface, and prevents any damage to the parts or build plates for improved process stability.

**BuildPal**

System 3R's BuildPal build plates give the system its advanced flexibility and help to maintain reference points, even in advanced AM production strategies or across automated workflows. In order to maximise the productivity of PBF-LB machines, build plates must accommodate multiple parts,

*Fig. 3 An AMCarrier with two sizes of BuildPal build plates attached (Courtesy System 3R)*

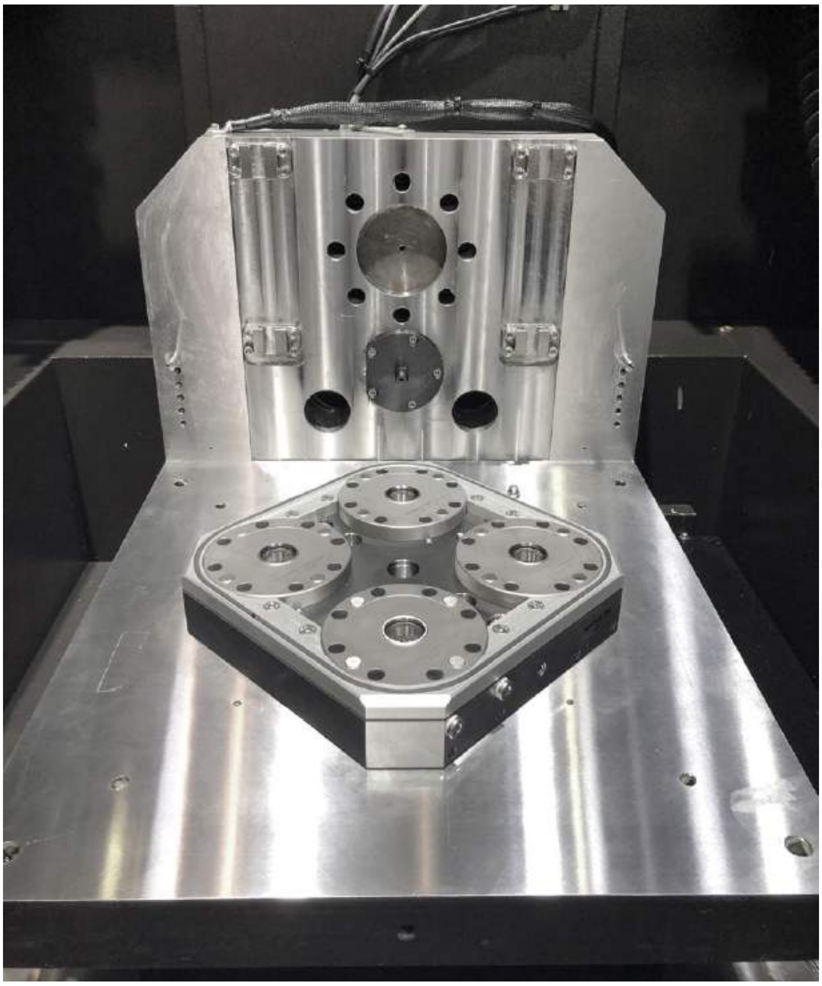

*Fig. 4 A DelphinCompact baseplate inside the CUT AM 500 wire-cutting Electrical Discharge Machining (EDM) machine (Courtesy System 3R)*

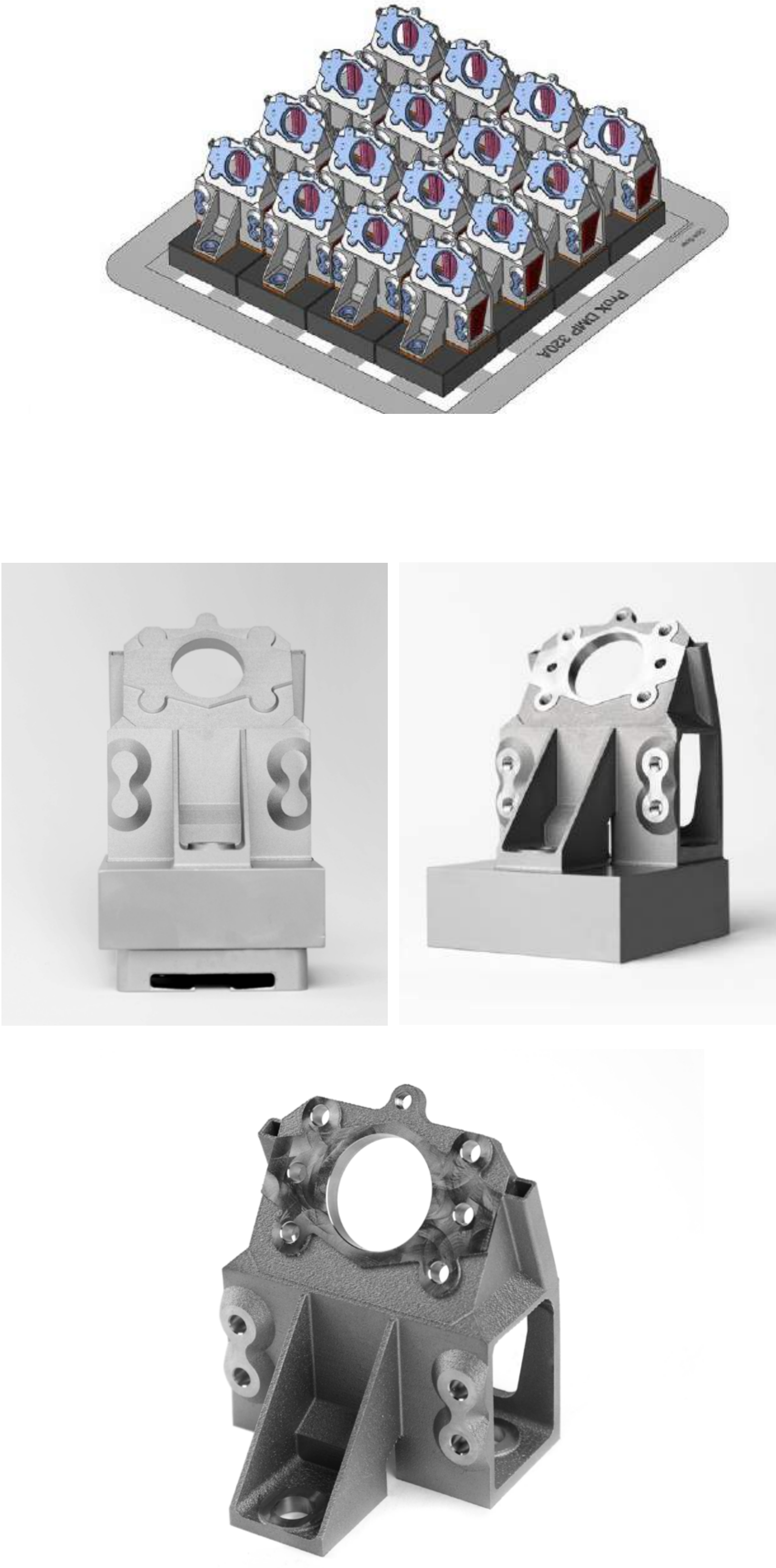

*Fig. 5 An aerospace satellite bracket case study developed with 3D Systems utilising the System 3R system. Top: parts arranged on individual BuildPal build plates; middle: a part on a BuildPal before machining (left) and after (right); Bottom: the finished part removed from the build plate (Courtesy System 3R)*

so the BuildPal is available in a range of sizes and materials that can be configured directly on the Delphin TableTop Chuck or the AMCarrier.

For instance, the 273 mm x 273 mm surface of the AMCarrier for the DMP Flex 350 features sixteen pin and groove positions. Using fastening pins and position or guide pins, BuildPal pallets ranging in size from 63 mm square to the full 273 mm can be affixed to the AMCarrier.

As a result, individual parts can be handled easily via their pallets without separation prior to finishing, maintaining reference positions for later processes. This also simplifies automation to a considerable degree. An example of this kind of pallet handling is an aerospace bracket case study developed with 3D Systems and showcased at Formnext 2019 (Figs. 5, 6). Thanks to topology optimisation, the weight of the satellite bracket, additively manufactured in titanium, was reduced.

## Post-processing

Metal AM can offer surprisingly fine finishes, but, in most cases, parts will require post-processing. Naturally, this means that the workholding in the milling machine must be compatible with the rest of a manufacturing process chain. The System 3R DelphinCompact baseplate serves as an ideal solution for this workholding application, as it can hold the complete AMCarrier with all BuildPals for single-setup finish machining.

In addition to the AMCarrier, DelphinCompact baseplates accommodate a variety of other chucks and workholding options for various production environments. A diverse range of drawbars can be used to accommodate different types of post-processing, from EDM to grinding and beyond.

Manual chucks and pneumatic chucks can be used when appropriate, and with System 3R chucks, it can be possible to hold numerous parts, such as 3D-printed dental bridges, at once for setup time reduction.

The DelphinCompact baseplate is also generally used for BuildPal refurbishment. Thanks to the regular maintenance of reference points, refurbishing operations are simple, and, following this process, the BuildPals can be used again. In combination with palletised automation, even this step can be conducted unattended, allowing for completely automated work cells.

*Fig. 6 BuildPal build plates benefit from the ability to use automated pallet handling for workflow optimisation (Courtesy System 3R)*

## Software for AM tooling

While System 3R AM tooling links the GF Machining Solutions AM workflow in terms of hardware, the software that makes this system work is 3DXpert® from 3D Systems. Thanks to the 3DXpert software, everything from the design stage to the finished part is managed with a single interface. The software also manages the production of preforms and post-processing using Mikron Mill technology.

Additionally, System 3R also offers software that can help manufacturers optimise their AM workflow, especially when it comes to linking the entire process through automation.

## Conclusion

AM has gone from a niche area of research to an advanced solution for serial production in a number of industries in a matter of years. However, the automation solutions required to make this technology viable at even low-volume production levels have only recently started to appear, including GF Machining Solutions' holistic, end-to-end AM workflows.

The technology remains complex. Indeed, simply dealing with AM-grade metal powder can be a challenge without automated modules. The critical piece of the jigsaw necessary to link all of the various machines together to form a single part-production system is effective tooling. With its AM tooling portfolio, System 3R provides that critical piece, and with it, truly seamless production which makes AM technology more widely applicable than ever before.

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## TK Mold and the production of 'hybrid' mould inserts

The use of AM as optimised by System 3R was used to great effect at TK Mold's factory in Shenzhen, China. Using an end-to-end AM workflow developed with GF Machining Solutions and 3D Systems, TK Mold achieved significant cost savings – and a cycle time reduction for its injection moulds.

The company's hybrid manufacturing approach depended on both the DMP Flex 350 – enabling the manufacture of advanced conformal cooling channel inserts in moulds for end products, thereby establishing precise locations on mould preforms with respect to build platform – and System 3R AMCarrier Tooling

For more information, see the article 'Hybrid inserts for mould and die production: How workflow optimisation can help make the business case for AM' in the Autumn 2020 issue of *Metal Additive Manufacturing*.

# Metal AM in South Africa: Research and commercial initiatives bring the benefit of AM to the African continent

The Additive Manufacturing industry in South Africa has come a long way since the installation of the country's first AM machine in 1991, with a number of research and commercial initiatives driving the development of world-class applications and knowledge. In this article, Terry Wohlers and Olaf Diegel, Wohlers Associates, present an overview of metal Additive Manufacturing activities in South Africa, from the technology's life-changing use for medical implants to its development for rapid, large-scale part production and beyond.

The first AM machine installation in South Africa was in 1991. Until 1994, a total of three machines operated in the country. During this time, the Council for Scientific and Industrial Research (CSIR) and a few universities worked to create interest in AM, with support from technology transfer programmes and industry workshops.

In many countries, AM membership groups and associations were forming. Back then, most referred to the technology and industry as 'rapid prototyping', because this was by far the most popular application. The founding meeting of the Global Alliance of Rapid Prototyping Associations (GARPA) took place at the SME RAPID event in Dearborn, Michigan, USA in 1998. South Africa was invited under the auspices of the Time Compression Technologies Centre (TCTC), and received an invitation to become a member of GARPA.

The Rapid Product Development Association of South Africa (RAPDASA) held its first meeting at the University of Stellenbosch in 1999, resulting in the first international RAPDASA conference in November 2000 at the CSIR, in Pretoria. This expanded awareness and validity of AM in South Africa's manufacturing space. By 2018, an estimated 5,700 AM machines were operational in the country.

South African companies are now pushing the boundaries of metal AM, resulting in world-class results. Three areas have emerged as strengths in the country: they include the design and production of medical devices,

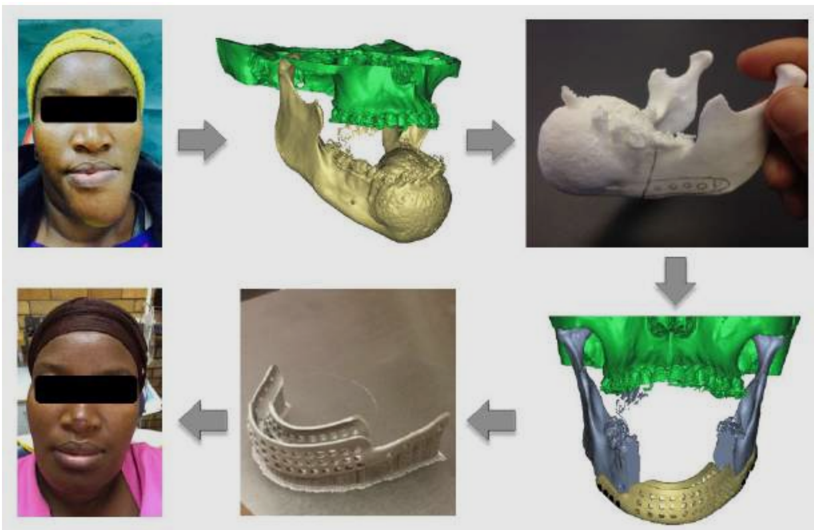

*Fig. 1 Clockwise from top left: The patient before surgery; medical scan data showing tumour; polymer additively manufactured model showing tumour; digital model of metal additively manufactured custom mandibular implant; additively manufactured titanium implant; the patient after the surgical fitting of the implant (Courtesy Centre for Rapid Prototyping and Manufacturing)*

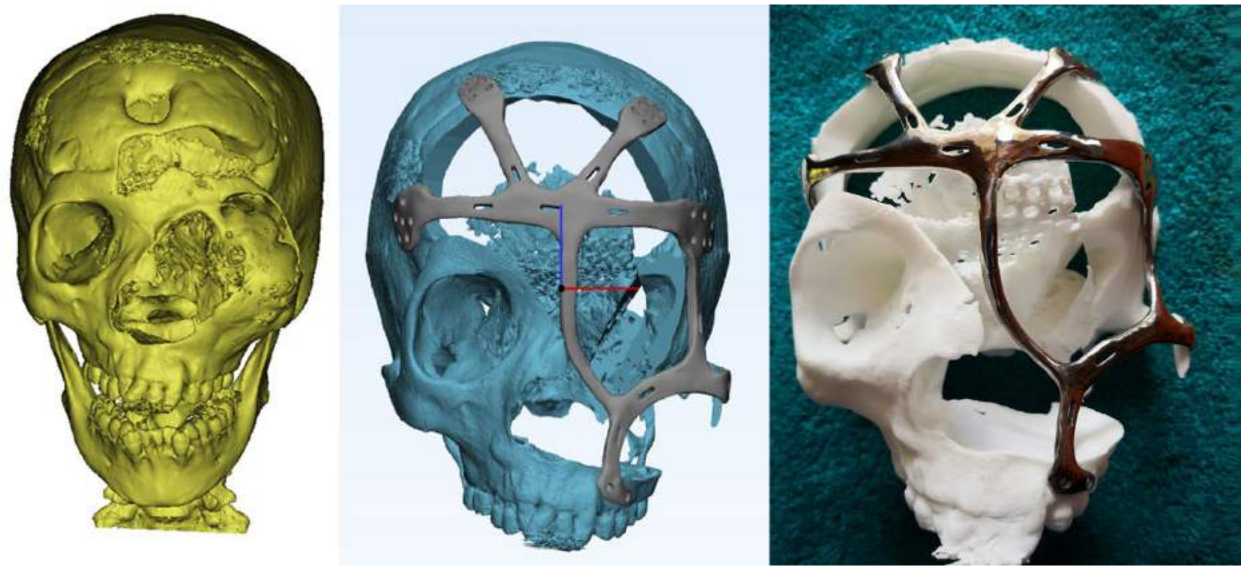

*Fig. 2 From left to right: Medical scan data; digital model of skull and custom implant; titanium implant shown on polymer AM model (Courtesy Centre for Rapid Prototyping and Manufacturing)*

aerospace parts, and foundry applications. In support of these areas, South Africa has an estimated eighty AM service providers, with an estimated twelve metal AM machines installed.

## AM adoption for medical applications

The Centre for Rapid Prototyping and Manufacturing (CRPM) at Bloemfontein's Central University of Technology (CUT), founded in 1997, is arguably the most developed and advanced AM facility in South Africa. It has produced thousands of medical implants and industrial parts over the past two decades, and received ISO 13485 certification in 2016, meaning its quality management meets the safety and efficacy requirements of medical devices. This certification applies to the design, development, and production of patient-specific titanium implants, preoperative models, jigs and nylon cutting guides by AM, and the production of these products on a contract basis.

With support from Materialise, Technimark, Stellenbosh University, and CSIR, CRPM produced a custom titanium implant for a thirty-two-year-old patient with ossifying fibroma: a slow-growing tumour that caused the expansion of her lower jaw. Using advanced methods developed over many years, the team resected the tumour and restored the function and appearance of the patient's mouth and jaw, as shown in Fig. 1.

Another project involved a complex titanium facial implant made by AM, shown in Fig. 2. The work was supported by CRPM's clinical advisor Cules van den Heever, as well as the Carl and Emily Fuchs Foundation, under the programme 'Changing Faces, Changing Lives'. The project won an award for being the best managed under the foundation, and an award recognising it as the project with the most impact.

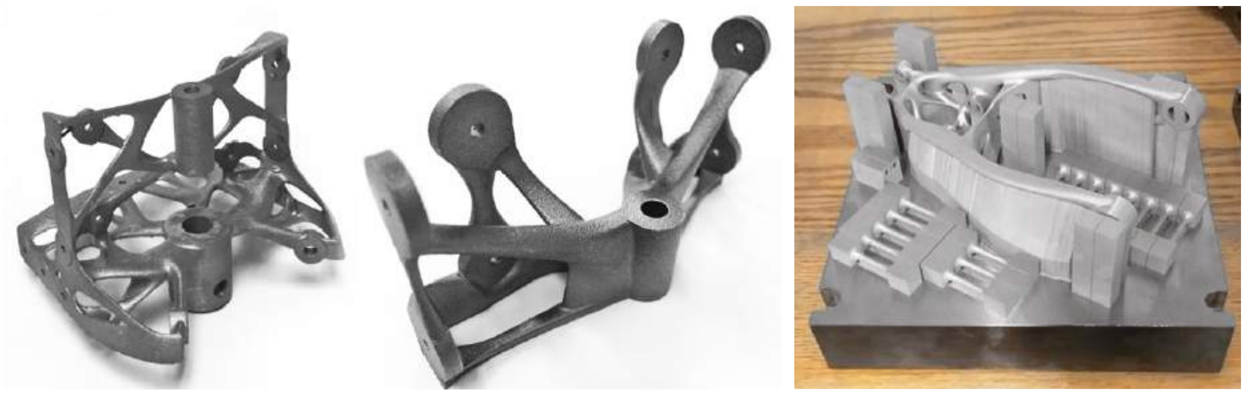

*Fig. 3 Lower hinge bracket (left) and upper hinge bracket (centre) (Courtesy Aerosud). Nose wheel fork for AHRLAC aircraft (right) secured to build plate with support material intact (Courtesy Aerospace Development Corporation)*

## Aerospace parts

Aerosud is an established supplier of aerostructure and aircraft interior parts that has been pushing the boundaries of titanium aircraft part design and manufacturing for many years. Using aspects of Design for Additive Manufacturing (DfAM) such as topology optimisation, Aerosud's engineers created the two rudder brackets shown in Fig. 3, explained Jean-Pierre Serfontein, Senior Research and Development Engineer at the company.

The parts shown are the hinge brackets attached to the rudder for a vertical stabiliser. The lower hinge bracket was consolidated from three parts that are normally machined from AA7050 aluminium alloy and assembled. Both additively manufactured brackets, produced in Ti6Al4V titanium alloy, went through an optimisation study to minimise weight while maintaining or increasing stiffness. Following successful Additive Manufacturing, they were assembled into the rudder and survived structural testing.

## Toolmaking

Toolmaking in South Africa has made a considerable industrial impact by applying the advantages of Additive Manufacturing. Berry Astrapak, near Durban, is the first South African tool and die maker that offers metal AM in house. The company uses AM to produce plastic injection mould inserts, such as those shown in Fig. 4.

Metal Heart is a service provider with experience in producing metal AM parts for series production applications, including the manufacture of steel valves for motorcycle engines, which are produced by Laser Beam Powder Bed Fusion (PBF-LB). The company has also done extensive work on die-casting tools with conformal cooling channels. The company has used W720 (1.2709) maraging steel to additively manufacture inserts

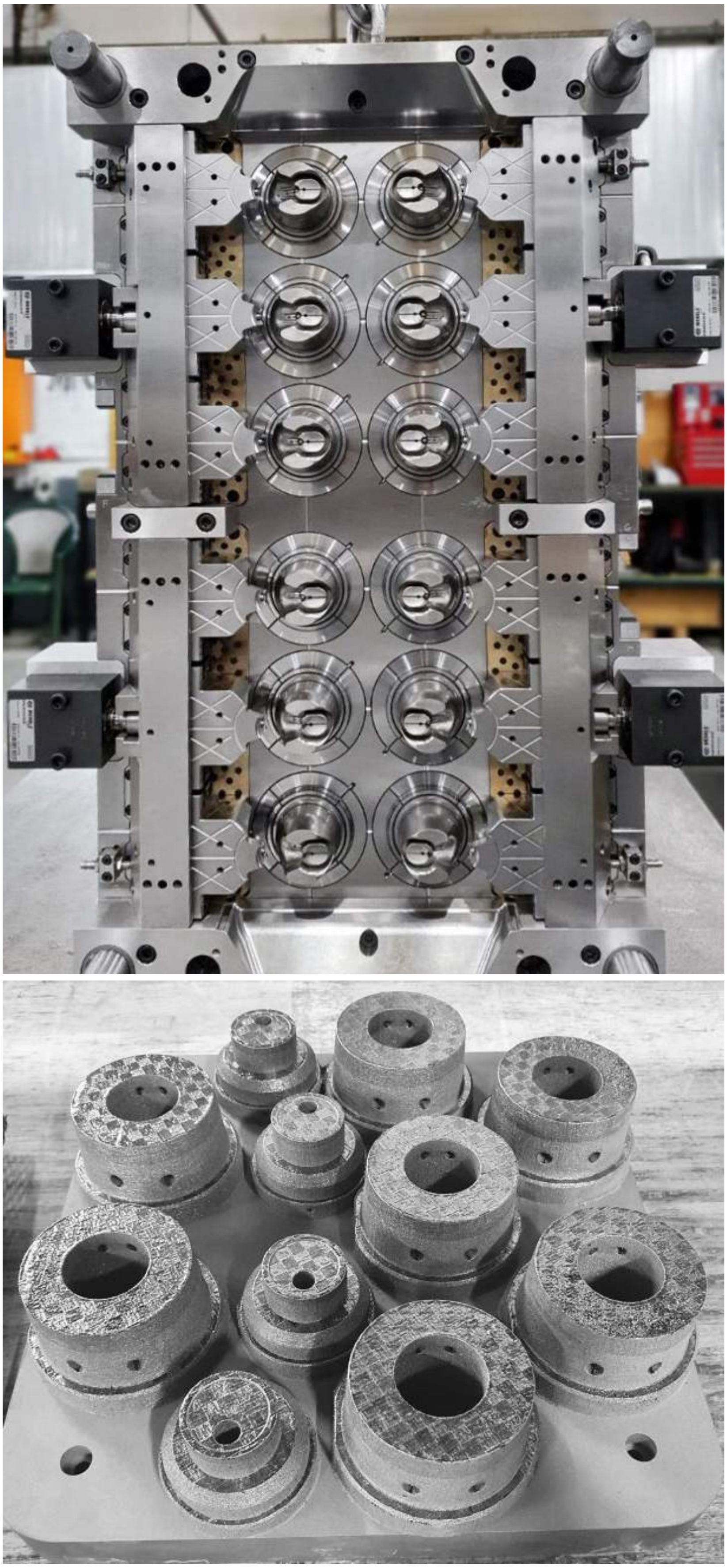

*Fig. 4 Assembled multi-cavity injection moulding tool (top) and metal additively manufactured mould inserts (bottom) (Courtesy Berry Astrapak)*

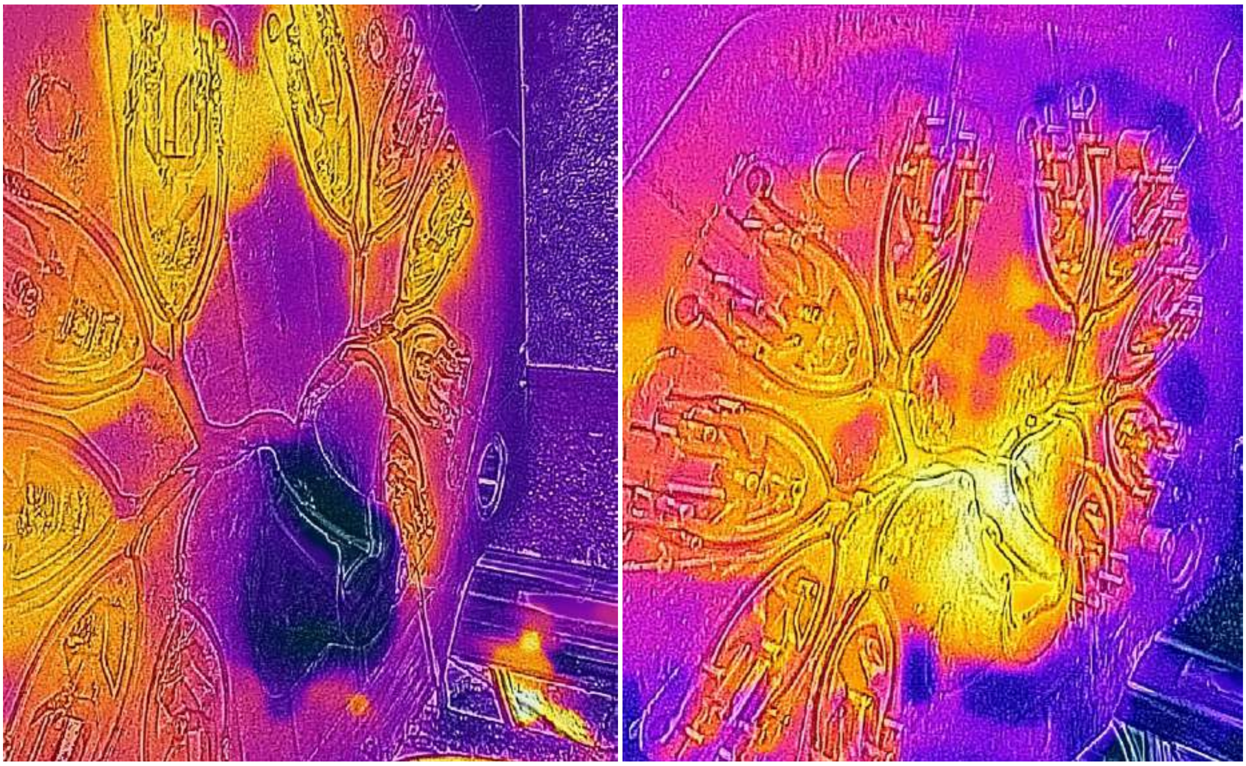

*Fig. 5 Temperature distribution in a maraging steel tool insert with conformal cooling (left) and without conformal cooling (right) (Courtesy Metal Heart)*

and sprue bushes with conformal cooling channels. The work has reduced cycle time for aluminium castings from 1 min 38 sec to 48 sec, nearly doubling output without compromising tool life.

From a performance point of view, Metal Heart has achieved an average insert lifespan of about 115,000 cycles by adopting metal Additive Manufacturing for its inserts. By comparison, the best performing conventionally-made insert, machined in W302 steel, lasted 60,000 cycles. The surface hardness of W720 steel maintains dimensional accuracy through the life of the tool, and the material does not temper, so the core of the inserts remains structurally sound.

## Valve parts and spares

Akhani 3D, an advanced service provider, supplies specialised valves for water reticulation (Fig. 6). In recent months, due to the coronavirus (COVID-19) pandemic, the supply chain was compromised, forcing the company to find a new source for several critical parts needed to sustain its business. Investment

*Fig. 6 Additively manufactured valve parts (left) and spares (right) (Courtesy Akhani 3D)*

casting and CNC machining had been used previously, but wax moulds for the complex parts in a range of sizes are expensive and would require an investment of about R150,000 ($40,000) per mould. A cost study was performed on the range of sizes of the complex parts, and the design was optimised on the smaller parts in the range. The cost of parts built on an M 290 metal AM machine from EOS GmbH, Krailling, Germany, was competitive for the two smaller parts in the range, enabling the production of small batches on demand without the need for tooling. What is more, delivery time for the parts using AM is about four days, compared to four weeks using the conventional process.

Akhani 3D has also seen increased demand for spare parts to support local manufacturing operations in a range of industrial sectors. These are typically small, complex parts that are difficult and expensive to source from overseas suppliers. The transition of these parts to AM requires re-engineering, often with functional improvements and DfAM-based optimisation.

## Additive Manufacturing of platinum

South Africa produces about 80% of the world's platinum. However, most of the metal is not converted into products of increased value which could boost the economy. An initiative to change this was led by Northwest University (NWU) and Lonmin PLC, which is now a part of Sibanye-Stillwater, in collaboration with CUT and Vaal University of Technology (VUT).

In 2017, CUT took the lead in a systematic R&D programme aimed at determining process parameters for the Additive Manufacturing of pure platinum. A reduction unit, used to reduce a build volume, was purchased for one of the EOS M 280 machines installed at CUT's CRPM, making it possible for the research team to use small amounts of the expensive platinum powder when

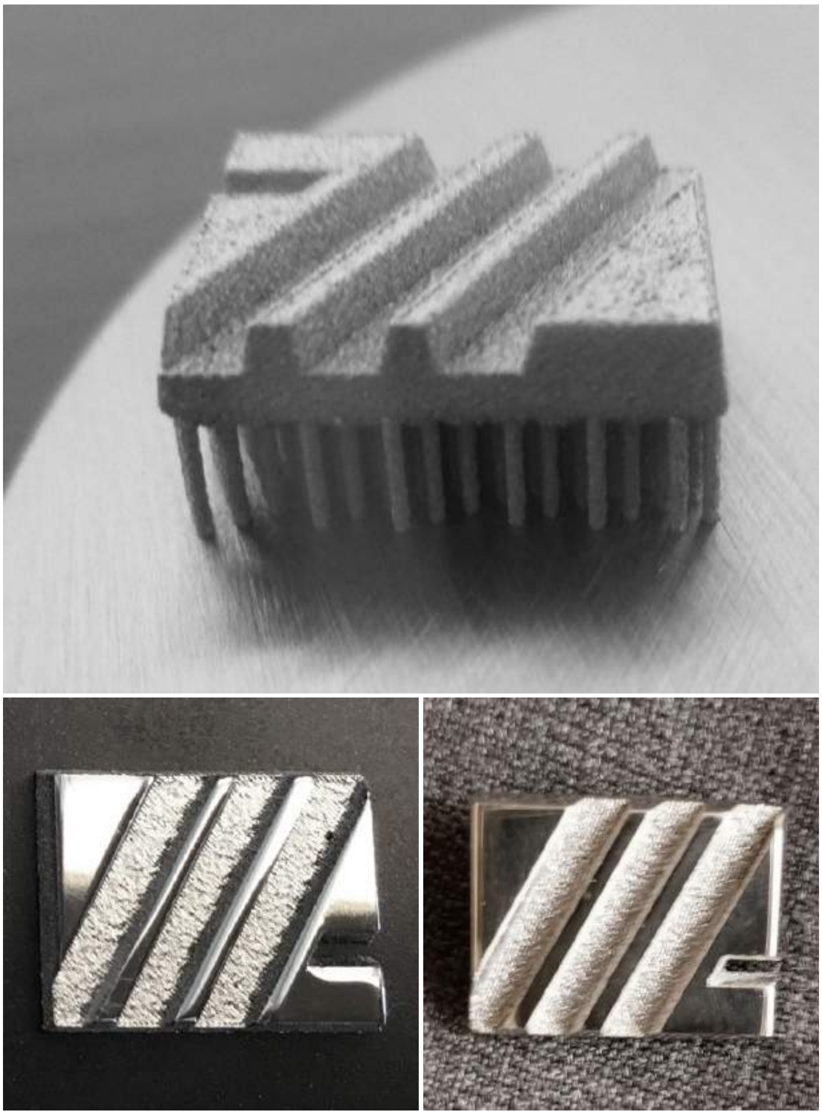

*Fig. 7 Platinum Wohlers Associates lapel pin attached to build plate (top) and finished (bottom right). Titanium version (bottom left) (Courtesy Platforum, Centre for Rapid Prototyping and Manufacturing)*

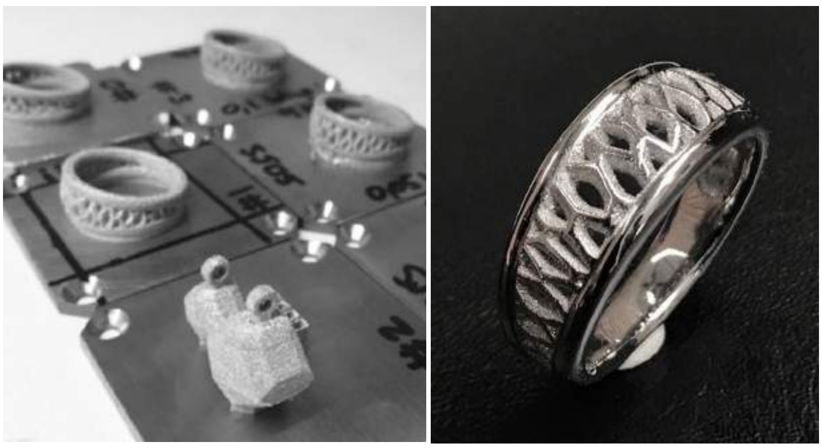

*Fig. 8 Jewellery pieces still attached to the build platform (left) and finished ring (right) (Courtesy Platforum)*

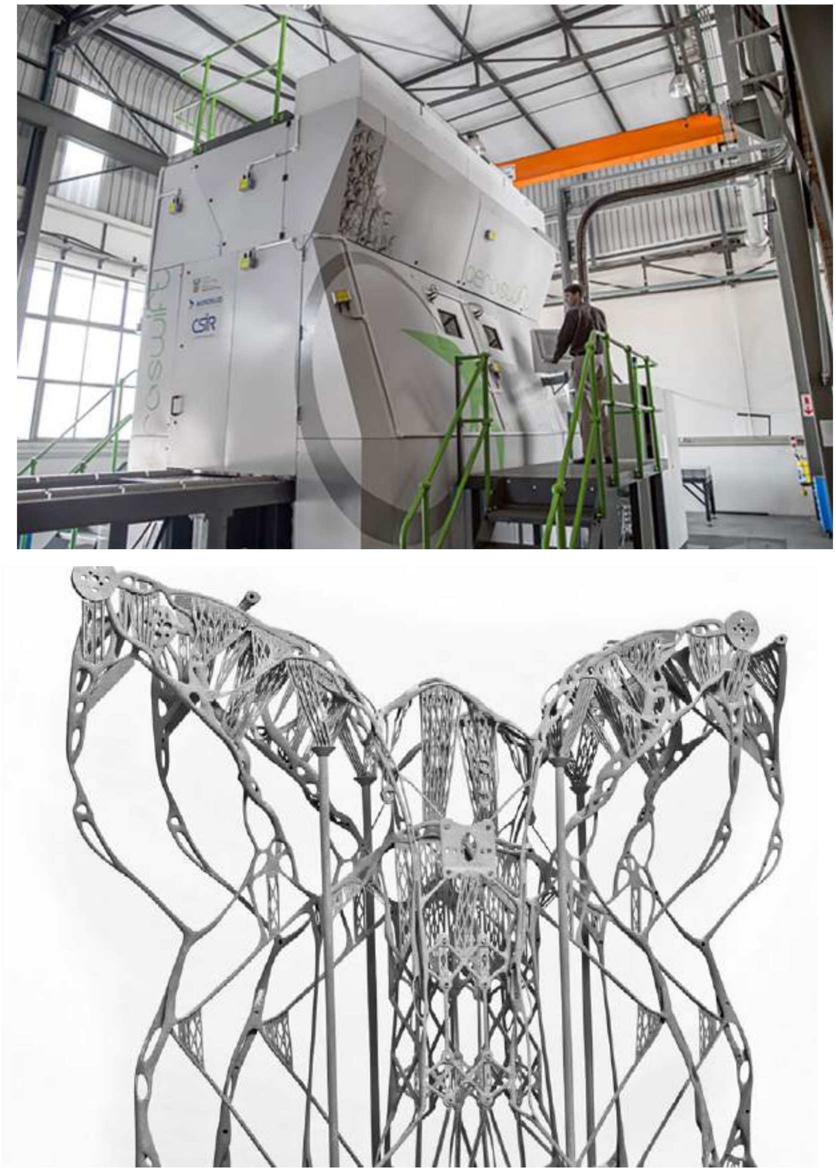

*Fig. 9 Aeroswift machine (top) and drone body produced in its large build volume (bottom), measuring 542 x 542 x 141 mm (Courtesy ADC Aeroswift)*

experimenting. Pure platinum powder suitable for AM was produced by Lonmin to specifications provided by CRPM.

The collaboration between CUT, NWU, VUT and Lonmin led to the launch of Platforum (Pty) Ltd., a consortium that aims to develop platinum as a viable AM production material. Successful development of AM build parameters for pure platinum by the CRPM has resulted in the production of additively manufactured platinum jewellery as benchmark parts.

## South African metal AM machines

ADC Aeroswift is a Pretoria-based company focused on metal Additive Manufacturing for high-end applications. Its Aeroswift machine, developed in collaboration with CSIR between 2011 and 2017, is one of the world's largest and fastest PBF-LB machines (Fig. 9). It can additively manufacture titanium parts in a build volume of 2 m long, 600 mm high x 600 mm wide.

Aditiv Solutions is a South African company focused on affordable metal Additive Manufacturing solutions which employs a team of experts with experience in developing high-end metal AM machines. Aditiv is developing a PBF-LB system called the HYRAX (Fig. 10). The aim of the company is to service the aerospace and medical industries, as well as the needs of the general engineering community. Its initial focus is on low-cost metals, such as stainless and tool steels, that are commonly used for industrial applications.

## Education and training in Additive Manufacturing

As awareness of metal AM grows, so too does the importance of fostering a new generation of engineers trained in parts design and manufacture using the technology. Removing support material and finishing parts, for example, are key elements to adoption success. Several AM education and training initiatives have been launched and continue to expand in South Africa.

In 2018, Wohlers Associates conducted a DfAM course targeted at South African organisations, in collaboration with CUT in Bloemfontein. The three-day course focused on the design methods, tools, and strategies that enable users to get the most value out of AM. Twenty-five people from ten organisations attended, including two people from Botswana (Fig. 11).

Another training and education initiative in South Africa is the Idea 2 Product (I2P) project, launched in 2011 as the brainchild of Deon de Beer, Chair of Innovation and Commercialization of Additive Manufacturing at CUT. An estimated fifteen I2P labs are in operation in South Africa, with ten in other countries. Each lab includes CAD workstations and AM machines for hands-on learning, experimentation, invention, and new product development. The primary goal of I2P is to offer opportunities for professionals and foster economic development, especially in underdeveloped regions of South Africa and other parts of the continent.

## Summary

Wohlers Associates has had the good fortune of watching AM develop in South Africa for more than two decades. The company has visited the country twenty-two times during this period, but sadly missed a trip in 2020 due to the ongoing COVID-19 pandemic. Regular communication continues with many South African friends and business acquaintances.

The RAPDASA organisation, with its annual conference and exhibition, has played an important role in creating awareness of AM in the country, and has done an excellent job of promoting AM research, development, and adoption for more than twenty years. It is great to see so many people, both manufacturing veterans and newcomers, engage in the many AM opportunities that this fine country presents.

The investment in AM by South Africa has, and will continue to, pay off in several ways. One future possibility is the expansion of the technology into other parts of Africa. Pioneers such as Professor de Beer and CUT's CRPM team have already taken steps in this direction, and it is our belief that RAPDASA could also play an increasingly important role in spreading the benefits of AM across the African continent. It is our hope that AM favourably impacts a growing number of organisations – and many local economies – in this part of the world.

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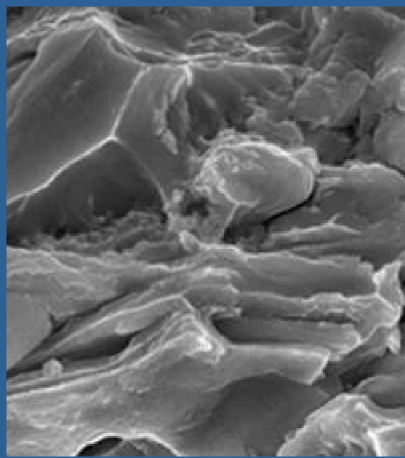
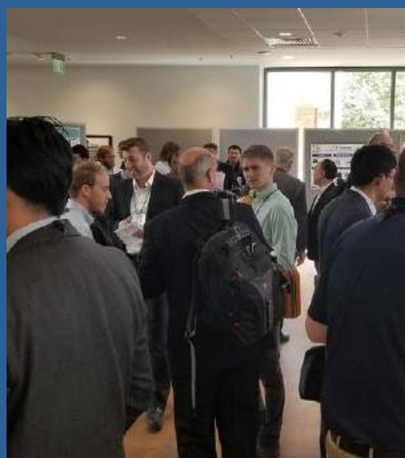
*Fig. 10 HYRAX metal AM system (Courtesy Aditiv Solutions)*

*Fig. 11 Attendees and instructors of the three-day Wohlers Associates DfAM course conducted in Bloemfontein, South Africa*





# CFD simulation for metal Additive Manufacturing: Applications in laser- and sinter-based processes

Computational Fluid Dynamics (CFD) is widely applied to solve a broad range of research and engineering problems, from aerodynamics to engine combustion and microfluidics. In this article, Pareekshith Allu, Senior CFD Engineer at Flow Science, Inc, explains how CFD can also be used to improve laser- and non-laser-based metal Additive Manufacturing processes, including Laser Beam Powder Bed Fusion (PBF-LB), Directed Energy Deposition (DED), Binder Jetting (BJT) and Material Extrusion (MEX).

Whether it is the car you drive or the coffee maker you use to brew your morning coffee, chances are you interact every day with a technology that was developed with the help of computational fluid dynamics (CFD). CFD is the study of fluid flow using numerical methods. Since the underlying equations of fluid flow have no analytical solutions, we use computers to solve these equations and simulate fluid interactions in different environments. CFD can be applied to a wide range of research and engineering problems in aerodynamics, engine combustion, water and environmental flows, microfluidics and manufacturing. In this article, I will describe how CFD simulations are used to improve both laser-based and non-laser-based Additive Manufacturing (AM) processes.

To begin with, it is important to understand the concept of a free surface flow and, thus, potential free surface flow problems unique to CFD. Free surface flow occurs when two fluids with largely different densities share an interface. Picture a river: a free surface exists between the water and the surrounding air, since the gas/liquid interface is free to move and change with time. Free surface flows are ubiquitous – they span civil engineering applications, microfluidics, and are prevalent throughout manufacturing. In metal casting, for example, a free surface exists between molten metal and the air in a mould as it's filled (Fig. 1); in a laser welding process, a free surface molten pool is formed when a laser beam melts and fuses two metal components or parts together.

Over forty years ago, the founder of Flow Science Inc., Dr C W Hirt, pioneered a computational technique

*Fig. 1 When molten metal fills up a mould, a free surface exists at the interface of the molten metal and the air*

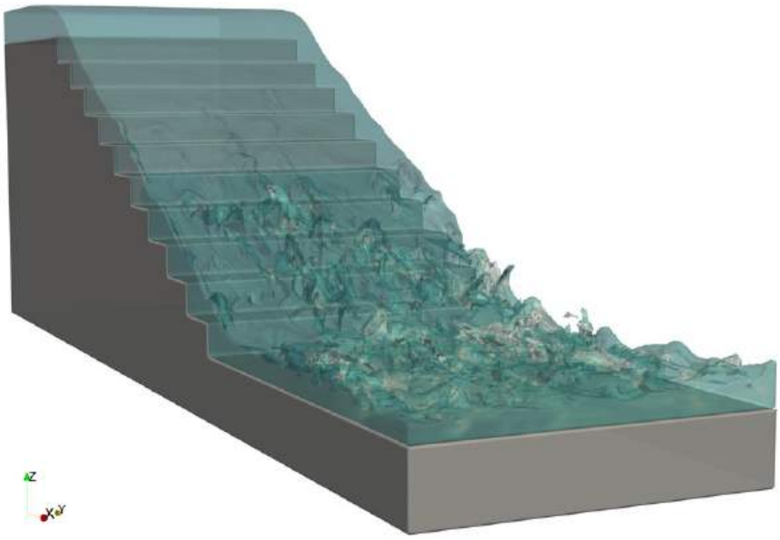


*Fig. 2 Another example of a free surface flow: water flowing along a stepped chute*

for tracking the evolution of the free surface called the Volume of Fluid (VOF) method – the underlying DNA behind FLOW-3D's CFD solver. Since then, FLOW-3D's VOF algorithm, TruVOF®, has been used to simulate fuel sloshing in space shuttle tanks, design spillways for dams, optimise inkjet printers and minimise casting defects. More recently, the company recognised the unique capabilities it could offer in simulating laser welding and AM processes and developed FLOW-3D AM.

## Laser Beam Powder Bed Fusion

In the Laser Beam Powder Bed Fusion (PBF-LB) process, a part is manufactured layer by layer. First, powder is spread onto a build plate and a laser beam then melts and fuses the powder in a specific pattern. Then, another layer of powder is spread onto the initial layer and a laser beam melts the new layer, fusing the two layers together. This process is repeated until a part is fully built. There are several aspects of the PBF-LB process that can be better understood and optimised through CFD simulations. For example, using a discrete element method (DEM), it is possible to simulate the powder spreading process in detail. A DEM simulation accounts for particle dynamics, particle collisions and geometry effects. In Fig. 3, you can see how the formation of a packed powder bed can be modelled.

Strictly speaking, DEM is not CFD. However these micro-scale simulations operate at a similar spatial resolution to CFD simulations of the melt pool and provide an important input for modelling the laser beam's interaction with the powder bed and subsequent melt pool formation. Through DEM, it is possible to optimise powder size distribution, recoater blade dimensions and recoater blade speed to obtain an ideal bed compaction; any speeding up that can be achieved during powder spreading directly translates into faster build rates. Additionally, factors such as the existence of moisture, friction coefficients and non-sphericity of particles can be incorporated into DEM simulations to better understand powder spreading and compaction.

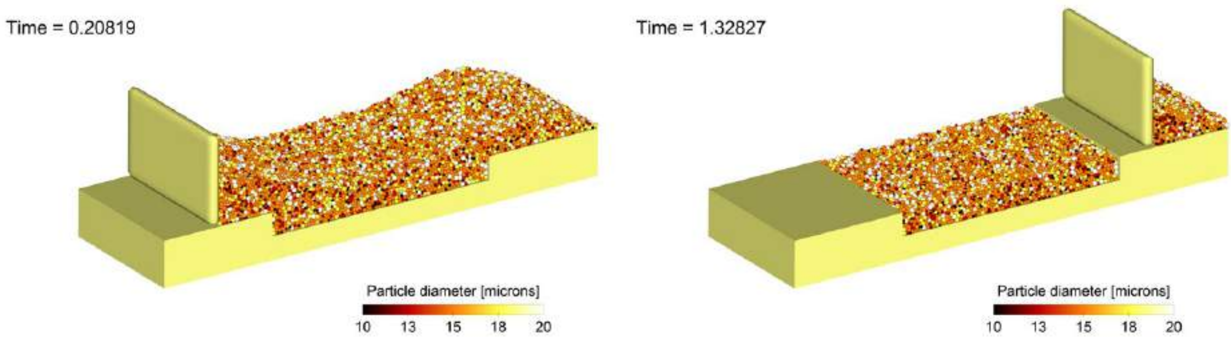



*Fig. 3 Simulation of powder packing. Once the powder has been deposited on the substrate, a recoater blade is used to pack the powder bed prior to laser melting. The particles are coloured based on the diameter of the particles simulated a) before recoater blade packing, and b) after recoater blade packing*

Once the powder bed is generated in a DEM simulation, it is extracted as an STL file. The next step is simulating the laser melting process using CFD. Here, we model the interaction of the laser beam and the particle bed. To capture this process accurately, the relevant physics includes viscous flows, laser reflections within the melt pool (through ray tracing), heat transfer, solidification, phase change and vaporisation, recoil pressure, shield gas pressure and surface tension. Clearly, there is a lot that needs to be incorporated along with the VOF method to accurately simulate this complex process (Figs. 4, 5). Once the melt pool track solidifies, DEM can be used to simulate the spreading of a new powder layer on the previous layer. Similarly, laser melting can then be performed on the new powder layer to analyse fusion between subsequent layers and any other defects that can form during a multilayer build.

Why are these melt pool models important? The status quo in Additive Manufacturing simulations, especially for PBF-LB and Directed Energy Deposition (DED) processes, is focused on thermomechanical simulations that help with part-scale modelling to predict thermal distortions, residual stresses and the generation of support structures. While these simulations are useful, information about melt pool dynamics and related defects such as balling, keyholing, lack of fusion and porosity are outside the realm of such models. It is important to keep in mind that fluid flow, heat transfer and surface tension within the melt pool also affect thermal gradients and cooling rates, which in turn influence microstructure evolution. Fig. 6 shows the various scales at play in an AM process.

Process parameters such as laser power and speed, scan path, hatch spacing, powder size distribution and powder bed packing influence the AM build process and the mechanical properties of the built part. Through CFD modelling, researchers can understand the effects of these process parameters on underlying

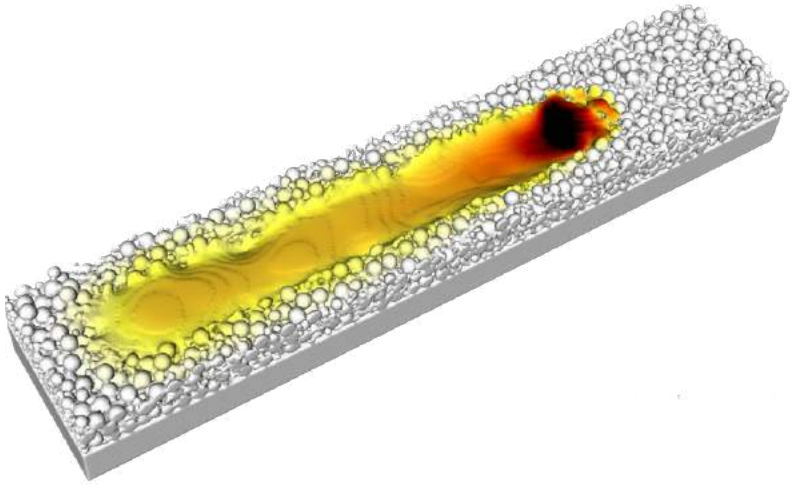


*Fig. 4 Melt pool evolution in a laser powder bed fusion process*

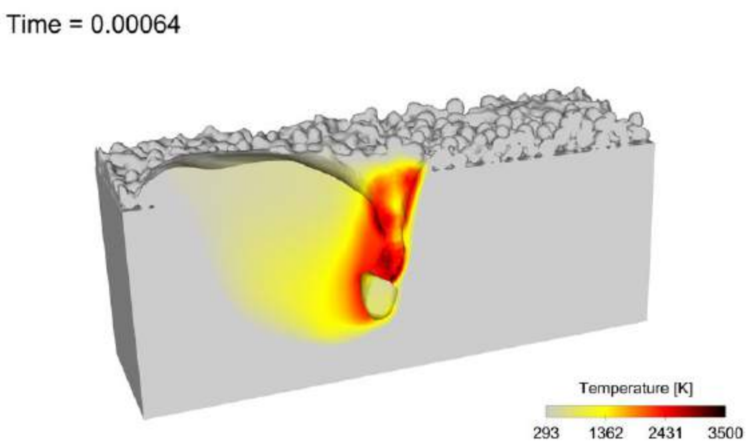



*Fig. 5 The laser-material interaction and the progression of a melt pool*

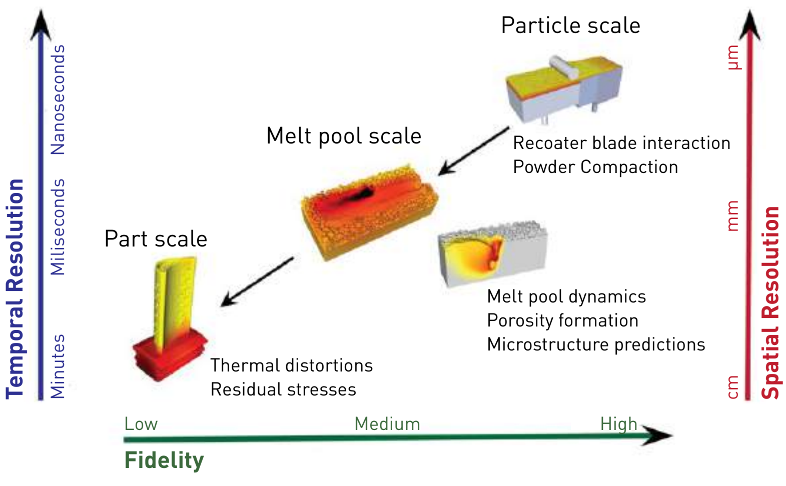



*Fig. 6 The different spatial and temporal scales in a PBF-LB process; the powder and melt pool scale constitute micro- and meso-scale simulations*

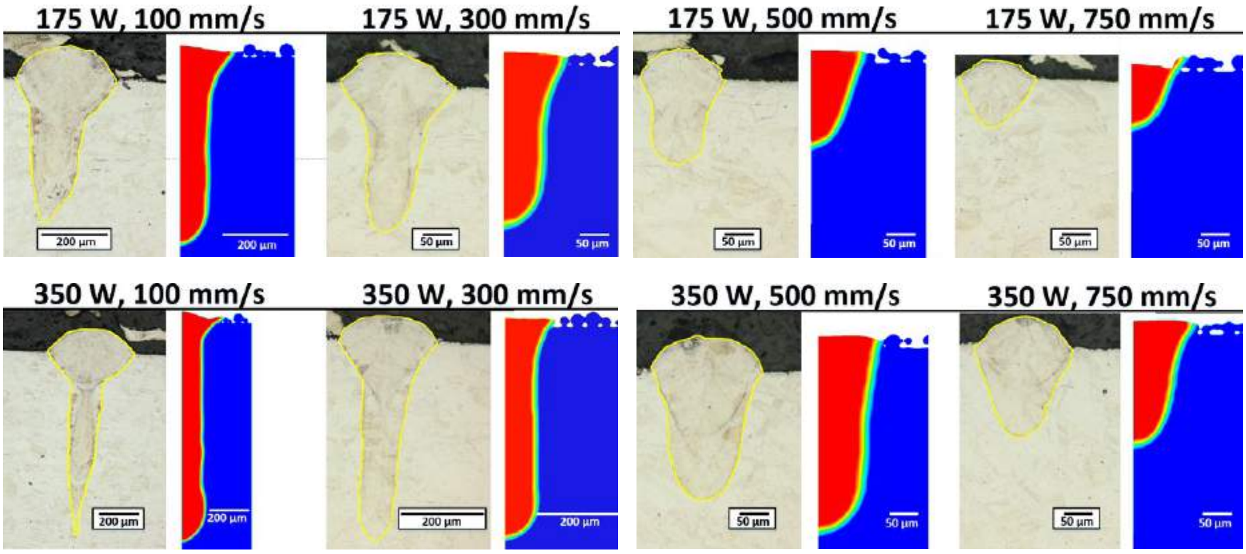



*Fig. 7 Melt pool dimension comparison between simulations and experiments [1]*

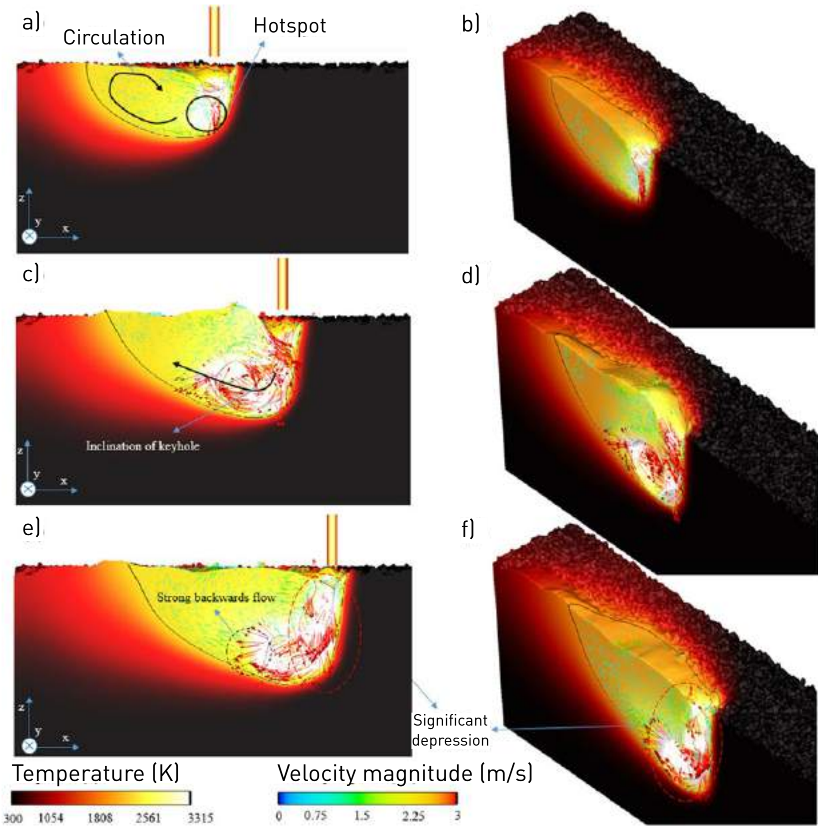



*Fig. 8 Formation of a keyhole due to strong recoil pressure, downward convection and multiple laser reflections that impart more energy into the melt pool [2]*

physical phenomena such as melt pool dynamics, phase change, solidification and microstructure evolution. Such numerical models, which are based on a rigorous solution of the conservation equations of mass, momentum and energy, can provide useful insights into fluid convection in the melt pool, formation of keyholes, temperature gradients and solidification rates. These insights can then drive development of process windows for newer alloys that take full advantage of the benefits of Additive Manufacturing.

Simulation models can only be trusted when they are validated against experimental data, but gathering real-time information from the melt pool while a build is underway can be challenging. Some research groups have generated ultrafast X-ray synchrotron images and videos of the melt pool as the laser beam melts and fuses powder particles together; these videos show that the process can be quite explosive and dynamic. It is possible to use these data as well as data generated from solidified melt pool tracks, formed by the laser melting of powder particles, to validate the CFD models. This is another advantage of CFD: when validated, CFD models can explain a lot of the underlying phenomena in a PBF-LB process, something which is difficult to analyse in real time.

### PBF-LB case studies

Researchers from Robert Bosch LLC used CFD to investigate the melt pool dynamics of PBF-LB for 316L stainless steel [1]. Through their study they were able to validate the melt pool dimensions and keyhole-induced pore defects obtained in CFD simulations against experimental data (Fig. 7).

Researchers from the Technical University of Denmark investigated the onset of porosity during keyholing in a PBF-LB process of Ti6Al4V [2]. At high energy densities, a strong recoil pressure is generated on the melt

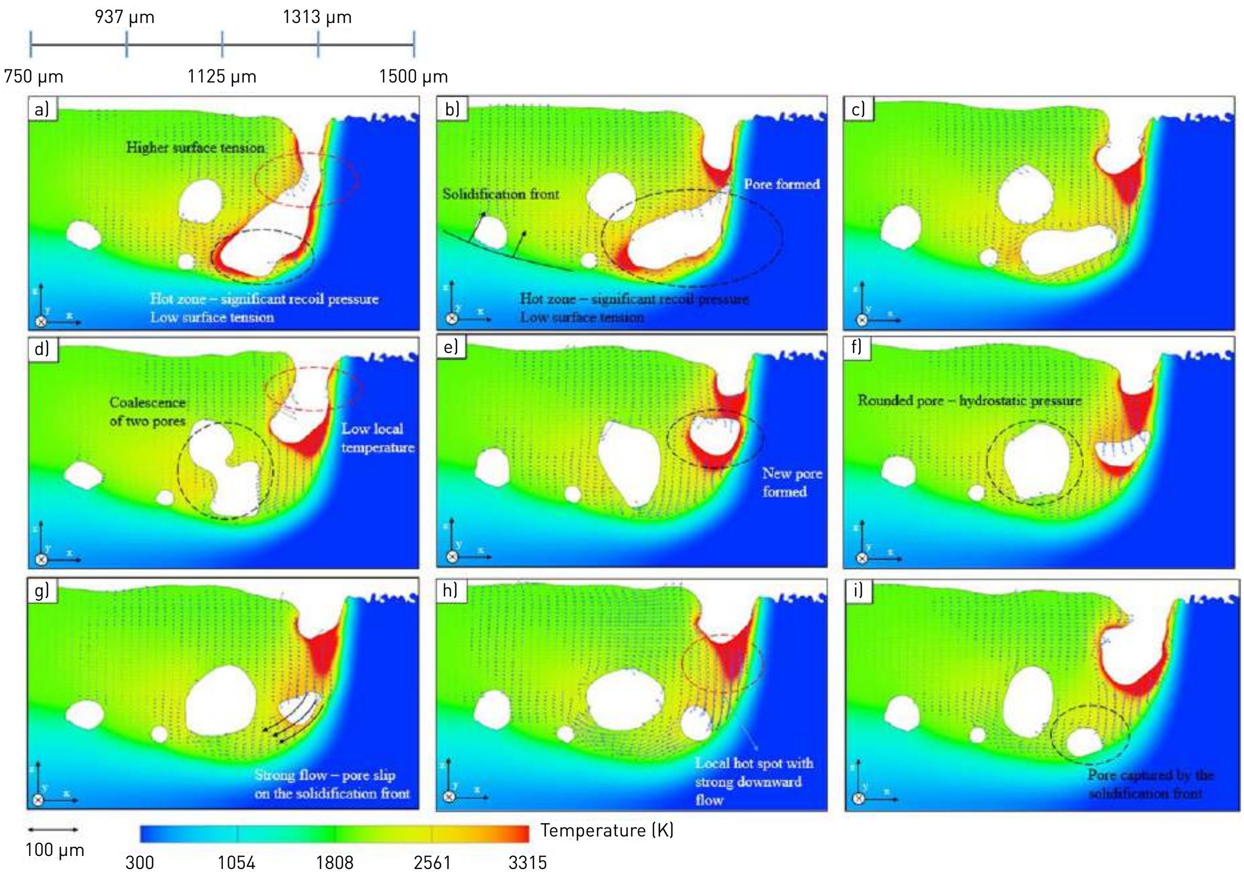



*Fig. 9 Porosity formation mechanism during keyholing of a PBF-LB process [2]*

pool surface due to laser/material interactions and phase change due to vaporisation. The coexistence of a strong downward flow and additional heating due to laser reflections within the melt pool leads to the creation and further growth of a keyhole (Fig. 8).

Eventually, this runaway effect results in high temperatures and high recoil pressures at the bottom of the keyhole, and higher surface tension forces in the upper region. The cold zone at the upper region closes to minimise surface energy, which creates an irregularly-shaped pore that detaches from the keyhole. The strong downward flow then pushes the pore into the back of the molten pool, where it rounds off due to hydrostatic pressure and is eventually trapped by the advancing solidification front, resulting in porosity (Fig. 9).

In Fig. 10, the size and location of porosity predicted in the simulations agree with the experimental data. It

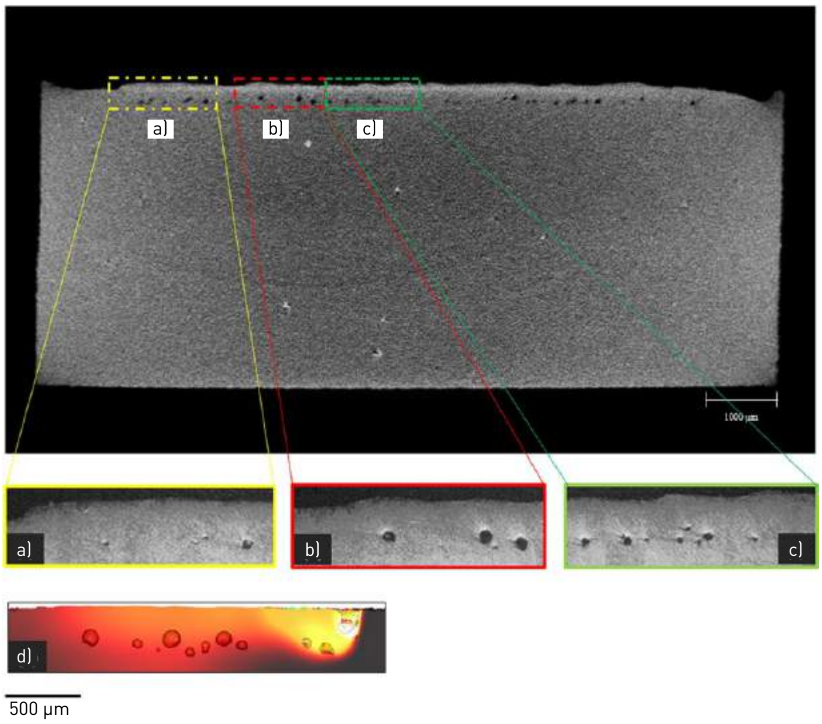



*Fig. 10 Optical and X-ray images (a)–(c) of the pores formed during keyholing in a PBF-LB process. Corresponding simulation results are shown in inset (d) [2]*

becomes easier to run simulations with varying process parameters to understand how the melt pool behaves, instead of running multiple experiments and resorting to trial and error. This lets us see how CFD simulations help develop optimal process windows for different alloys used in PBF-LB processes.

## Directed Energy Deposition

The above melt pool simulations can be similarly extended to other laser-based processes such as Directed Energy Deposition. In laser-based DED, a wire or a powder source, or sometimes both, feed into a laser beam to build parts layer by layer (Fig. 11). A melt pool similarly forms and can be modelled using CFD. Parameters such as powder or wire feed rate, laser power and scan path can be optimised to ensure a stable melt pool with controlled microstructure evolution.

CFD results can help elucidate surface finish, dimensional accuracy and defect formation in built layers.

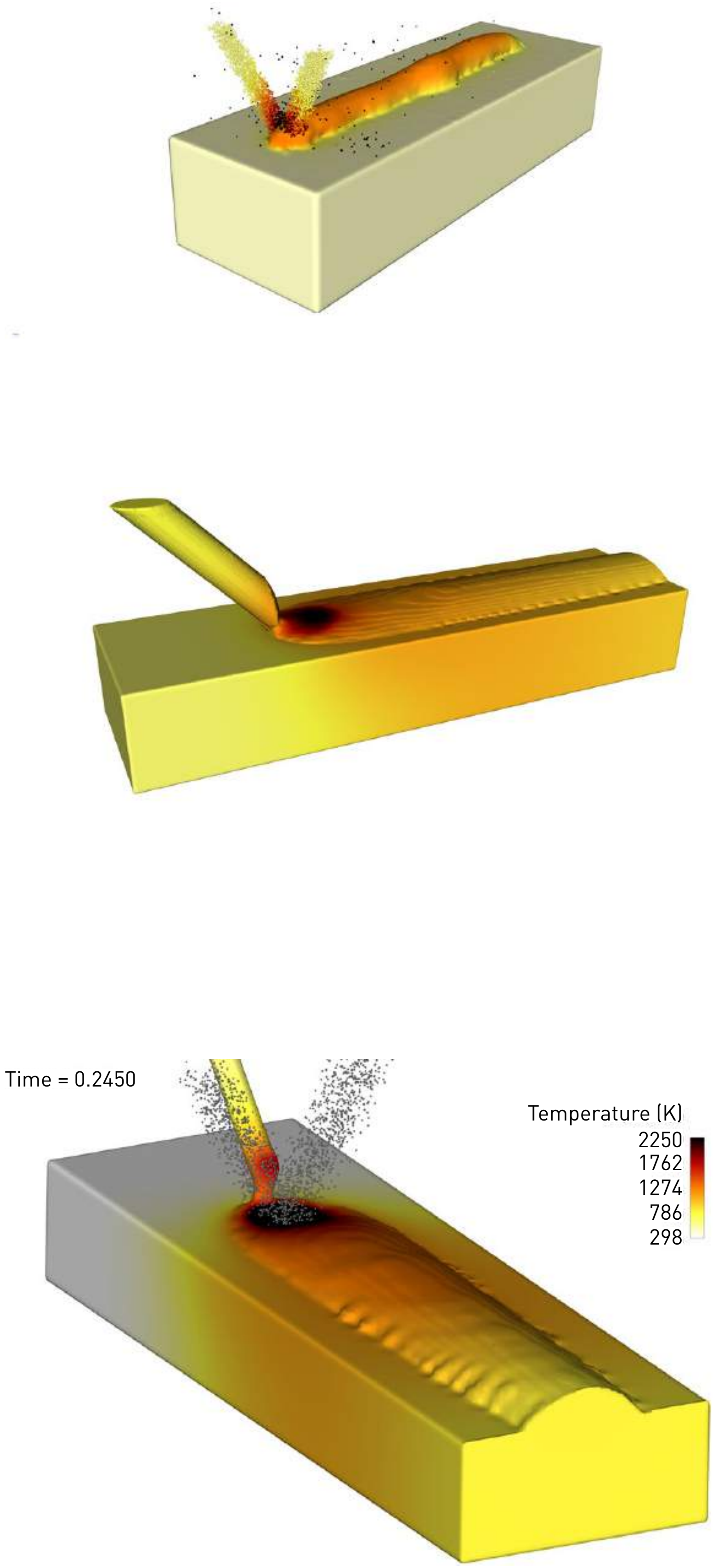



*Fig. 11 CFD simulations for directed energy deposition processes using a) powder b) wire and c) wire and powder*

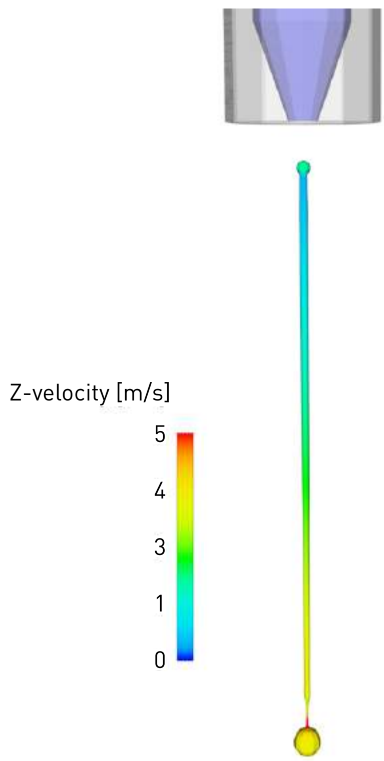



*Fig. 12 Velocity profile of an ejected droplet with satellite formation*

Moreover, results from a CFD simulation, such as thermal gradients, can be fed into FEA models to determine residual stresses and thermal distortions. Processes like DED also offer the ability to build custom parts with one or more powder and wire materials, aiding in the manufacturing of parts with location-specific material properties. CFD simulations help us understand material mixing within the melt pool, formation of pores and intermetallics and fusion between subsequent layers.

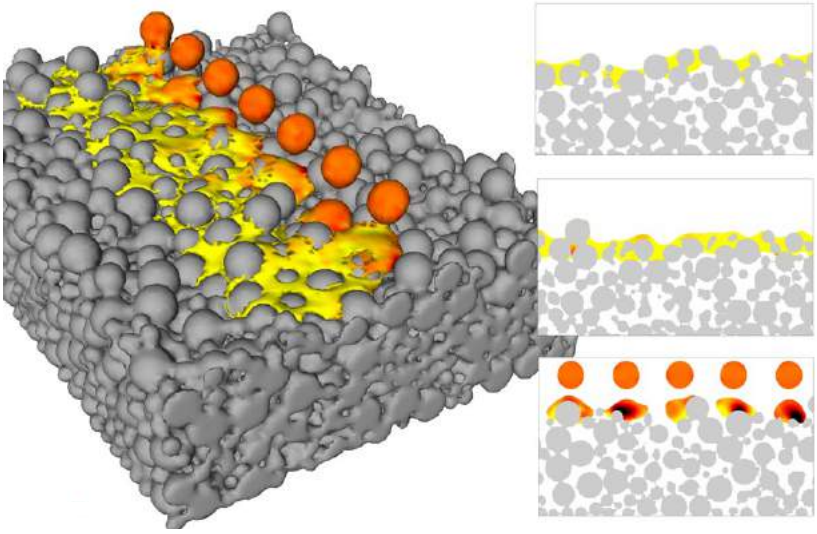


*Fig. 13 Impact of binder droplets on a stationary powder bed showing binder infiltration, spreading and coalescence*

## Binder Jetting

CFD simulations can also be beneficial in non-laser-based AM processes. In the Binder Jetting (BJT) process, powder is spread onto the build plate using a roller. A printhead then moves across the powder bed, depositing droplets of binder in a specific pattern. Sometimes the binder is cured by a heat source to better bond the powders together. The print bed is then lowered, and fresh powder is spread onto the build plate, followed by the deposition of additional binder droplets from the printhead. This process is repeated layer by layer to build a 'green' part, which is then sintered to achieve better part densification.

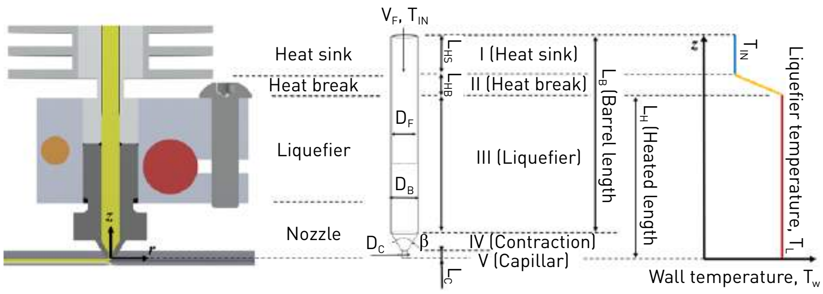



*Fig. 14 A schematic of the fused deposition modelling setup that extrudes polymer filament to build a part layer by layer*

As with the powder laying step in PBF-LB, DEM simulations can be beneficial for studying powder compaction under different roller configurations and powder size distributions. Interestingly, in BJT, the application of CFD can be multi-fold. A typical printhead ejects millions of droplets per second onto the powder bed. CFD can help optimise the volume, shapes, velocities and satellite formation of these droplets by incorporating the effects of nozzle geometries, temperature, bubble energy and material properties such as surface tension and viscosities (Fig. 12).

CFD can also help with the study of droplet impact and the subsequent absorption of the binder into the powder bed. In a CFD model, we can consider tens, or even hundreds of spherical droplets impacting the powder bed. This is a good model for understanding binder/powder interactions at the micro-scale, helping optimise and scale up the process. CFD, however, does have its drawbacks in this use: the effects of powder cratering are neglected in this model, and the powder bed is assumed to be fixed in place, a similar assumption that is made in the PBF-LB process. Nevertheless, the model provides valuable insights into binder infiltration, spreading and coalescence within the powder bed. It shows how surface tension and capillary forces dominate and influence the movement of the binder within the inner layers of the powder upon impact. The simulations also show how long the binder takes to spread and infiltrate within the powder layers and how much spacing needs to be implemented between subsequent droplets to ensure optimal coalescence (Fig. 13). Overall, CFD simulations can lead to a better understanding of how different binder materials interact with powder and help optimise the build rate in a Binder Jetting process.

## Material Extrusion

Last but not least, let's consider Material Extrusion (MEX)-based AM. Take the Fused Filament Fabrication (FFF) process: a polymer-based filament moves through a liquefier that melts the solid filament, which is then extruded through a nozzle onto a build substrate to build a part layer by

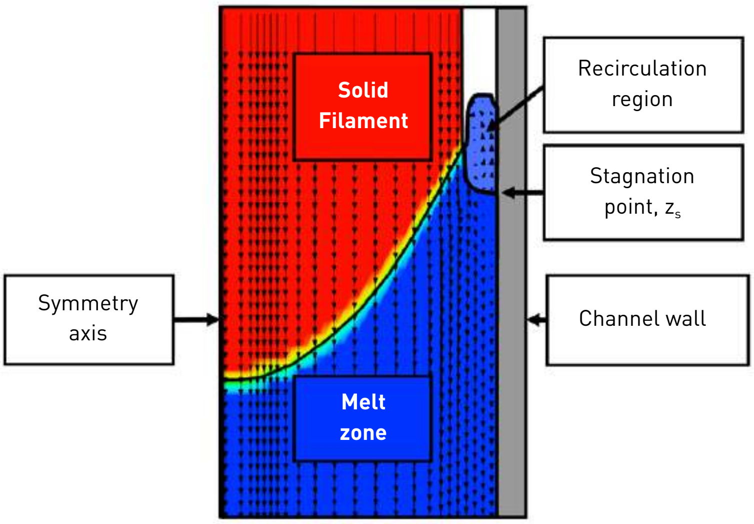



*Fig. 15 Sketch illustrating the recirculation zone that prevents backflow of the molten polymer through the liquefier [3]*

layer (Fig. 14). Researchers from the Technical University of Denmark have developed a free surface flow CFD model that sheds light on the process [3]. As the solid filament moves through the liquefier, it contacts the chamber walls that melts the filament. The liquefier then fills up with molten filament. A recirculation region of low temperature and high viscosity is formed near the interface of the solid and liquid filament, which is crucial to preventing the backflow of polymer (Fig. 15). Such models can illustrate the effects of conduction, convection and radiation on filament melting and flow.

In an FFF process, CFD is used to study different channel designs that improve heat transfer and maximise the extrusion rate of the filament, ensuring a stable regime. Such models help optimise the pressure drop inside the nozzle, resulting in smaller torque requirements for the stepper motor used to extrude the polymer. This analysis paves the way for faster build rates for FFF and a wider adoption of materials that can be additively manufactured.

## Last thoughts

To give you an idea about the simulation times, all the simulations discussed were run on desktop computers that took anywhere from a couple of hours to a day, depending on the physics modelled. By creating a series of simulations, it becomes easier and more economical to develop process windows through modelling instead of having to perform many experiments through trial and error.

I hope you are convinced that CFD simulations are a useful and necessary part of Additive Manufacturing research and development. CFD simulations are by no means standalone aspects of the AM simulation workflow. Outputs from CFD simulations can be input into FEA models to analyse thermal distortion and residual stresses, paving the way for a macro-scale analysis. Data from CFD models can also be input into microstructure models to help predict crystal growth and dendrite arm spacing, which in turn can help predict material properties of the built part. Lastly, combining data-driven modelling with physics-based simulations can be quite beneficial in optimising the build parameters for AM.

Being able to bridge the various simulation scales in an AM process to predict how process parameters affect part quality will help AM leverage newer designs and alloys. I hope you are inspired to incorporate CFD into your own AM workflow!

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## References

[1] Cheng, B, Loeber, L, Willeck, H et al. Computational Investigation of Melt Pool Process Dynamics and Pore Formation in Laser Powder Bed Fusion. *Journal of Material Engineering and Perform*, 28, 6565–6578 (2019). https://doi.org/10.1007/s11665-019-04435-y

[2] Mohamad Bayat, Aditi Thanki, Sankhya Mohanty, et al. Keyhole-induced porosities in Laser-based Powder Bed Fusion (L-PBF) of Ti6Al4V: High-fidelity modelling and experimental validation, *Additive Manufacturing*, Volume 30 (2019). https://doi.org/10.1016/j.addma.2019.100835

[3] Marcin P. Serdeczny, Raphaël Comminal, Md. Tusher Mollah, David B. Pedersen, Jon Spangenberg, Numerical modeling of the polymer flow through the hot-end in filament-based material extrusion additive manufacturing, *Additive Manufacturing*, 36; 101454, 2020. doi.org/10.1016/j.addma.2020.101454

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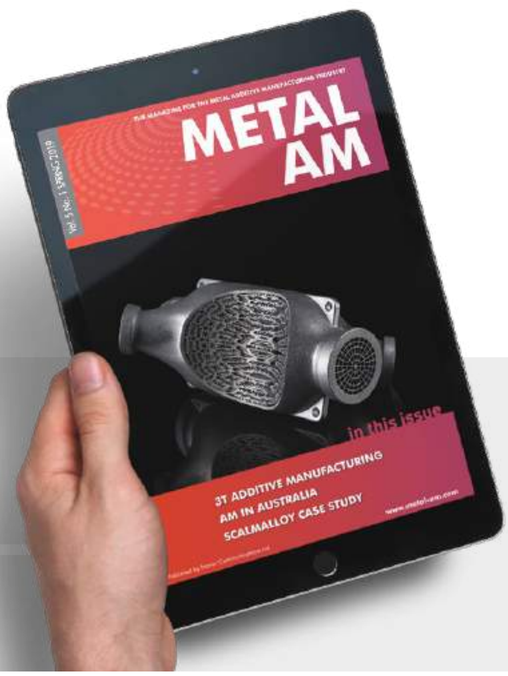




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