Vol. 9 No. 3 AUTUMN 2023

THE MAGAZINE FOR THE METAL ADDITIVE MANUFACTURING INDUSTRY

METAL AM

in this issue

HOW AM IS CHANGING AEROSPACE

METAL AM THE NORWEGIAN WAY

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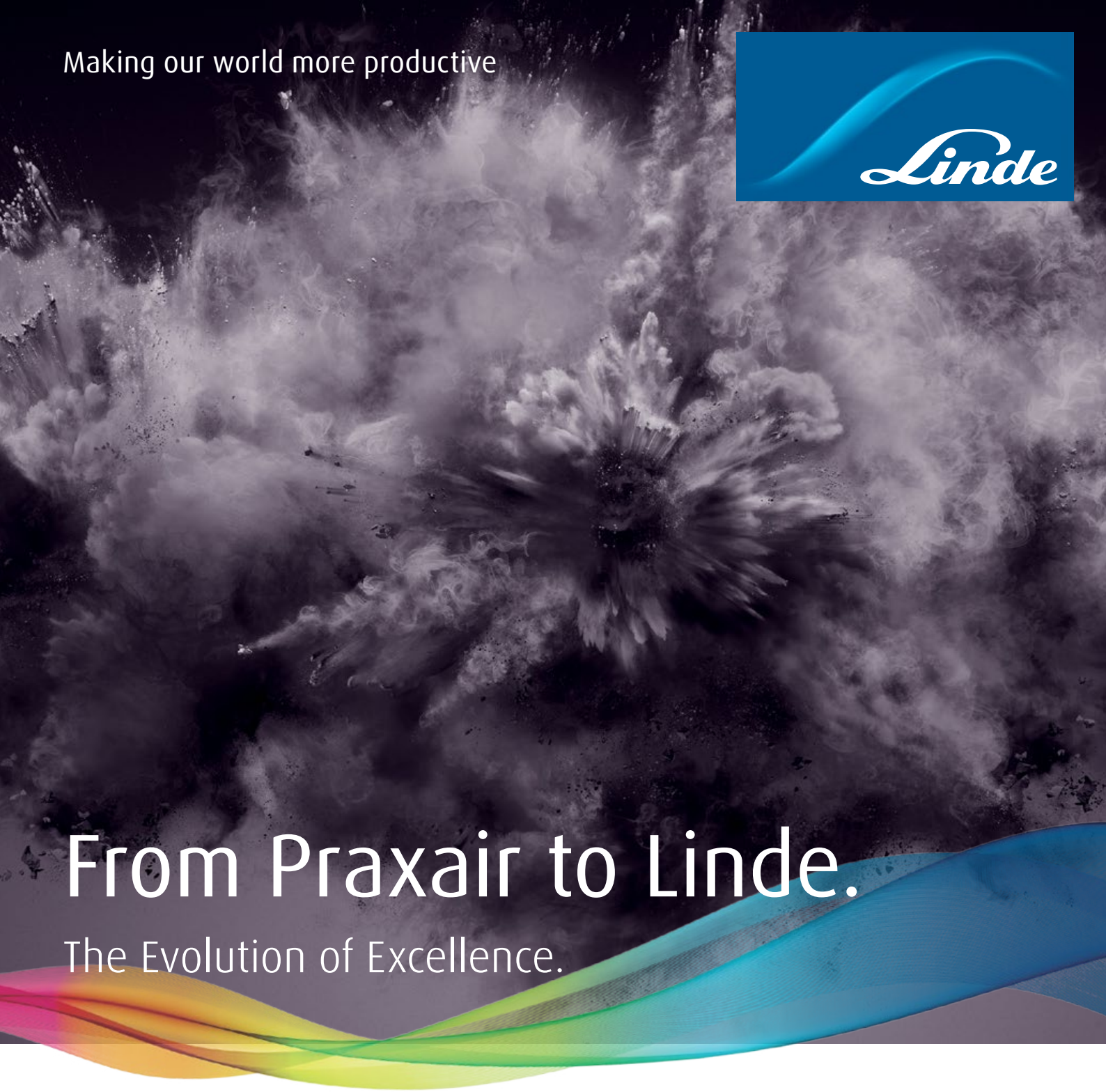

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Subscriptions
Metal Additive Manufacturing is published on a quarterly basis as either a free digital publication or via a paid print subscription. The annual print subscription charge for four issues is £150.00 including shipping. Rates in € and US$ are available on application.

Design and production
Inovar Communications Ltd.
ISSN: 2057-3014 (PRINT)
ISSN: 2055-7183 (ONLINE)

This magazine is also available for free download from **www.metal-am.com**

INOVAR COMMUNICATIONS

METAL ADDITIVE MANUFACTURING

A vision made real: in anticipation of Formnext 2023

Sometimes we have to look to the past to see just how far we've come. For those readers who are at Formnext for the first time and have just picked up a copy of *Metal AM* magazine, it is hard to appreciate the metal Additive Manufacturing industry's journey to this point in its relatively short history.

When I look back to 2015 – the year of the very first Formnext and the year that we launched this magazine – and consider the progress that has been made in the intervening years, the industry's transformation is deeply impressive. From a landscape that was dominated by one AM process, Laser Beam Powder Bed Fusion (PBF-LB), we now see a multitude of processes that are ready for industrial use. Many of these 'new' processes have the advantage of being built on the foundations of other industrial technologies, for example welding in the case of wire-based Directed Energy Deposition (DED) or Metal Injection Moulding in the case of Binder Jetting (BJT).

Back to 2015, it was very much a case of a 'technology looking for markets' at Formnext. Today, there is a real sense that it is now the major end-user sectors that are taking the initiative and laying the groundwork for the widespread adoption of AM. In this issue we offer insight into two distinct area of application – aerospace, and oil and gas. To say that AM has been transformative in aerospace engineering is an understatement, with a new generation of engines being designed around AM.

The story of oil and gas, and the related maritime sector, is in many ways the opposite to aerospace. Both are leveraging very different opportunities presented by AM. As our feature on Norway highlights, here much of the value of AM is for larger parts that were designed for conventional manufacturing processes. However, they can now be produced on demand and where needed, avoiding the need for vast spare parts warehouses - a major shift to faster, greener and more cost-effective 'digital' spare parts solutions.

So a vision made real, thanks the efforts of all players in the AM industry, from machine producers to those developing industry standards, software innovators to materials developers.

Nick Williams
Managing Director

Cover image
A wire/plasma Directed Energy Deposition (DED) build at Norsk Titanium (Courtesy Norsk Titanium)

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Across the world, a new wave of aerospace engineers are designing and building the next generation of aero engines and systems around the revolutionary capabilities of Additive Manufacturing.

Twenty years ago this was a vision, but today it is a reality. From fuel nozzles to Stage 5 and Stage 6 low pressure turbine (LPT) blades, housings to structural elements, in this article *Metal AM* magazine's Technical Consultant Martin McMahon reviews the progress that has been made, shining a light on selected applications that offer insight to those in the aerospace industry who want to get up to speed with progress. >>>

161 Slowly but surely: Industrialising metal Additive Manufacturing the Norwegian way

While the Norwegian market for Additive Manufacturing has long revolved around prototyping and polymer materials, metal Additive Manufacturing has seen rapid development in recent years. This is in large part thanks to the opportunities that the country's oil and gas industry is now seeing in the technology.

In this article, Joppe N Christensen considers why it has taken so long to get started with metal AM in Norway and introduces companies and individuals who are now leading the way. >>>

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177 **Hot Isostatic Pressing and AM: How to improve product quality and productivity for critical applications**

Metal Additive Manufacturing is rapidly gaining momentum across a broad range of industries and is often used for producing components for challenging applications such as medical implants and rocket engines.

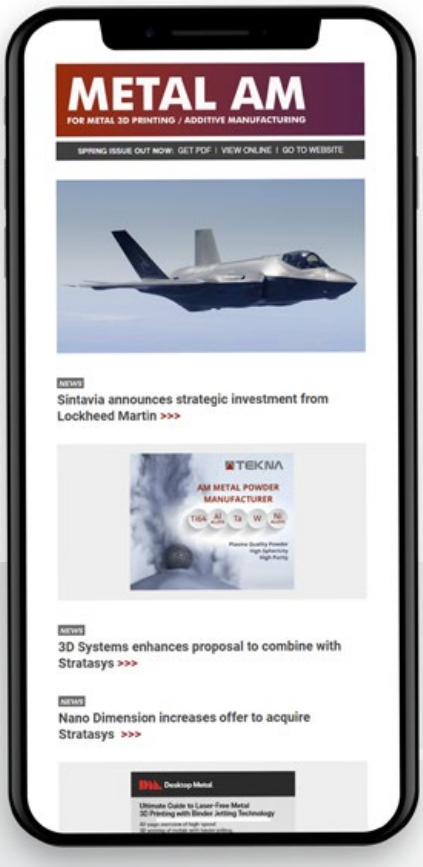
To maximise the mechanical strength and fatigue resistance of such critical AM parts, they must be processed by Hot Isostatic Pressing (HIP) to eliminate any residual porosity, and heat treated.

Jim Shipley from Quintus Technologies provides an overview of HIP and High Pressure Heat Treatment technology for Powder Bed Fusion AM and considers the opportunities that a new generation of HIP equipment presents. >>>

189 **The convergence of Additive Manufacturing and Artificial Intelligence: Envisioning a future that is closer than you think**

The frenzy of media attention surrounding Artificial Intelligence (AI) dwarfs the past hype surrounding Additive Manufacturing (AM). Whether you look to the future with fear or excitement, there is no escaping the wave of change that is coming.

Whilst we once again hear words like 'revolution' being used – to which so many have become immune – Dr Omar Fergani believes that we are now at a crucial point of convergence for AM and AI. Here, he explains why AM is in an especially strong position to leverage the potential of AI, with the power to transform many areas of our industry, from part design to machine operation, quality management and beyond. >>>



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201 ADAXIS: On a mission to reduce the layers of complexity in robotic Additive Manufacturing

France's ADAXIS is tackling two of the most complex advanced industrial manufacturing disciplines head on — Robotics and Additive Manufacturing. Its solution aims to make robotic Additive Manufacturing more accessible to any company that wants it, including for metal processes, irrespective of background or industry sector.

Rachel Park spoke with Henri Bernard and Emil Johansson, two of ADAXIS' co-founders, as well as project partners, to discover their story and ambitions. >>>

209 Exploiting your metal Additive Manufacturing data assets: Faster industrialisation and new revenue streams

While metal Additive Manufacturing is revolutionising industries from aerospace to healthcare, the need for efficient process development and the acquisition of validated material data is becoming increasingly important. In this context, a groundbreaking solution emerges – that of the platform-based exploitation of metal AM data assets to accelerate industrialisation and unlock new revenue streams.

Here, Rosswag GmbH's Philipp Schwarz and Gregor Graf delve into the significance of this concept and how it fits as a crucial piece in the AM industrialisation puzzle. >>>

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Industry news

PBF-LB titanium hinge part highlights AM's potential in high-volume consumer electronics

The recently launched Honor Magic V2 folding mobile phone is reported to be the first high-volume 3C device to use Additive Manufacturing in the final production stage. The phone is a new generation of mobile device that features a foldable screen, with the hinge using titanium components manufactured via Laser Beam Powder Bed Fusion (PBF-LB). At just 9.9 mm thick when closed, and weighing 231 g, it is reported to be the thinnest and lightest foldable phone currently available from any manufacturer.

Being one of the key components in the phone, the hinge has been tested to operate for 400,000 folds – which equates to being opened and closed over one hundred times a day for ten years.

The hinge was developed by Honor, with the involvement of several Chinese Additive Manufacturing companies, including HBD and Eplus3D. The hinge shaft cover is made of titanium alloy, which makes the component lighter and thinner and is crucial to reducing the overall thickness and weight of the folding screen.

After the shaft cover has been additively manufactured, it is sent to a further supplier for grinding and polishing before being delivered to Honor. Eplus3D stated that the cost of the additively manufactured raw part was approximately $4, with the cost of grinding and polishing stage adding around $40. However, compared to a more traditional manufacturing method, this cost was said to be affordable and the process more efficient.

It is reported that around one million Magic V2 phones have been ordered so far, double that of the previous generation model (Courtesy Honor)

"Honor is very confident in this product and is currently placing an order. The volume has doubled from that of the previous generation, and the first batch of orders is about one million units," added Eplus3D, quoting an unnamed supplier in the mobile phone supply chain.

Celine Xie, Overseas Business Development & Marketing Manager at HBD told *Metal AM* magazine that the significance of this achievement extends beyond the Honor Magic V2. "Reports have surfaced indicating that the next generation Apple Watch Ultra will also incorporate titanium 3D printing, partially replacing traditional CNC milling technology."

Although the use of metal Additive Manufacturing in the Apple watch is currently unconfirmed, it would represent a major breakthrough for the technology. "This transition highlights the industry's recognition of the immense potential offered by 3D metal printing in terms of enhanced product design and functionality. The growing trend of integrating 3D metal printing in various 3C products emphasises its increasing importance in the consumer electronics industry," added Xie.

www.hihonor.com | en.hb3dp.com
www.eplus3d.com

The hinge shaft cover is additively manufactured using aerospace-grade titanium alloy, key to reducing the overall thickness and weight of the folding screen (Courtesy Honor)

Stratasys and Desktop Metal merger rejected

Following an Extraordinary General Meeting, Stratasys shareholders have voted to reject the company's previously announced merger with Desktop Metal Inc. Although Desktop Metal's shareholders had approved the deal during the company's own shareholder meeting, the merger agreement has now been terminated.

Stratasys announced it would begin a comprehensive process to maximise shareholder value immediately. Potential alternatives to be explored or evaluated include a strategic transaction, potential merger, business combination, or sale, the company added.

"We have decided to undertake a comprehensive and thorough review of all available strategic alternatives," shared Dov Ofer, chairman of Stratasys' Board of Directors. "We are entering this review as the leader in the Additive Manufacturing space and will continue to execute our strategy, powered by innovation and profitable growth, which has led Stratasys to outpace the competition. Importantly, we remain focused on our mission to deliver value to customers and are committed to taking the appropriate actions to maximise value for all Stratasys shareholders."

Desktop Metal reported that it remains focused on its path to profitability, with continued improvements in non-GAAP gross margins, operating expenses, adjusted EBITDA, and operating cash flow expected to result in adjusted Q4 EBITDA profitability.

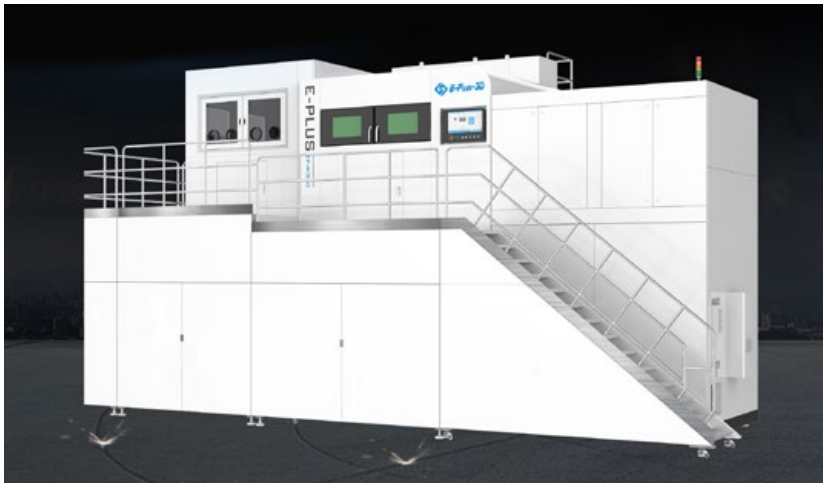
Ric Fulop, founder and CEO of Desktop Metal, stated, "We're grateful for our shareholders' support. While the team at Desktop Metal believed in the merits of our combination, and is disappointed in the outcome of the merger agreement, we are completely confident in the trajectory of our business, which continues to lower operating costs while growing revenue. Our plan to reduce costs and generate revenue remains on track as customers continue transitioning to our AM 2.0 technologies for mass production of metal, polymer, ceramic and health products."

www.stratasys.com
www.desktopmetal.com

Eplus3D launches sixteen-laser EP-M1550 with twenty-five laser option

Eplus3D, located in Hangzhou, China, has expanded its large-format metal Additive Manufacturing machine range with the release of its sixteen-laser EP-M1550. With the option to upgrade to twenty-five lasers and a build volume of 1558 x 1558 x 1200 mm (with a further option to extend this to 2000 mm in height), the EP-M1550 is now the largest metal AM machine in the company's lineup.

The EP-M1550 Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine incorporates a novel four-by-four laser matrix and sixteen galvanometers. This allows the sixteen lasers to operate synchronously, ensuring a high build rate of up to 650 cm^3/h. If the machine is upgraded to twenty-five lasers, the optics system includes a five-by-five laser matrix and twenty-five galvanometers.



The new EP-M1550 features sixteen or twenty-five lasers (Courtesy Eplus3D)

Further options include either 500 W or 700 W fibre lasers, providing the capability to process a wide range of materials such as titanium alloys, aluminium alloys, stainless steels, and tool steels. This offers the same number of material options as Eplus3D's smaller frame systems. The EP-M1550 can manufacture at a layer thickness of between 20–120 µm and is reported to be well suited to manufacturing large-size, high-precision, and high-performance parts for the aerospace and other demanding industries.

"We have solved the technical challenges and bottlenecks associated with ultra-large metal LPBF machines and approached the leading level in the industry in terms of advancement and stability of our systems," stated Mary Li, General Manager International Division, Eplus3D. "Delivering nearly twenty ultra-large machines with printing size 1250 x 1250 x 1000 mm or bigger to our customers where they are producing parts in a production environment. Eplus3D will continue to provide more reliable and applicable production-level AM systems and solutions to help more customers from the industry."

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Farsoon expands range with sixteen-laser and four-laser machines

Farsoon Technologies, based in Changsha, China, announced the launch of both sixteen-laser and four-laser metal Additive Manufacturing machines. Both are Laser Beam Powder Bed Fusion (PBF-LB) machines, and both use an array of 500 W fibre lasers.

FS1521M sixteen-laser

The FS1521M has a build chamber diameter of 1,530 mm and height of 85 mm, with a variant, the FS1521M-U, increasing that height to 1,650 mm. Both are available with square build cartridge configurations, with the larger FS1521M-U model having a build volume of 3,862 litres.

Due to the new calibration algorithms, each laser's operation and overlap can be precisely controlled to ensure uniform mechanical properties throughout the build area. The advanced multi-laser scanning strategies offer optional modes towards efficiency, quality, or balanced performance for different manufacturing needs.

The FS1521M series has a high build rate of up to 400 cm^3/h (for example, 3.27 kg/hr in Inconel) and features innovative gas flow design, ensuring stable, real-time particle removal throughout the large platform. Parallel permanent filtration systems allow uninterrupted operations for longer build times.

The contactless, closed-loop powder handling system includes powder supply, recycling and sieving conducted under a fully inert gas-protected system for operational safety. The system offers continuous feeding and collection of overflow powder, streamlining the powder management process.

Farsoon confirmed that multiple FS1521M systems have already been installed at the sites of manufacturing customers in China.

FS350M-4 four-laser

The FS350M-4 has a build envelope of 433 x 358 x 400 mm and is equipped with advanced multi-laser scanning strategies and calibration algorithms, enabling optimal build efficiency and uniform part performance throughout the build area. It also features an efficient inert gas system, with a purge process that takes only eleven minutes. During the manufacturing process, the system consumes around 3-5 l/min of inert gas, reported to be significantly lower than the industry average.

The FS350M-4 comes with an integrated, advanced three-stage filter module. It features a powerful back-flush function in an effort to ensure longer filter life. A permanent filter solution will also be available in the near future, further enhancing machine uptime and ease of operation. The powder refill unit can be easily docked, enabling quick refill of the material without interrupting the build process.

www.farsoon-gl.com

Farsoon has launched a sixteen-laser FS1521M metal Additive Manufacturing machine (Courtesy Farsoon Technologies)

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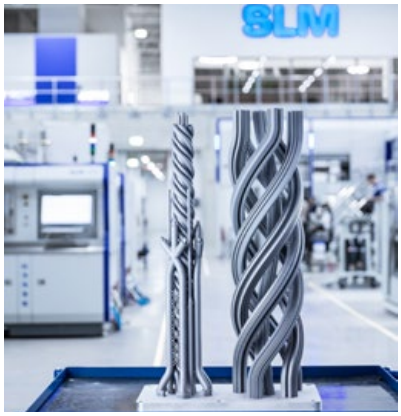
Nikon SLM Solutions reports record revenues in first half 2023

Nikon SLM Solutions Group AG, headquartered in Lübeck, Germany, has released its financial results for the first half of 2023, reporting record revenues of €51.9 million for the first six months, up 22% when compared to the company's results for the same period in 2022. The first half figures followed strong revenues in Q1, alongside a 7% improvement year-on-year in the second quarter with revenue of €27.9 million.

"We continue to grow the business at a steady pace, which is evident in the robust nature of revenue growth delivered," stated Sam O'Leary, CEO of SLM Solutions. "The integration with Nikon has made good progress and we expect this to continue further as we begin to realise synergies between the businesses. Overall, we remain confident about the long-term prospects of the business."

For the first six months of 2023, the company posted an EBITDA of -€8.4 million (H1 2022: -€3.03 million). Operational profitability during the first half of 2023 was said to be impacted by adverse currency effects, a significant discount on a one-off order with a major customer along with an order for an NXG XII 600 with a notable component of variable compensation which would be due upon fulfilment of specific preconditions that were not fulfilled during the reporting period.

Additionally, EBITDA for H1 2023 was also impacted by a significant increase in electricity expenses as well as extraordinary expenses due to the Nikon takeover.



Nikon SLM Solutions reported record revenues of €51.9M in the first half of 2023 (Courtesy Nikon SLM Solutions)

As communicated in Nikon SLM Solutions' Annual Report 2022, the company expects to continue on its growth path in FY 2023 and expects notable sales growth. Furthermore, the company's management board is said to expect a significantly improved EBITDA for FY 2023.

www.slm-solutions.com

Velo3D reports 28% revenue increase in second quarter 2023

Velo3D, Inc, headquartered in Campbell, California, USA, has announced its financial results for its second quarter, ended June 30, 2023, reporting a revenue of $25.1 million – a 28% increase from the previous year. Operating expenses for the second quarter were $28.7 million, compared to $27 million in the first quarter of 2023. Non-GAAP operating expenses, which excludes stock-based compensation expense of $6.5 million, was $22.2 million.

The net loss for the quarter was $23.2 million, which included a gain of $2.7 million on the fair value of warrants and contingent earnout liabilities. The non-GAAP net loss, which excludes, among other items, the gain on fair value of warrants and contingent earnout liabilities, as well as stock-based compensation expense, was $19.3 million for the three months ended June 30, 2023. Adjusted EBITDA for the quarter, excluding the same metrics, was a loss of $17.5 million.

"Our second quarter results reflect strong execution as we expanded our global footprint, improved manufacturing cycle times through our efficiency initiatives and prudently managed our costs," said Benny Buller, CEO of Velo3D. "Demand for our industry-leading technology remains strong as we booked a record amount of new customer orders during the quarter and exited Q223 with a growing pipeline across a diverse set of industries. In particular, we continued to expand our presence in the defence vertical while maintaining our leading position as a preferred supplier to the global space industry. However, despite these positive demand trends, second quarter bookings came in below plan, primarily due to delays in booking certain orders, which will impact our second half revenue forecast. As a result, we now expect our fiscal year 2023 revenue to be in the range of $105 million to $115 million. Importantly, our path to profitability remains clear and with the announcement of our registered direct offering of $70 million of senior secured convertible notes, we believe we have strong liquidity to reach our goal of sustained profitability."

Buller continued, "Operationally, manufacturing cycle times continue to improve for our Sapphire XC and Sapphire XC 1MZ systems. As these systems have become the majority of our quarterly shipments, we are now seeing the benefits of scale in our production processes. This scale, combined with the continued improvement in materials costs and manufacturing efficiency, has enabled us to improve our gross margin in the second quarter. We also remain committed to managing our expense structure and expect to materially reduce our operating costs in the second half of the year."

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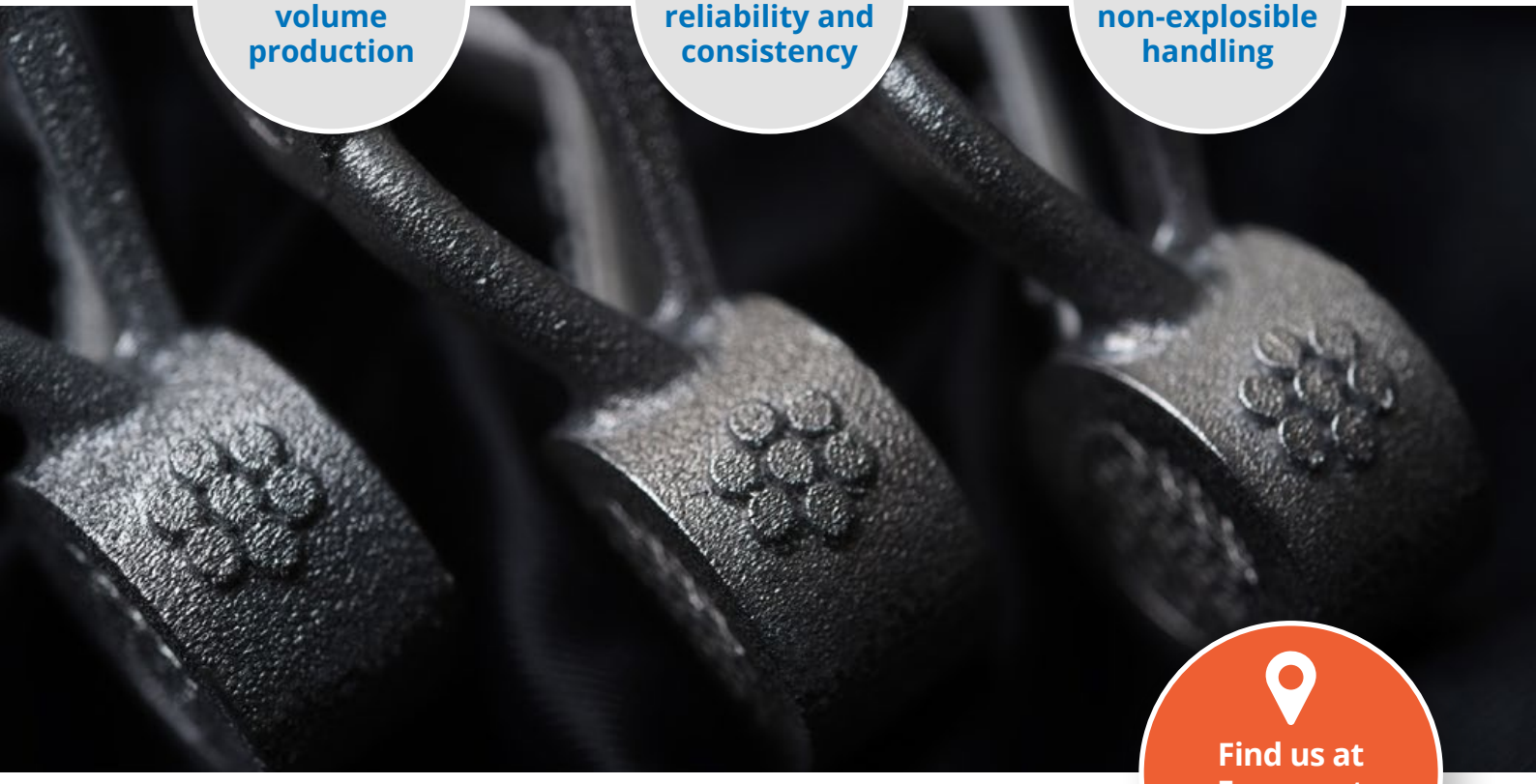

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Pelagus 3D established by thyssenkrupp and Wilhelmsen to bring AM to global maritime industry

thyssenkrupp Materials Services, Essen, Germany, and Wilhelmsen Group, Oslo, Norway, have launched Pelagus 3D, a new joint venture company established to bring additively manufactured spare parts to the worldwide maritime industry.

Headquartered in Singapore, the newly formed company will use Additive Manufacturing technology and a global partner network to produce and deliver spare parts more efficiently in terms of time and cost. Customers will, therefore, be able to ensure the seaworthiness of their ships and maintain their operations as planned, it was stated.

"The global economy relies on resilient and flexible supply chains. The dynamic market environment has shown us this again and again, at least since Corona," stated Ilse Henne, Chief Transformation Officer of thyssenkrupp Materials Services. "In our partnership with Wilhelmsen, we are showing how we can maintain the operation of ships and secure the flow of goods in shipping, which is so important for international trade."

For the joint venture, thyssenkrupp will leverage its expertise in AM, as well as the capabilities of its own Tech Centers in Singapore and Germany, to supply metal additively manufactured products. thyssenkrupp Materials Services, the company's materials distribution and service provider, further adds its knowledge in the development of digital supply chain solutions and platforms. Wilhelmsen, in turn, will bring in its in-depth maritime expertise and direct ongoing experience in understanding the needs of vessel fleet managers, supporting the delivery of a wide portfolio of maritime products and services for an array of vessels.

Kjell André Engen, President of Wilhelmsen Ships Service, added, "Through our collaboration with thyssenkrupp, we are able to introduce Pelagus 3D to the market and solve a substantial and evolutionary logistics puzzle. Not only is Wilhelmsen excited to see Pelagus 3D being released, but as the shaper of the maritime industry, we are also proud to finally offer this service to the global merchant fleet."

Global partner network for local manufacturing

At the core of Pelagus 3D will be a digital platform developed by thyssenkrupp Materials Services, which will serve as a link between customers as well as ship managers and OEMs. Through this platform, users will have access to a global partner network offering Additive Manufacturing and a number of other manufacturing technologies.

This allows the manufacturing to take place locally, where the spare part is needed, reducing transportation costs and environmental impact.

Pelagus 3D will be managed by Ken Lip Ong, Head of TechCenter Additive Manufacturing at thyssenkrupp in Singapore, as CEO, and Håkon Ellekjær, Head of Ventures for 3D Printing at Wilhelmsen, as CCO. The Supervisory Board includes Cetin Nazikkol, Chief Transformation Officer and CEO of the Asia Pacific Africa Region at thyssenkrupp AG; Dr Sebastian Smerat, Head of Customer Innovation at thyssenkrupp Materials Services, as well as Kjell André Engen and Nakhul Malhotra, Vice President Emerging Opportunities Portfolio at Wilhemsen.

www.wilhelmsen.com
www.thyssenkrupp.com
www.pelagus.com

Indo-MIM acquires CMG Technologies to expand presence in UK and EU markets

Indo-MIM, a supplier of both Metal Injection Moulding and metal Additive Manufacturing components, as well as metal powders, headquartered in Bangalore, India, has announced that it has acquired CMG Technologies, a leading MIM producer based in Woodbridge, Suffolk, UK.

It was stated that CMG's team of directors and employees will remain the same, with the business expected to grow substantially thanks to the resources that Indo-MIM will provide.

In addition to Metal Injection Moulding, CMG has sinter-based metal Additive Manufacturing capabilities, as well as offering toll debinding and sintering services. The acquisition of CMG looks to further expand Indo-MIM's penetration of European defence, medical and consumer markets by providing on-shore manufacturing supported by a robust overseas supply chain that encompasses all key aspects of the MIM process. It also aims to bolster Indo-MIM's current manufacturing presence in India and the USA through this added presence in the UK.

Indo-MIM added that it intends to further enhance its manufacturing presence in the EU, USA, South America and South East Asia in the coming years, as it moves to better serve global markets using its advanced manufacturing technologies. The company added that this growth will be accomplished via both acquisitions and green field investments.

CMG offers both MIM and sinter-based metal AM (Courtesy CMG Technologies)

www.indo-mim.com
ww.cmgtechnologies.co.uk

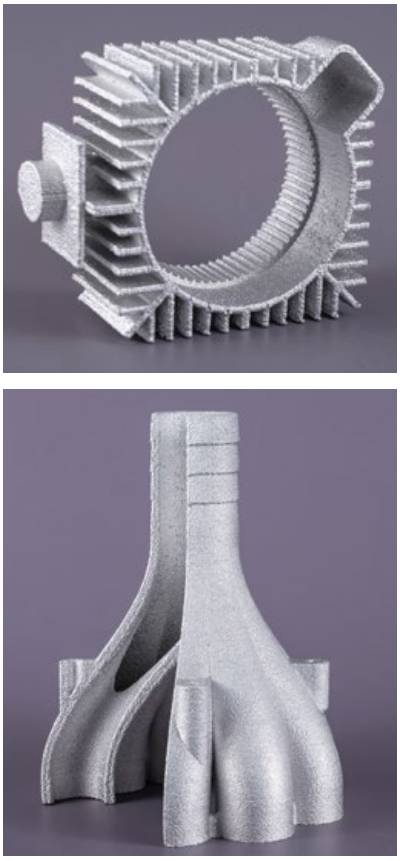
ADDiTEC acquires Elem Additive Solutions from Xerox to expand into liquid metal AM

ADDiTEC, headquartered in Palm City, Florida, USA, has announced the acquisition of Elem Additive Solutions from Xerox Holdings Corporation. The deal will see ADDiTEC expand its portfolio to include Elem Additive's Liquid Metal Printing (LMP) technology, and is expected to open up new opportunities for growth and enhance its ability to serve the growing AM industry.

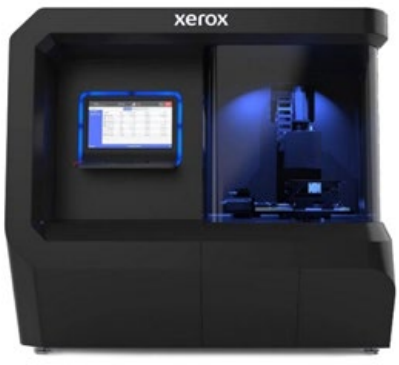
The LMP process falls broadly into the ISO/ASTM 52900:2015 category of Material Jetting, using widely available aluminium wire as the primary feedstock. The process then utilises magnetohydrodynamics to jet molten metal droplets at a specific rate and a specific mass. This method of Additive Manufacturing was developed by Vader Systems, which was acquired by Xerox in 2019. Since the acquisition, Xerox has matured the technology, leveraging its strong ink jetting expertise to refine the process.

"The Elem Additive team has seen tremendous success since the organisation was stood up nearly four years ago," stated Steve Bandrowczak, Chief Executive Officer at Xerox. "In evaluating partners for this sale, it was critical we found a company with a shared mission that would sustain and advance Elem Additive's innovation into the future. We are confident that ADDiTEC is the right partner and look forward to witnessing both teams' shared success on the road ahead."

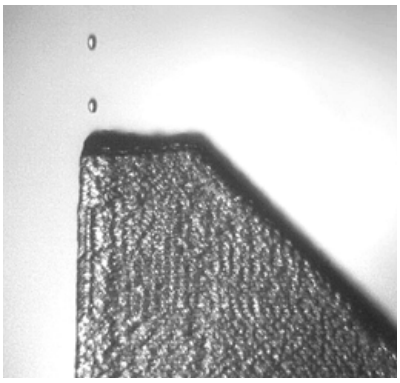
Brian Matthews, founder and chief executive officer at ADDiTEC, added, "We're very excited to have completed the acquisition of Elem Additive Solutions. This acquisition is a significant step for our company, we see incredible value in liquid metal print technology, and Elem Additive's success supplements our growth efforts as we continue to develop new offerings and bring to market our turnkey metal Additive Manufacturing systems. We are delighted to have acquired Elem Additive Solutions and will strive to create further innovative services and solutions for our customers with the addition of this exciting liquid metal printing technology."



A heat sink (top) and a fluid distribution nozzle (bottom) produced using the ElemX (Courtesy Xerox)



Xerox's Elem Additive Solutions produces the ElemX AM machine above (Courtesy Xerox)



An in-process image showing the release of multiple droplets of molten material (Courtesy Xerox)

In early 2021, Xerox unveiled and officially announced a strategic collaboration with the Naval Postgraduate School, installing its first ElemX machine at the school. A year later, in a first-of-its-kind installation, the ElemX was installed on a US Navy ship. Additional Elem Additive customers include Siemens, the US Department of Energy's Oak Ridge National Laboratory, Rochester Institute of Technology, and Vertex Manufacturing. ADDiTEC stated it will continue to support these customers as the Xerox Elem Additive team transitions to the organisation.

www.additec3d.com

Discover more:

Want more information on Xerox's Liquid Metal Printing technology? *Metal AM* published a deep dive into the technology in the Summer 2022 issue. 'What Xerox's aluminium liquid metal AM offers for supply chain resiliency' is available to read here, in full on our website at:

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SWISSto12 secures €26.15M financing for HummingSat AM satellite production

SWISSto12, a provider of additively manufactured antenna and radio frequency (RF) system products based in Renens, Switzerland, has announced that it has secured a €26.15 million working capital facility from the multinational bank, UBS Switzerland AG. The finance is expected to provide SWISSto12 with the flexible growth capital needed to meet customer demand for its geostationary SmallSat HummingSat.

"This CHF 25 million working capital facility with UBS gives us additional agility to execute on the manufacturing and delivery of our first HummingSats and address strong customer demand," stated Emile de Rijk, founder and CEO of SWISSto12. "With HummingSat, SWISSto12 is creating a new class of agile, high-performance SmallSat for geostationary orbit that is approximately three to five times smaller and lower cost than conventional geostationary satellites, while still reliably delivering critical services. We're excited to build on customer demand from global satellite operators and national governments with our innovative geostationary communications satellites that will better connect and protect users worldwide."

Since its foundation in 2011, SWISSto12 has raised over €50 million in venture capital, with prominent Swiss and European investors including Constantia New Business (CNB Capital), Swisscom Ventures, Swisscanto, and Zürcher Kantonalbank (ZKB).

Pär Lange, partner, Swisscom Ventures, added, "SWISSto12 is the first ever growth-stage company to sell a whole geostationary satellite to global satellite operators – testament to the uniquely transformative market potential of the HummingSat platform and the team's technical and commercial acumen. Having generated over €200 million in customer orders, SWISSto12 is also one of the few growth-stage companies able to secure a growth facility of this magnitude from a multinational bank such as UBS – the company is in a tremendously good position to reinvigorate the geostationary communications market on which billions of people depend for broadband, broadcast and safety services."

In 2022, SWISSto12 announced that it had secured a deal to supply a HummingSat satellite to Intelsat. This was followed in May 2023 by a deal to supply three HummingSats to Inmarsat. The company's radio frequency products and subsystems business currently have more than €200 million in back orders from customers, and has partnered with ESA and recently secured HummingSat contracts. In addition to its growing RF product and subsystem business, SWISSto12 also partnered with the European Space Agency (ESA) to support the design of the HummingSat platform. This project has secured over €30 million in support and is said to be the first SmallSat for geostationary orbit.

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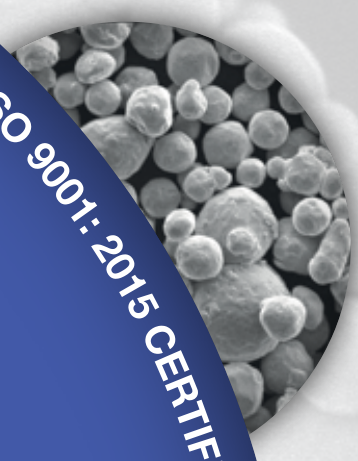

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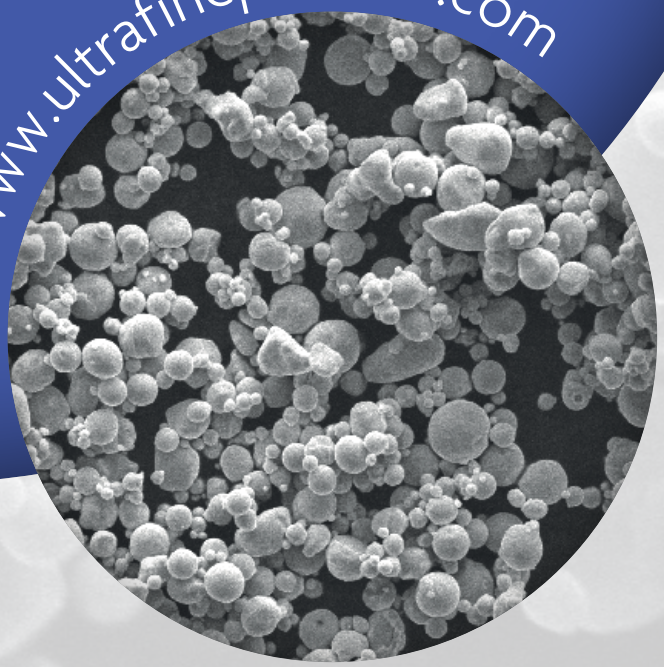

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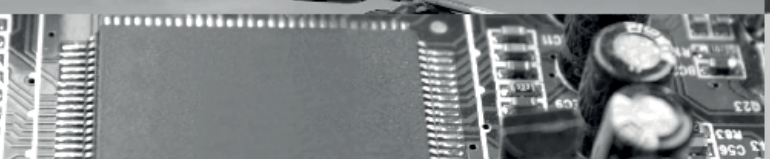

Shapeways reports strong Q2 2023 with 40% increase in software revenues

Shapeways Holdings, Inc, based in New York City, USA, has released its results for the second quarter ending on June 30, 2023, reporting revenue of $8.4 million for the three-month period and gross profit of $3.4 million, a small decrease from the $3.6 million in the same period in 2022. In the six months ended June 30, 2023, revenue was $16.6 million compared to $16.0 million for the same period in 2022, with gross profit at $6.7 million compared to $7.1 million for the same period in 2022.

The company announced a 40% increase in software revenues for the quarter compared to the same period last year, with year-to-date software revenues of $1.4 million. Shapeways said it believes it is on track to more than double software revenues for the full year 2023 from 2022.

"We made notable progress year-to-date on each of our key objectives, particularly with regard to our software tools and services, as well as with enterprise manufacturing customers," shared Greg Kress, Shapeways' Chief Executive Officer. "We are encouraged by our growing traction of SaaS contract commitments on our refreshed MFG platform. We have launched several new software features in recent months, which should provide for increased customer acquisition, retention, and lifetime value, as well as additional sources of revenue. For example, the 3D Model Viewer is a feature requested by users, which allows viewing 3D models of custom parts, streamlining the quoting process, and allowing for greater accuracy and speed."

"With MFG Materials, we are providing a very compelling return to our customers by helping them save on raw material costs. In addition, our increased customer focus on middle market and enterprise opportunities has translated into several exciting new multi-year customer contracts and developing a growing pipeline in our target industries."

Kress continued, "We believe the market is approaching an inflection point in the overall adoption of digital manufacturing solutions. Furthermore, we believe that Shapeways is well-positioned to take advantage of this market opportunity across an array of industries with a platform that combines high-quality, flexible, on-demand manufacturing with purpose-built proprietary software. We are pleased with our ongoing traction and will remain disciplined and prudent as we execute our operating plan."

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FreeFORM owns world's largest fleet of Desktop Metal machines

Desktop Metal has announced the sale of sixteen metal Binder Jetting machines to FreeFORM Technologies, located in St Marys, Pennsylvania, USA. Now including a Production System P-50, along with the shop System, and X-Series models, FreeFORM has a fleet of twenty-five Desktop Metal machines.

"FreeFORM's investment in metal Binder Jetting demonstrates our continued commitment to employing world-class Additive Manufacturing processes to meet the needs of our customers," stated Nate Higgins, president of FreeFORM. "This addition of DM printers strengthens our capabilities in this area, allowing us to provide greater cost efficiency and speed to market."

The company now offers Additive Manufacturing in a wide range of metals, including 17-4PH, 316L, and 420 stainless steels, as well as 4130, 4140 and 4340 low-alloy steels, S7 and M2 tool steels, and infiltrated materials. To-date, FreeFORM has produced over 350,000 parts using Binder Jetting technology for customers in the industrial, defence, medical, robotic, and consumer goods markets.

Founded in 2020, FreeFORM's primary investor is Ryerson Holding Corporation, a processor and distributor of industrial metals. Ryerson has been a primary investor in FreeFORM since 2022.

"Desktop Metal is delighted to see a startup with deep experience in powder metal and sinter-based technologies pushing the limits of what metal binder jet 3D printing technology can do," added Ric Fulop, Founder and CEO of Desktop Metal. "FreeFORM is leading the way among our Super Fleet owners, which we define as customers using three or more of our Additive Manufacturing 2.0 systems. Desktop Metal now has hundreds of Super Fleet customers worldwide delivering final production of metal, polymer, and ceramic parts with our binder jet Additive Manufacturing systems. We remain confident that the cost, quality and material flexibility offered by Binder Jetting will continue its momentum in serial AM production."

www.desktopmetal.com
www.freeformtech.com

FreeFORM Technologies President Nate Higgins in front of a Desktop Metal X25Pro (Courtesy Desktop Metal)

Hankook Precision Works opens Korean Additive Manufacturing centre

Hankook Precision Works recently opened its new 3D Printing Convergence Technology Center at the Hankook Engineering Lab in Yuseong-gu, Daejeon Metropolitan City, Korea. The new facility will provide production capabilities for tyre moulds using Additive Manufacturing and is equipped with a wide range of testing equipment.

The company states that there is a growing demand for kerfs in tyres (small slits in a tyre's tread block which creates additional tread surface area), particularly in those tyres designed for EVs and high-performance vehicles. Additive Manufacturing allows for the optimisation of product-specific performance, including features such as reduced noise, robust grip, and superior handling.

Additionally, the use of Additive Manufacturing to build mould components reduces the length of the tyre production process when compared to conventional methods.

Hankook Precision Works was established in 1973 as a mould manufacturing company, and has been at the forefront of tyre mould, tyre curing container and precision parts development through its casting and machining technology. In 2015, the company introduced a metal Additive Manufacturing machine for the development of tyre moulds.

www.hankookandcompany.com

Hankook Precision Works has opened its 3D Printing Convergence Technology Centre (Courtesy Hankook Precision Works)

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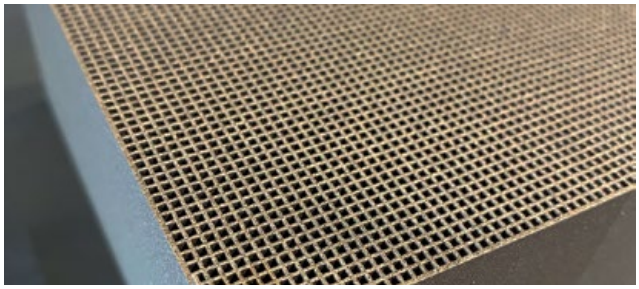

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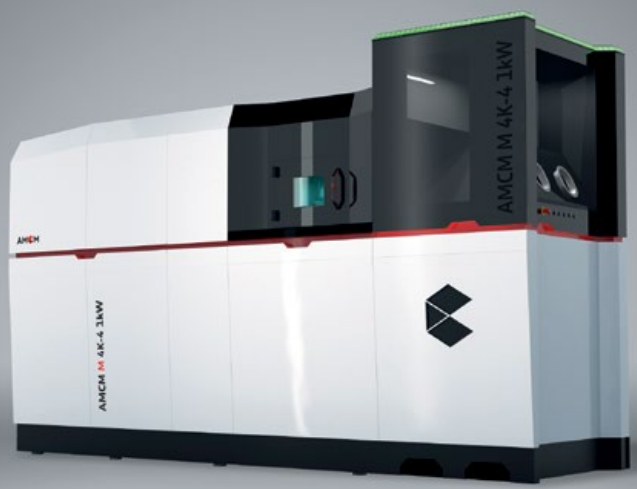

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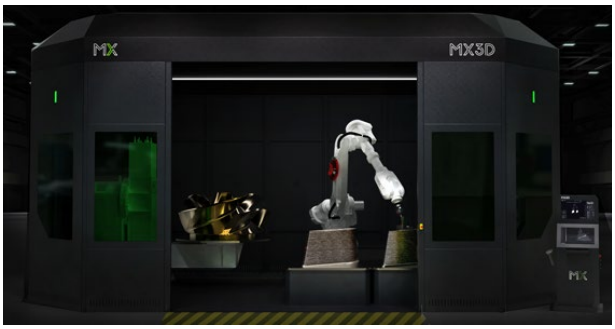
* by courtesy of Launcher
** by courtesy of CERN, European Organization for Nuclear Research

MX3D's MX Metal AM System for large metal parts

MX3D, based in Amsterdam, the Netherlands, has announced that it will launch its new MX Metal AM System, a turnkey robotic wire-based Directed Energy Deposition (DED) system for the Additive Manufacturing of large, certified metal parts, at this year's Formnext Forum Austin exhibition. The new machine, with a build volume of 600 x 150 x 350 cm, was developed following requests from various industrial customers who operate within the energy, manufacturing, and maritime sectors and need to manufacture larger-scale metal components.

The MX Metal AM System operates on multiple adjustable build plates, including a heavy-duty two-axis positioner, and can manufacture parts that weigh up to five tons or more. The system includes an eight-axis heavy-duty industrial robot setup, high-productivity power source and the MX3D 24/7 automation package.

All elements are fully-integrated with the latest version of MX3D's proprietary end-to-end workflow software and control system MetalXL. This latest version software supports several new productivity tools, dynamic sensors, and active closed-loop processes. The goal is to enhance the autonomous 24/7 manufacturing of qualified industrial metal parts.



The MX Metal AM System is a turnkey robotic wire-based DED system (Courtesy MX3D)

"Several of our customers see opportunities for applying WAAM [Wire Arc Additive Manufacturing] on much bigger parts. Especially in the energy and maritime industry where they will replace large casted or forged parts with 3D printed parts to accelerate the lead time, bring down cost and reshore production of critical parts," shared Gijs van der Velden, CEO of MX3D. "Since the launch of MetalXL and the M1, we have received many customer requests about whether we could supply them with a system capable of printing radically larger parts. The MX Metal AM System is the answer to this call. Now customers can also print very large and extra heavy certified metal components in-house, accelerating 24/7 automation and operational excellence."

The new MX Metal AM System provides a fully customisable robotic system for manufacturing large-scale metal parts. Customers can configure custom systems for additively manufacturing large, heavy, and custom metal components by utilising renowned brands such as ABB and KUKA robotics, as well as Fronius' advanced welding equipment.

The MX Metal AM System can be optimised by various heavy-duty-cycle power sources to achieve higher build speeds at >10 kg/hr deposition rate, and can be configured for multi-material manufacturing of various metal alloys. All of these features are fully integrated and automated by the proprietary MX3F workflow platform and control system for flexible, controlled, and advanced robotic Additive Manufacturing. This technology is used by companies such as BMW Group, Shimoda Iron Works, Dalhousie University, and Whittaker Engineering.

The MX Metal AM System can be enhanced with several additional sensors, such as advanced thermal cameras, 3D scanners, weld pool cameras, and acoustic emission sensors.

"The MX Metal AM System is an impressive production system and by far the largest AM system MX3D has released to the market. It certainly is the heavyweight champion of Metal 3D Printing," added Thomas Van Glabeke, CPO of MX3D. "We specifically configured it for our customers in the heavy industry markets, and we engineered it to ensure speed, quality, and cost-effectiveness for the production of large-scale metal parts."

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AMCM's new M 8K metal AM machine to build large-scale rocket engine combustion chambers

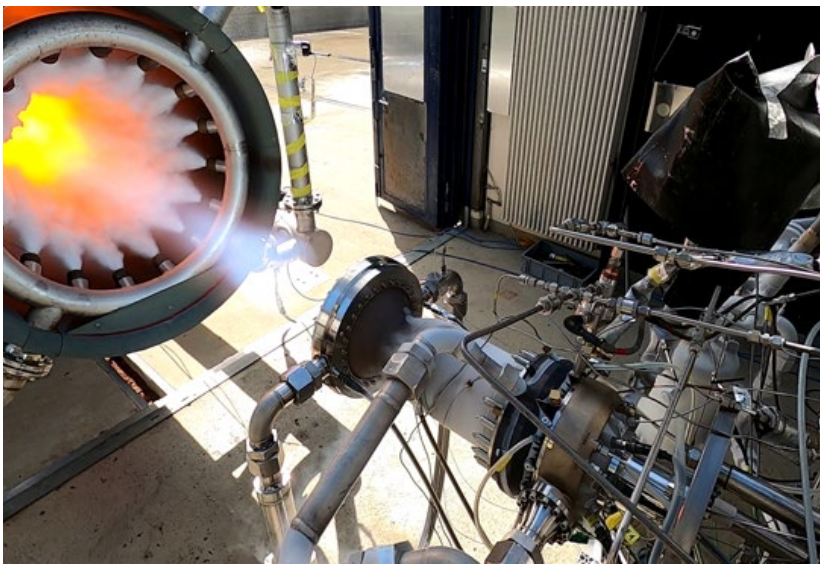
AMCM, an EOS Group company based in Starnberg, Germany, has announced details of its M 8K Laser Beam Powder Bed Fusion (PBF-LB) metal Additive Manufacturing machine, expected to be released towards the end of 2024. The M 8K will have a build area of 800 x 800 x 1,200 mm and, with eight lasers, is aimed at the production of large-scale components for aerospace and other demanding applications.

AMCM reports it has been working with ArianeGroup on the development of rocket engines that will be used to power the new Ariane 6, and has received funding through a National Grant to help improve the rocket's competitiveness. The company expects to use the new M 8K to build the rocket's Prometheus engines, having already proved the performance of its AM technology through its smaller M 4K machine.

"We needed to find a partner who was willing to work with us to push the boundaries of what's possible," stated Jan Alting, Head of Future Propulsion of ArianeGroup. "This is literally AMCM's DNA, who have already built an excellent reputation having multiple M 4K systems in this industry. ArianeGroup projects must meet ESA's strict requirements to be approved for launch. As a result, we place the greatest value on part quality, e.g., material microstructure and surface roughness."

AMCM has already built the combustion chamber for a launcher upper stage engine as part of the ESA's Expander-Cycle Technology Integrated Demonstrator (ETID) project. This was produced on the M 4K machine, which has a build area of 450 x 450 x 1,000 mm and is powered by four 1 kW lasers.

In June this year, ArianeGroup completed the final test of the reusable Ariane 6 Prometheus engine for the Themis rocket stage demonstrator. The engine, with almost 70% of its components built using Additive Manufacturing, successfully performed a twelve-second burn. Typical of ArianeGroup's portfolio of large rocket engines, the Prometheus combustion chamber is built from CuCr1Zr and measures over 1,000 mm tall, with a maximum diameter of 800 mm.



ArianeGroup has successfully tested combustion chambers produced by Additive Manufacturing (Courtesy AMCM/ArianeGroup)

"Designing a system of this size involves a whole range of challenges. The excellent laser, scanner and optics design with our tried-and-tested beam sources is based on decades of process expertise from EOS," explained Martin Bullemer, Managing Director at AMCM. "The build volume is 4 X that of the M 4K, which also means mass. Therefore, the z-axis of the system must be able to move up to 5 tons of powder with highest precision."

Other challenges include maintaining a uniform protective gas atmosphere and a reliable, uninterrupted powder supply. The process gas needs to evenly cover the large powder surface of 0.7 m^2, while ensuring that fumes are safely dissipated to prevent any degradation in quality during long manufacturing times.

The importance of material supply is often underestimated, explained Bullemer, "For printing up to 1.2 m tall parts with high productivity and quality, powder management is key. Reliably feeding tons of metal powder over several days is no walk in the park. You do not want to interrupt the process in any case."

As parts become larger and build runs become longer, process control and validation become more crucial. However, X-ray computed tomography remains a commonly-used method for inspecting the structural integrity of additively manufactured parts. In the M 8K, AMCM states it will integrate the latest technology from EOS Group – including SmartFusion and EOSTATE Exposure OT (optical tomography). This integration aims to enhance in-process quality assurance and process monitoring, ultimately reducing the need for extensive subsequent testing.

"Metal printing offers the potential to make the rocket engine manufacturing process more flexible, less expensive, and faster. Our new M 8K system will be operational within a year. We have promised ArianeGroup the first printed combustion chambers before the end of 2024," concluded Bullemer.

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AMEXCI to invest in state-of-the-art Additive Manufacturing facility

AMEXCI, headquartered in Karlskoga, Sweden, has announced it is investing in a state-of-the-art Additive Manufacturing facility in Örebro, Sweden, to streamline operations for high-volume serial production, and create space for future growth.

"We feel that the time is right to expand," Edvin Resebo, CEO of AMEXCI commented. "Having built AMEXCI from the ground up over the past plus five years together with our partners and customers, we have tuned our processes to fit a variety of different industries and specialised towards serial production. Our greatest asset is the talented team we have formed, with deep knowledge across various AM verticals. It is key for our expansion to continuously invest in the latest technology, enabling us to offer unique industrial 3D printing capabilities in Europe and the Nordic region."

The key stakeholders in AMEXCI, include FAM, Saab, Scania, and Ericsson, leading the investment. Håkan Buskhe CEO of FAM, stated, "FAM are great supporters of AMEXCI's expansion. We think it's a good next step for the company and believe it will create value for the whole industry. We hope that AMEXCI will be able to support companies to take the next step in their production, allowing for the next generation of great products. We are glad to be part of this journey and think its relevant to build competence and capacity within the area of AM in Sweden."

AMEXCI is investing in a state-of-the-art AM facility in Örebro, Sweden (Courtesy AMEXCI)

Saab serves the global market of governments, authorities and corporations with products, services and solutions ranging from military defence to civil security. Micael Johansson, CEO of Saab Group, added, "Additive Manufacturing is of strategic importance for Saab and the number of applications in our product portfolio constantly grows. We see the AMEXCI expansion as a way to support our growth and to enable technology to increase our competitiveness."

The expanded capabilities of AMEXCI aim to equip the company to act as an enabler for future innovations. "Expanding our AM capacity with AMEXCI is not just a strategic move, but a testament to our commitment to innovation and delivering superior products to our customers. The key to successfully embracing this transformative technology lies in the knowhow we have diligently built together. This expertise empowers us to push boundaries, drive progress, and shape the future of manufacturing," Börje Ekholm, CEO of Ericsson commented.

Christian Levin, CEO of Scania and TRATON GROUP, shared his view on the investment, "Since the start of AMEXCI, the company has been important for us providing knowledge, training, and competence within the area of Additive Manufacturing. We believe these technologies will be even more important in the future, both as a possibility to manufacture parts with a complex design, a quick way to produce short series and contribute to our transformation towards the sustainable transport system."

An important component of this expansion is the brand-new factory being built in the industrious region of Örebro, Sweden. This significant investment underscores Örebro's standing as an industrial hub in Sweden, particularly for AM. The new factory will not only boost AMEXCI's operational capabilities but also enable deepened research collaboration, opening up further engagement with Örebro University.

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NAVSEA improves readiness of USS Bataan with on-board metal Additive Manufacturing

The crew of USS Bataan (LHD 5), a Wasp-class amphibious assault ship in the United States Navy, supported by the Naval Sea Systems Command (NAVSEA), has additively manufactured and replaced a sprayer plate used in a de-ballast air compressor (DBAC) while at sea. Completed in just five days, this was the first time the crew had used the ship's permanently installed metal Additive Manufacturing machine under these conditions, and enabled the ship to mitigate the time spent obtaining a replacement assembly.

"This success story shows the self-sufficiency we can achieve when our Sailors are provided with cutting-edge technology," shared Rear Adm Joseph Cahill, commander, Naval Surface Force Atlantic (SURFLANT). "The impact technology like this can have on operational readiness, particularly in a combat environment where logistics capabilities will be challenged, is critically important."

The metal sprayer plate is used to force pressurised air through saltwater tanks and discharge the accumulated saltwater. These tanks are filled to lower a ship's draft for amphibious operations.

"Rapidly learning how to utilise AM shipboard and scaling these capabilities is a key enabler to us sustaining our platforms and weapons systems," commented Rear Adm Jason Lloyd, deputy commander for NAVSEA's Naval Systems Engineering & Logistics Directorate. "I am excited to see how Bataan embraced this technology to enhance readiness at the point of need."

The AM machine was installed as a joint effort between SURFLANT and the NAVSEA Technology Office. It includes the Phillips Additive Hybrid system, which integrates a Laser Metal Deposition (Material Extrusion) build head from Meltio3D onto a Haas TM-1 computer numerical control mill. The Haas TM-1 platform has been proven to operate reliably in an afloat environment aboard several aircraft carriers. By integrating the Meltio3D deposition head with the Haas TM-1, the system provides both additive and subtractive manufacturing capabilities, which increases efficiency and reduces waste when compared to typical machining.

The repair effort was led by Machinery Repairman First Class Mike Hover. He began by creating a computer-aided design (CAD) model of a sprayer plate, using a functional sprayer plate from one of the ship's other DBAC systems as a reference. After creating the preliminary CAD model, Hover utilised NAVSEA's 'Apollo Lab' to obtain engineering and fleet support and training.

In 2018, NAVSEA established the 'Apollo Lab' to provide engineers with better support for forward-deployed sailors. The lab is led by NAVSEA field activity Naval Surface Warfare Center, Carderock Division, Johns Hopkins University Applied Research Laboratory (JHU APL), and Building Momentum. It provides distributed, reach-back engineering support for Additive Manufacturing equipment through civilian engineers. Additionally, the Apollo Lab designs AM components that sailors can produce while at sea to support the fleet.

Bryan Kessel, a mechanical engineer at Naval Surface Warfare Center, Carderock Division, refined the CAD file. He worked with JHU APL to develop software instructions that guide the operation of the metal Additive Manufacturing machine. Kessel then securely transferred those instructions back to the ship, where the sprayer plate was produced and installed.

NAVSEA is the largest of the Navy's six system commands and is responsible for the procurement, maintenance, and modernisation of ships, submarines, and systems for the US Navy. NAVSEA's Technology Office is leading multiple areas of research and development, including the evaluation of Additive Manufacturing equipment under shipboard conditions. These evaluations should ensure that current and future shipboard implementations of this equipment are capable of fabricating parts repeatedly and reliably, thus allowing sailors to address an increasing number of applications.

www.navy.mil

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Trumpf's updated support-free Additive Manufacturing technology reduces waste and opens up new applications

Trumpf has reported updates to its TruTops Print Additive Manufacturing software, enabling users build parts with overhang angles as low as 15° without requiring support structures. Typically, these structures provide support for parts that feature cavities or overhangs, anchoring these to the build platform. Support structures also help to dissipate heat from the part and prevent internal tensions and deformations during manufacturing. However, Trumpf's new technology is reported to allow for many AM applications to be carried out without supports, even when working with hard-to-process materials like stainless steel.

TruTops Print software enabled users to build parts with overhang angles as low as 15° (Courtesy Trumpf)

TruTops Print enables Additive Manufacturing machines to use the optimal manufacturing process for each different area of a part, eliminating the need for support structures. Additionally, Trumpf's new AM machines feature improved gas flow, resulting in uniform processing conditions and support-free manufacturing.

"When we 3D print a part, we want as much control as possible over when and where the material melts and re-solidifies. The skill lies in choosing the right exposure strategies to prevent internal tensions and overheating in the overhang region," stated Timo Degen, product manager for Additive Manufacturing at Trumpf. "Users from any industry can benefit from the ability to 3D print parts without supports. The advantages of support-free printing are particularly appealing for parts that feature large cavities or challenging overhangs," Degen added. Examples include tanks, heat exchangers, hydraulic blocks and tool moulds.

The new technology also enables new applications that were not feasible when support structures were necessary, such as additively manufactured radial compressors and shrouded impellers. Previously, manufacturers could not build support-free impellers due to their overhang angles. "The need for supports meant that 3D printing wasn't an economically viable alternative to conventional manufacturing. But now things are different," Degen concluded.

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AML3D signs $2M contract with US Navy for additively manufactured submarine parts

AML3D Limited, headquartered in Edinburgh, Australia, has signed a contract to develop and additively manufacture replacement metal components used in US Navy submarines. The high-demand component is no longer available from conventional manufacturers, and will present an ideal opportunity to demonstrate the role that AML3D's Additive Manufacturing technology can play in addressing supply chain constraints across the US Navy's Submarine Industrial Base.

The nine month contract, valued at approximately AUS $2.02 million, has been signed with BlueForge Alliance, a nonprofit, neutral integrator that supports the strengthening and sustainability of the US Navy's Submarine Industrial Base, including the acceleration of advanced manufacturing technologies.

The non-safety-critical (NSC) components are made with AML3D qualified nickel-aluminium-bronze (NAB) alloy material. The manufacturing contract presents an opportunity for AML3D to demonstrate that its ARCEMY Additive Manufacturing technology can produce complex components to a high quality and exceed the material strength properties of equivalent cast parts.

The NSC components manufacturing contract is directly aligned with AML3D's strategy to scale up in the US and embed the company's proprietary ARCEMY technology within the US defence and maritime sectors. This contract follows recent alloy testing contracts and ARCEMY sales to support the US Navy's submarine industrial base, demonstrating the increasing momentum across AML3D's US operations.

AML3D Interim CEO Sean Ebert, shared, "AML3D is excited to continue to deepen its long-term, strategic partnership with the US Navy's submarine industrial base. The NSC components manufacturing contract is further evidence of the growing momentum in our US scale-up strategy. This strategy is driving the growth of the company and creating value for our shareholders over the immediate term and beyond."

"The delivery of these complex submarine components, which is no longer available from traditional manufacturers, demonstrates the important role of AML3D's ARCEMY technology at a time of heightened interest in advanced manufacturing to help meet demand driven by the AUKUS alliance. AML3D's focus is on the US defence, aviation and maritime sectors and the Company is well-positioned to access the many opportunities that will be created as a result of the AUKUS Alliance, in the US, Australia and Europe," Ebert continued.

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DSB Technologies adopts Desktop Metal's complete X-Series metal Binder Jetting lineup

DSB Technologies, a manufacturer of Powder Metallurgy and Metal Injection Moulding components headquartered in Janesville, Wisconsin, USA, has adopted Desktop Metal's complete X-Series metal Binder Jetting product lineup, including Live Sinter simulation and correction software.

As demonstrated in a new customer video, DSB is currently using Desktop Metal's InnoventX, X25Pro, and X160Pro machines to develop and deliver customer parts made from a variety of metals, including 316L and 17-4PH stainless steels, 4140, and M2 Tool Steel. DSB also intends to utilise Desktop Metal Binder Jetting technology for aluminium in the future.

"Binder Jetting really is a forming technology that gives us unlimited design potential," stated Paul Hauck, Chief Operating Officer at DSB Technologies. "We can go from a very simple shape to very complex things you can't produce in hard tooling, taking complexity beyond what's possible with Metal Injection Moulding. Binder Jetting creates applications never produced before, and we want to be a leader in that."

DSB is home to over thirty high-temperature continuous sintering furnaces, which is believed to be the largest installed capacity in North America. Additionally, there is post-processing technology to support volume production in metal Binder Jetting. Out of the 3,630 tonnes of metal powder processed by DSB annually, approximately 90% are grades of stainless steel. Currently, DSB serves various markets including aerospace, automotive, defence, electronics, industrial, medical, and sports equipment.

DSB has implemented Desktop Metal's Binder Jetting technology over the past few years (Courtesy Desktop Metal/DSB Technologies)

"The exciting part about Binder Jetting is the path from concept to part is all digital," Hauck added. "You're not sending a CAD file over to a tool shop that then creates a reverse image. So, you're taking as few as eight weeks, and maybe as many as sixteen or twenty weeks, out of that process."

DSB has gradually implemented Desktop Metal's BJT technology over the past few years. The InnoventX lab-sized machine, first installed in 2021, is used for material development and testing initial sintering parameters. The X25Pro, installed in 2022, allows the team to scale those successful tests up to application development in a mid-size machine that is also capable of bridge production. The X160Pro, installed in 2023, offers the largest build volume for taking applications to serial production.

Regarding the addition of Live Sinter software, Hauck explained that it is highly effective in reducing iterations and saving time, "We now have very useful scientific analytical tools that enable successful outcomes. It's helping us solve application problems, get successful outcomes, and get there faster."

www.dsbtech.com
www.desktopmetal.com

toolcraft acquires 50% stake in PT YPTI to establish presence in Asian market

toolcraft AG, located in Georgensgmünd, Germany, reports it has acquired a 50% stake in PT Yogya Presisi Teknikatama Industri (PT YPTI), based in Yogyakarta, Indonesia. toolcraft has maintained long-standing links with Indonesia and has a successful working relationship with PT YPTI, said to make the acquisition of a stake in the company the next logical step.

The move will bring toolcraft's AM experience to PT YPTI. "This partnership marks a new chapter in our company's history. Through it, we will extend our areas of competency, become more competitive, expand our foothold in the market and be in a position to offer our customers the best possible solutions," stated Petrus Tedja Hapsoro, Managing Director of PT YPTI.

toolcraft will also benefit from the partnership, enabling the company to use PT YPTI as a base in the Asian market.

"This will allow us to avoid long and costly transport routes, saving both time and resources as well as helping us to operate more sustainably," added Christoph Hauck, Chief Technology and Sales Officer at toolcraft. "Our aim is to build a vibrant partnership from which both sides will benefit."

www.toolcraft.de
www.ypti.co.id

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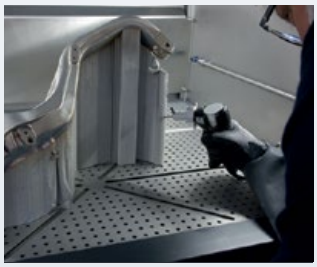

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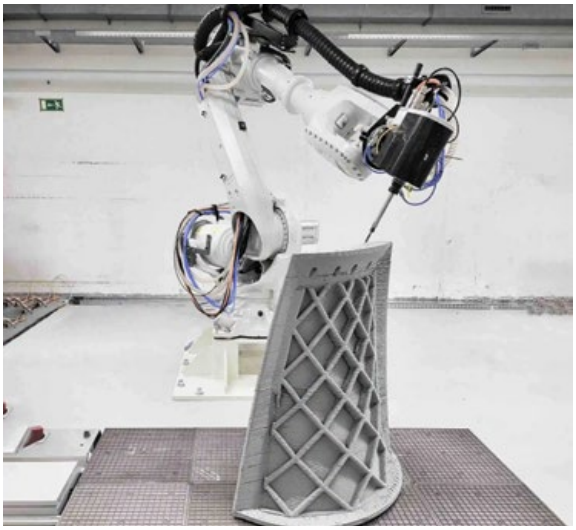
SAEKI launches with $2.3M funding for manufacturing with robots-as-a-service

SAEKI Robotics AG, based in Lupfig, Switzerland, has launched from stealth, announcing a $2.3 million seed funding round. The startup aims to create fully-automated manufacturing plants that use industrial robots and Additive Manufacturing technology to produce a wide range of products, from aircraft wings to construction site installations.

The funding round was led by Wingman Ventures, with participation from Vento Ventures, Getty Capital, and angel investors. SAEKI, founded in 2021 by Andrea Perissinotto, Oliver Harley, and Matthias Leschok, works with the architectural design, engineering design, and construction services industry to bring complex designs to life whilst reducing CO_2 emissions.

Andrea Perissinotto, co-founder of SAEKI, stated, "From what we build underground, to what we build on earth, to what goes to space, from the construction to aerospace industries, there is a need for large, one-off (custom) components, that are mostly used a couple of times at most, then scrapped. Manufacturing these parts, from the moulds to make concrete elements to the tooling required to build composite rockets, is labour intensive, has long lead times, and is very expensive. Moreover, these factors delay hardware iteration to get to the final product."



SAEKI has announced a $2.3 million seed funding round as it aims to create fully-automated manufacturing plants that use industrial robots and AM technology (Courtesy SAEKI Robotics AG)

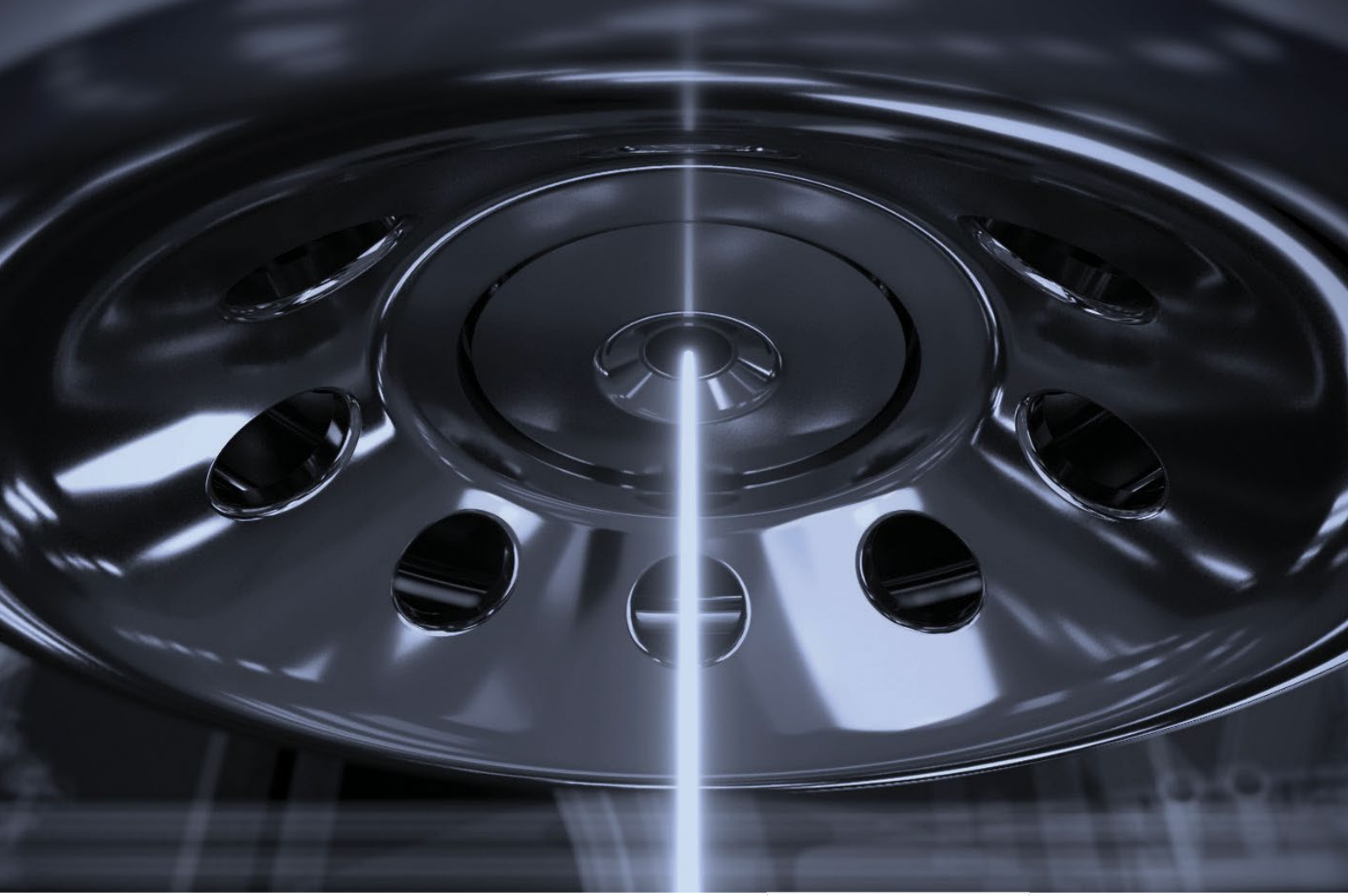
"For vast swathes of industry it's not practical to own and manage robots that can create what you need quickly. We are at the forefront of addressing this and democratising access to the best tools and creating productive, sustainable and effective outcomes for industry. Long lead times for large components will be a thing of the past and we can provide faster and cost-effective iterations. Our comprehensive approach sets us apart – it's not just about being faster or cheaper; it's about providing a complete solution that caters to the entire spectrum of challenges, which is resonating well with our customers," Perissinotto added.

SAEKI is constructing its first production hub, which will serve as the model for future expansion. In an industry hindered by manual processes, the company looks to take on the challenge of addressing manufacturing issues, acting as a catalyst and enabler for significant growth and progress across the industry.

The production hub will offer industrial robots built by SAEKI. These robots will combine several digital manufacturing methods, including Additive Manufacturing, milling, inspection, and creating an all-in-one low-waste production process using recyclable materials. The robots will act as micro-factories, self-contained units capable of performing all manufacturing steps. They can be easily deployed for localised manufacturing.

In addition, SAEKI will provide a quoting platform tailored to the customers' business needs. This platform aims to remove the complex and opaque approach currently present in the market.

www.saeki.ch



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Desktop Metal releases Live Monitor software for real-time production data

Desktop Metal Inc has launched Live Monitor™, a software application that provides real-time data from Additive Manufacturing machines and ancillary equipment to monitor and improve efficiency of either one or a full fleet of AM machines.

As part of the Live Suite™ package of software from Desktop Metal, Live Monitor provides access to system data from any web browser at any time. This new software includes dashboards that allow for fleet management and detailed analysis of AM machine or furnace performance, features which support capacity planning and maintenance management. Real-time information provided by Live Monitor includes job and event status, time reporting, and consumable usage, among other important metrics.

"At Desktop Metal, we're committed to driving Additive Manufacturing into production, and Live Monitor is a vital tool for managing a single productive printing system, such as a Shop System and Furnace, or an entire fleet," stated Ric Fulop, Founder and CEO of Desktop Metal. "Our goal is to help users improve their Overall Equipment Effectiveness (OEE) to optimise their utilisation and scale their business with ease."

Aidro srl, a subsidiary of Desktop Metal, based in Taino, Italy, has served as a beta tester for Live Monitor in its Desktop Metal Shop System and Furnace for the past year.

"Live Monitor is an essential tool for keeping the most important process variables under control and giving customers with critical parts, such as those in the energy industry, visibility and traceability of AM part production," Valeria Tirelli, president and CEO of Aidro, shared. "The variables are visible, customisable, and recordable and this is the basis for having a qualified process. Thanks also to this tool, DNV has awarded Aidro AM manufacturer certification in accordance with the DNV-ST-B203 standard. Compared to other systems, Live Monitor can be customised in a simple and efficient way depending on the specific needs of the user."

Live Monitor will be available as an optional add-on feature to Live Studio users for the Studio, Shop, and Production System AM machines, as well as Desktop Metal branded furnaces. This feature will also be introduced in the future to users of other Desktop Metal and Team DM equipment sold under the ExOne, Desktop Health, and ETEC brands.

www.desktopmetal.com
www.aidro.it

Höganäs appoints Henrik Ager as president and CEO

Swedish metal powder producer Höganäs AB has announced Henrik Ager as its new president and CEO. The appointment follows the departure of Fredrik Emilson who stepped down in January after a thirteen-year career at Höganäs, of which nearly six years were spent as president and CEO.

Prior to joining Höganäs, Ager served as the CEO of Copperstone Resources AB and prior to this spent eight years at Sandvik AB in various roles, including Business Area President of Sandvik Mining and Rock Solutions, Division President of Sandvik Rock tools, and Vice President Strategy of Sandvik Mining.

"We are very pleased to welcome Henrik Ager as the new CEO of Höganäs. Henrik has strong experience leading successful businesses based on involving leadership and a clear strategic agenda. Under the leadership of Henrik, the board looks forward to further executing on our existing strategy to be the preferred supplier of sustainable metal powder, thus continuing to strengthen Höganäs position as the market leader of metal powders for demanding uses in automotive and many other industries," shared Magnus Hall, chairman of Höganäs.

Ager is a Swedish national and holds an MSc in Accounting & Finance from the Stockholm School of Economics.

"I am both proud and excited to lead Höganäs going forward. Höganäs is a global leader in Powder Metallurgy and surface coating, with an exceptional team and a world-leading portfolio of products and innovations. We now need to continue to leverage these strengths to both lead and support the sustainable transition for customers and society at large, utilising the capabilities of metal powder technology," Ager commented.

Henrik Ager has been named president and CEO of Höganäs (Courtesy Höganäs)

Magnus Eriksson, who acted as interim CEO and CFO during the search for a new , added, "It is very positive that a new CEO has been recruited, I am happy to welcome Henrik to Höganäs and to team up with him and the leadership team to continue refining and executing on our exciting strategy."

www.hoganas.com

Nano Dimension acquires Additive Flow technology to enhance simulation and optimisation software

Nano Dimension Ltd, Waltham, Massachusetts, USA, reports it is acquiring the technology and intellectual property of Additive Flow, a software company based in London, UK.

Additive Flow has developed simulation software for mechanical, thermal, thermo-mechanical properties, as well as frequency and fatigue across a range of materials and processes. The product addresses design, production, and quality decisions whilst working to optimise for cost, weight, as well as manufacturing productivity and yield.

The company's customer base consists of the advanced optics & optoelectronics, aerospace & defence, semiconductors, advanced energy, and electronics vertical market sectors.

The acquisition of Additive Flow is considered a significant achievement in Nano Dimension's product development roadmap. Computer-aided engineering and design components are integral to the company's design-through-manufacturing product strategy. Simulation algorithms and optimisation capabilities are particularly important for utilising the benefits of Additive Manufacturing. Additive Flow's AI and GPU accelerated software is expected to improve the ability of Nano Dimension's customers to replicate, design, and enhance prototypical layouts of AME electronic components in a fast and cost-effective manner. Nano Dimension will integrate Additive Flow's core technology into its proprietary FLIGHT design package suite.

"The Additive Flow team is thrilled to join Nano Dimension," stated Alexander Pluke, CEO and CTO of Additive Flow. "Our solution was born out of real engineering challenges we faced to harness the capability of advanced manufacturing. Our platform is built from the ground up to handle all the complex data and decisions of digital engineering, so teams can focus on their key goals. We are fortunate to have found a great partner in Nano Dimension where our innovation can be leveraged to its maximum potential. We look forward to building on our impressive track record and continuing to develop Additive Flow's software and enhance Nano Dimension's leading AM and AME product offerings."

Nick Geddes, Senior Chief Technology Officer of Nano Dimension, added, "We have been looking at the software market for simulation and optimisation offerings for some time. There are many strong solutions in the market that do certain elements of those complicated tasks, but it is Additive Flow's product that stood out in terms of the functionality we needed for a holistic solution, especially in the context of our requirements across AME and multi-dimensional polymer, metal and ceramic AM. The acquisition will add considerable firepower to the ability of our customers to leverage our leading digital manufacturing solutions."

www.nano-di.com
www.additiveflow.com

Additive Flow can improve Additive Manufacturing build time (Courtesy Additive Flow)

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AMS receives Innovate UK funding to further aerospace recycling for Additive Manufacturing

The 'Recycling and Reuse of Aerospace Materials for Additive Manufacturing' (R2AM2) project from Additive Manufacturing Solutions (AMS), Burscough, West Lancashire, UK, has received funding from Innovate UK to explore the potential for recycling parts into feedstock for metal Additive Manufacturing as well as the processability and final part performance of recycled AM production.

'Research on Scrap Recycling of Retired Civil Aircraft' by Dan Zhao et al (2021) estimates that there are 740 tonnes of non-ferrous metals (excluding aluminium) available for recycling each year, but only a fraction of that is actually recycled. The project aims to explore a potential environmental step change in the ways materials are used for Additive Manufacturing.

Research suggests that the international AM powder market is expected to exceed $1 billion in 2023, with titanium accounting for approximately one-third of that market, per 6K Additive. In light of restrictions in supply and increased costs due to ongoing conflicts, and the fact that our planet's resources are not endless, it is more important than ever to consider utilising the approximately 600 tonnes of recycled aircraft parts that could support this growth by providing a lower-cost, high-quality product. AMS refers to this process as "high-value scrap mining" and believes that if reusable feedstock is available, an alternative to mining can be seen in the UK market.

Robert Higham, CEO and founder of AMS, said, "The UK was once a leader in AM technology, and we have since seen a stagnation period, with our work alongside the output of this project we aspire to enable a vibrant and highly-profitable UK-source of feedstock and catalyst for material producing parts for our defence, space, aerospace, and automotive industries. Having Innovate UK support our research and development in this field is a significant and crucial step in our plans as AMS. If we are to continue with our ambitious plans to promote and increase on shore manufacturing, it is crucial we enable a secure and sustainable supply chain of product. This project is the first step in providing valuable data as to the true possibilities of high-value circular economy development. We are honoured to be awarded the funding to allow us to take this idea to an industrial feasibility state."

The project is currently underway and expected to conclude in November 2023. AMS plans to recycle scrap aerospace parts into powder, which will be tested and used to manufacture new parts. These parts will provide crucial data to evaluate the effectiveness of this process in providing recycled materials for high-quality feedstock for Additive Manufacturing in the UK.

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Nikon acquires Avonix Imaging to strengthen X-Ray digital inspection

Nikon Americas Inc, the US subsidiary of Japan's Nikon Corporation, has purchased the US company Avonix Imaging LLC. Avonix has been a strategic X-ray CT equipment manufacturing partner to Nikon Industrial Metrology Business Unity (IMBU) since 2015. The company uses systems from Nikon for both X-ray/CT 3D and 2D inspection, using X-rays to investigate the interior and exterior of industrial components.

Tadashi Nakayama, Corporate Vice President, General Manager of the IMBU stated, "Merging the respective strengths of our companies will reinforce our position as market leader in 3D and 2D X-ray inspection and measurement. It will massively enhance our ability to deliver best-in-class, next-generation solutions to the manufacturing industry."

"In the run-up to making Avonix a wholly-owned subsidiary, we worked intensively with them to develop and build new X-ray CT systems with medium to large inspection envelopes. We recently launched a new model that realises the largest imaging area for a single-piece cabinet in the industry. Work on expanding this revolutionary machine series and other new products is continuing apace," continued Nakayama.

Referring to the partnership, Brian Ruether, co-founder and co-Managing Director of Avonix, added, "Nikon's proprietary rotating target X-ray sources and proven software combined with our expertise in the design of configurable systems, controls, and product handling create a customised experience for our clients, which can contribute to their efficiency and profitability."

Jeff Diehm, co-founder and co-Managing Director of Avonix commented, "The historical collaboration between Nikon and Avonix has been rooted in the goal of mutual success for all involved, including partners, vendors and, of course, our customers. It is no coincidence that the goal of mutual success is at the heart of Avonix's ACE Core Values (Authenticity, Competency and Empathy). The merger will result in enhanced value through the release of new and innovative products. We are excited to take our long-standing strategic relationship to the next level."

Nikon and Avonix aim to further advance the development of new products, while enhancing the business, especially in the automotive and aerospace industries. In its medium-term management plan, from FY2022 to FY2025, Nikon has positioned digital manufacturing as its key strategic business.

www.nikonusa.com
www.avonixiimaging.com

Airbus Helicopters announces new AM centre with metal Additive Manufacturing from Trumpf

Airbus Helicopters has announced plans to expand its Additive Manufacturing capabilities by establishing a new AM centre in Donauwörth, Germany. Trumpf will provide metal Additive Manufacturing machines for the facility, in addition to the ones already used by Airbus Helicopters to produce structural components made of titanium and high-strength aluminium.

Airbus Helicopters will initially use the new facility to produce components for the electric-powered CityAirbus concept and an experimental high-speed Racer helicopter, as well parts for the Airbus A350 and A320 passenger aircraft, among others.

"With innovative manufacturing processes, we are working on the helicopters of the future in Donauwörth. Among other things, 3D printing helps reduce the weight of components," stated Helmut Färber, Site Manager of Airbus Helicopters in Donauwörth.

Additive Manufacturing allows entire assemblies to be built as one component, saving further weight and offering unique opportunities to designers and engineers. This ability to produce assemblies as a single component can also lower costs and help save fuel.

"Additive Manufacturing saves expensive raw material and can lower production costs in the aviation industry. 3D printers only use the material that designers actually need for their components and that ends up taking off in the aircraft," added Richard Bannmüller, CEO Trumpf Laser and System Technology.

Airbus Helicopters will use AM to produce components for its CityAirbus concept (Courtesy Airbus)

"With its manufacturing know-how, Trumpf is a reliable partner to the aviation industry worldwide," continued Bannmüller. "Our 3D printing systems are a key technology on the path to sustainable flying and they reduce dependency on long supply chains."

www.trumpf.com
www.airbus.com

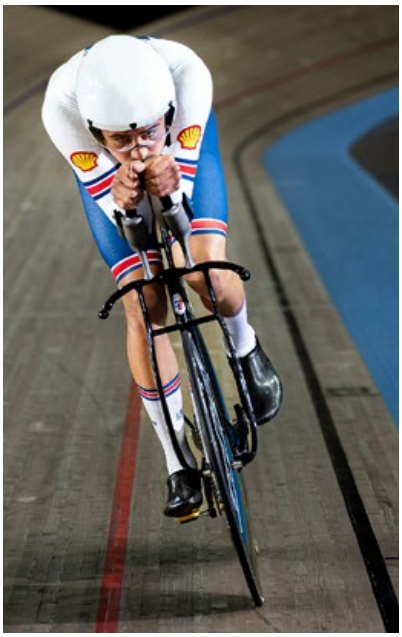
Renishaw collaborates with British Cycling to develop track bike for Great Britain's 2024 Olympic team

Renishaw, headquartered in Wotton-Under-Edge, Gloucestershire, UK, has collaborated with British Cycling – the national governing body for cycling in Great Britain – and other partners to develop a new version of the Hope-Lotus track bike. Unveiled at the 2023 UCI Cycling World Championships held in Glasgow in August, the new bike will be used by Great Britain's track cyclists during the 2024 Paris Olympic Games.

The improved bike is an evolution of the model used by the Great Britain Cycling Team in the 2020 Tokyo Olympic Games, which helped them win seven Olympic medals and take the top spot on the track cycling medal table. The new version features elements that have been rigorously tested, including unique forks and handlebars from Lotus Engineering that allow for increased aerodynamic porosity, together with the HBT Paris frame from Hope Technology that has refined headstock and seatstays.

The Renishaw team assisted with the prototype testing process and produced crucial additively manufactured metal components for the final bike. These parts were produced on RenAM 500Q Laser Beam Powder Bed Fusion (PBF-LB) AM machines.

"We have been busy designing, testing and building components for the new bike and we are really excited to see it in competitive action for the first time at the 2023 UCI Cycling World Championships," explained Louise Callanan, Director of Additive Manufacturing at Renishaw. "Working with British Cycling is a fantastic opportunity to showcase how our Additive Manufacturing technologies can help improve the performance of the bike and ensure that it is optimised for individual riders."



British Cycling has maintained its partnership with Renishaw in order to improve upon the bike that secured the top spot on the track cycling medal table at the 2020 Tokyo Olympic Games (Courtesy SWpix.com)

The new design features a split seatpost that looks to be additively manufactured by Renishaw. Although not stated, the profile is almost certainly intended to reduce drag (Courtesy SWpix.com)

Stephen Park CBE, Great Britain Cycling Team Performance Director, added, "To continue to win medals year-on-year at the highest level, we need everything to come together at exactly the right time: the best riders, the best equipment, the best technology. We have been working with Lotus, Hope and Renishaw for the past two Olympics as we believe that together we have the world-leading expertise needed to deliver what we believe to be the fastest track bike in the world."

"Their combined high quality manufacturing standards, renowned lightweight design, aerodynamic efficiency and their keen eye for finer details help us to unlock valuable marginal gains, which make all the difference come race day. This is the most advanced bike that has ever been ridden by British athletes," added Park.

www.renishaw.com
www.britishcycling.org.uk

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Materialise's new US facility brings personalised medical implants closer to patients

Materialise, located in Leuven, Belgium, has opened a new Additive Manufacturing centre in Plymouth, Michigan, USA. The new facility will specialise in the Additive Manufacturing of personalised titanium cranio-maxillofacial (CMF) implants, which are used in facial reconstructive surgery.

Prior to establishing the new Michigan operation, Materialise manufactured titanium CMF implants at its AM facility in Belgium. The dedicated US-based facility will, therefore, significantly reduce delivery times of the fully personalised implants to hospitals across the country.

"With the opening of our new metal 3D printing centre in the US, we bring personalised care closer to US patients," shared Brigitte de Vet, Vice President of Medical at Materialise. "The power of 3D printing paired with our three decades of experience in 3D planning and medical manufacturing, allows us to accelerate the delivery of personalised medical implants. We take pride in leading the charge to revolutionise patient-specific care and with our dedicated facility in Michigan we further enhance personalised care in the United States."

Surgeons are increasingly embracing Additive Manufacturing solutions as they recognise the added value it brings to personalised patient care. Patient-specific AM medical solutions include anatomical models for diagnostic purposes, surgical guides, and implants to enhance accuracy and efficiency. These solutions are designed to bolster surgeons' comfort before and during surgery, leading to more predictable and accurate surgical outcomes.

Materialise produces 280,000 personalised AM instruments and implants each year, including 160,000 for the US market. In 2017, it introduced one of the first personalised CMF implant portfolios in the United States, and in 2021, its 3D planning and AM instruments played a role in the world's first successful simultaneous double hand and face transplant performed at NYU Lagone Health in Manhattan in New York City.

www.materialise.com

The new facility specialises in the AM of titanium cranio-maxillofacial implants (Courtesy Materialise)

Materialise has opened a new AM facility in Plymouth, Michigan, USA (Courtesy Materialise)

Velta looks to establish titanium powder manufacturing facility in the US

Velta LLC, based in Dnipro, Ukraine, and its US-based parent company have contracted the global engineering consultancy, Hatch, to design a new titanium manufacturing facility in the United States. This new facility aims to produce titanium powders using its proprietary closed-cycle manufacturing process that bypasses the classic sponge stage.

"This new partnership brings Velta one step closer to bringing our revolutionary titanium powder technology to the US market, which is dangerously over-reliant on foreign supply chains," shared Andriy Brodsky, CEO, Velta. "Hatch's expertise in optimising metallurgical facility design and operation will help Velta meet the enormous, unmet US demand for quality titanium. We're ready to get to work."

The conventional production of titanium metal and its alloys, such as titanium aluminide, is both energy- and time-intensive. The new Velta Ti Process, which creates titanium alloy powders from ilmenite concentrate, reportedly results in a superior product with a carbon footprint between five and ten times smaller than those made through the traditional Kroll process.

Velta is currently engaged in an intensive site selection process to establish one of the few US facilities producing titanium. The new facility is designed to have a capacity of producing upwards of 1,000 tonnes of Ti powder per annum, with the potential to scale.

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Siemens to invest €1 billion in Germany, adding global development and manufacturing hub

Siemens Energy, headquartered in Munich, Germany, is set to invest around €1 billion in Germany as part of its €2 billion investment strategy. The company announced the establishment of its new Technology Campus in Erlangen, Germany, with investments of around €500 million expected for this site alone.

The Erlangen campus, which is to be built in the west of Erlangen, will focus on sustainable and future-oriented high-tech manufacturing, related research and development activities, and the opening of the location for an ecosystem of partners from the business and scientific communities. The plan for the location also calls for converting existing facilities and expanding the site.

Siemens Energy's planned investments focus on new manufacturing capacities, innovation labs and education centres (Courtesy Siemens)

The investment is reportedly an important element of Siemens' strategy to combine the real and the digital worlds. The company is strengthening its Erlangen location as a hub for digital production concepts – for example, through the use of the industrial metaverse and for modern technologies like industrial Additive Manufacturing and innovative power electronics.

"This investment is a strong signal for Germany as a location for innovation and production. The leading-edge manufacturing facility being built in Erlangen is a good example of how our economy is moving toward a climate-neutral future – as a strong industrial country with good sustainable jobs," said German Chancellor Olaf Scholz.

Roland Busch, president and Chief Executive Officer of Siemens AG, concluded, "Siemens is banking on innovation in Germany and launching the next stage of digitalisation: we're laying the foundation for the industrial metaverse in the Nuremberg metropolitan region. Here, on the new campus, we're combining the real and the digital worlds. Together with partners, we're developing new digital technologies in the metaverse and revolutionising how we'll run our production in the future – much more efficiently, flexibly and sustainably."

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Nabertherm celebrates 30 years of DIN ISO 9001 quality certification

Nabertherm GmbH, headquartered in Lilienthal, Germany, reports it has successfully recertified its quality management systems, marking the thirtieth year of the company's adherence to DIN ISO 9001 quality assurance standards. Nabertherm was an early adopter of the original standard, where a lean corporate organisation and the manufacture of high-quality products had been a central corporate philosophy. This meant there was already a good basis to implement the corporate goal of a quality assurance system.

In May 1987, the first edition of the DIN ISO 9001 standard on the subject of Quality Assurance Systems was published. Five years later, Nabertherm received customer enquiries as to whether it would comply with this standard. At that time, only few companies in Germany had set up a quality assurance system in accordance with the requirements of DIN ISO 9001 and had it certified by an external body. The topic of 'quality assurance' was increasingly discussed, but detailed knowledge was not widespread.

Nabertherm offers a range of furnaces for the heat treatment of metals, including hot-wall retort furnaces for debinding and sintering MIM components (Courtesy Nabertherm GmbH)

In 1992, the Bremen Chamber of Commerce organised an ad hoc working group on quality assurance. A group of companies from the Bremen economic area came together at the event. Although not every participating company understood what DIN ISO 9001 required in detail, the opportunities that could result from the introduction of a quality assurance system were recognised.

The day after the event, Conrad Naber set the corporate goal that Nabertherm should be the first furnace manufacturer in the world to introduce a certified quality assurance system. Together with three other companies from the working group, and the advisory support of Dr Günther W Diekhöner and his team from the Denkfabrik in Bremen, Nabertherm began to set up and introduce the quality assurance system in the summer of 1992.

Thanks to a good starting point, and the excellent support from the Denkfabrik, the QA system was introduced and in June 1993 an initial certification by Lloyd's Register Quality Assurance could be submitted. On June 24th, 1993, Nabertherm received the first DIN ISO 9001 certificate. At that time, fewer than 500 companies in Germany were certified accordingly. "It has never been possible to reliably determine whether Nabertherm was really the first furnace manufacturer in the world to be certified, but the probability is very high," the company stated.

Over the years, the term 'quality assurance' has become synomymous with the term 'quality management.' The requirements of DIN ISO 9001 have also changed, though the basic idea has remained the same: quality means recognising and fulfilling the needs and expectations of customers.

www.nabertherm.com

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AMEXCI inaugurates Finnish Additive Manufacturing facility in Tampere

AMEXCI, headquartered in Karlskoga, Sweden, has held the inauguration ceremony for its Additive Manufacturing facility in Tampere, Finland. The ceremony was opened by Johannes Karjalainen, Managing Director of AMEXCI Oy, who acknowledged the hard work that led up to the day and outlined the role of the new subsidiary as a hub for innovation and technology advancement.

"The unity between Sweden and Finland is crucial in order to pave the way in AM in the Nordic Region, where AMEXCI and its partners plays a key role in the industrialisation and innovation that is currently happening," Karjalainen shared.

Edvin Resebo, CEO of AMEXCI AB, added, "The success for us in Finland is dependent on strong cooperation with Finnish industry, academia, and government functions. We are expanding our overall capacity in the group to be able to grow as new innovations take flight and we will be able to offer our services at a completely different scale where our operations in Finland act as a strategic competence hub."

Cutting the ribbon marked the official opening of the new facility, equipped with technology that is hoped to assist in fuelling innovation in Additive Manufacturing. Following the ribbon cutting, guests were invited to tour the facility, getting a first-hand view of the facility and its capacity in an effort to connect with customers and possible future collaborators.

www.amexci.com

Athena Manufacturing rebrands as A3D Manufacturing

Athena Manufacturing, a certified AM service provider based in Tempe, Arizona, USA, has rebranded as A3D Manufacturing. The company serves industries such as aerospace, military and defence, life science, transportation, and consumer products.

"Rebranding as A3D Manufacturing will open many more possibilities for us," said Jon Toews, Senior Vice President of A3D Manufacturing. "It allows us to continuously evaluate our mission and add bleeding-edge technologies and expertise to our portfolio, so our customers can harness these new capabilities to grow their business."

The company was established in 2019 with the aim of creating high-quality parts with production volume and pricing through Additive Manufacturing. Since then, it has expanded services to include various AM methods, as well as post-processing services, CNC machining, Injection Moulding, cast urethane, and more.

The company now specialises in creating custom metal and plastic components using Fused Filament Fabrication and Markforged technology.

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IperionX receives key permits for Ti powder production in Virginia

IperionX Limited, Charlotte, North Carolina, USA, has received all permits to commence construction and operations at its planned titanium metal production facility in Virginia, USA. The permits include the Industrial Wastewater Discharge permit issued by the Halifax County Service Authority, and the New Source Review (air pollution) permit issued by the Virginia Department of Environmental Quality. They meet the requirements to scale to the planned TCF-1 (titanium commercial facility) capacity of 1,125 tonnes per annum (tpa) of titanium metal within the existing building in Virginia.

All major engineering works for the planned Stage 1 TDF (titanium demonstration facility) are now complete, with key long lead time equipment ordered and procurement underway. First titanium production is planned for Q1 2024, and IperionX expects to reach a production run-rate of 125 tpa by Q3 2024. A planned modular Stage 2 expansion to the TCF-1 level would lift titanium production capacity to 1,125 tpa by the end of 2025.

IperionX has received all permits to commence construction and operations at its planned titanium production facility in Virginia, USA (Courtesy IperionX)

The design of the TDF and TCF-1 are based upon a scaled-up version of the current Industrial Pilot Facility, in Salt Lake City, which has been successfully operated by IperionX since January 2022. IperionX has upgraded this facility, and improved operational processes, to achieve a significant increase in the titanium production capacity with higher efficiency and consistency.

IperionX now plans to build the largest recycled titanium metal powder production facility globally, and reportedly the only titanium plant that uses 100% titanium scrap metal as feedstock. The titanium production facility in Virginia is designed to have zero Scope 1 & 2 emissions and is expected to produce UL validated 100% recycled titanium metal powder with the lowest carbon intensity on the market.

"IperionX is uniquely positioned to re-shore titanium metal production to the USA, reducing the acute reliance on titanium imports from foreign nations and lowering the significant environmental impacts from producing titanium metal using the existing 'Kroll Process' – which is energy intensive, high cost and generates excessive greenhouse gas emissions," explained Anastasios (Taso) Arima, IperionX CEO.

www.iperionx.com

Shapeways launches MFG Materials to provide discounted raw materials to manufacturers

Shapeways Holdings, Inc, New York City, USA, is expanding its software service offerings with the launch of MFG Materials. This new service is reported to offer a range of raw materials to manufacturers at discounted rates.

Shapeways claims that it can provide an average discount of 15% off the listed prices on the MFG Materials platform through strategic partnerships and negotiations with raw materials vendors. The discounts vary based on the material and quantity ordered.

"We're committed to supporting our manufacturers. With the launch of MFG Materials, we're taking a practical step toward helping them save on raw material costs," said Greg Rothman, GM of Software for Shapeways. "Depending on the volume, suppliers can realise a sound return on investment by purchasing their raw material inventory through us."

As the global market for industrial raw materials – including aluminium, iron/steel, and plastics – grows, Rothman spoke on the value proposition of the MFG Materials platform, "The growth trajectory of the industrial materials market is impressive. This presents immense opportunities, and MFG Materials is designed to help our customers tap into this opportunistic market. We are not only making these markets more accessible, but also enabling significant cost savings through our economies of scale. This boosts competitiveness and profitability for manufacturers, fuelling growth in the US manufacturing sector."

MFG Materials is now available to all current premium subscribers. Shapeways is also introducing a low-cost monthly membership option for manufacturers seeking access to MFG Materials exclusively.

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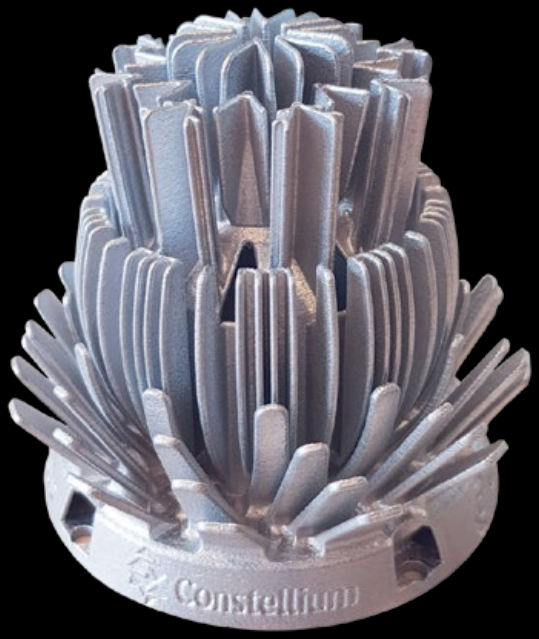

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Meltio named strategic technology partner by US Department of Defense

The US Department of Defense (DoD) has recognised Meltio, headquartered in Linares, Spain, and its US distributor Phillips Corporation, Hanover, Maryland, USA, as a strategic technology partner for its metal Additive Manufacturing solutions. Meltio was selected out of a total of three-hundred applicants from international technology firms, consolidating the company's relationship with the US Army whilst increasing the possibilities for relationships with other US defence departments, as well as armies from other countries.

"This is a technology with a very robust capability for fabrication and for near net shape part production," the US DoD commented. "It offers a very valuable approach that uses standard welding wire that is already available in US Department of Defense manufacturing environments, a coil of wire can be made into a near net shape for any part, thus avoiding the need for large stocks of shapes/forms/sizes of raw material." This move also marks the first time a Spanish Additive Manufacturing company has been recognised as a strategic technology partner.

Ángel Llavero López de Villalta, CEO of Meltio, shared, "The award we have received is a recognition to Meltio's professionals and gives reliability to our technology. For us, the military sector is a sector that allows us to bring together all the applications of our disruptive metal 3D printing technology. And it is an opportunity for Meltio to develop a dual application for the civil and military sector."

"Our technology has the potential to transform different sectors thanks to metal Additive Manufacturing such as supply chains, logistics, repair and manufacturing of metal parts compared to other conventional techniques such as forging and machining. There are currently many armies in other countries that have Meltio's metal Additive Manufacturing technology and we want to stand out as a strategic and technological partner for the military sector, also in Spain," Llavero López de Villalta added.

The US Department of Defense (DoD) has recognised Meltio and its US distributor Phillips Corporation as a strategic technology partner (Courtesy Meltio)

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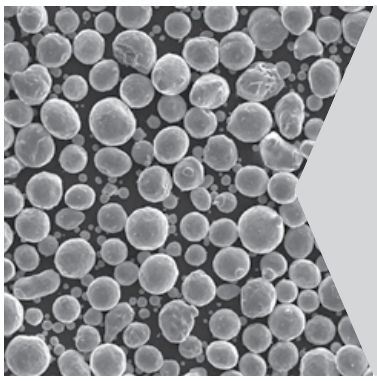

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3D Systems sees AM moving into factory production environments worldwide

3D Systems, Rock Hill, South Carolina, USA, has announced its financial results for the second quarter ended June 30, 2023, and the paths the company may take to scale. The company's financial results showed a Q2 2023 revenue of $128.2 million and year-to-date revenue of $249.4 million, which represents a decrease of 8.5% and 8.6% from the prior year, respectively. This decrease was mainly attributed to expected weakness in the dental orthodontics markets. However, when excluding this market, year-to-date revenue increased by over 3% and approximately 2% on a purely organic basis.

"Looking at the state of the Additive Manufacturing market today, it is increasingly clear to us that the industry is at an exciting inflection point, with 3D printing now moving into factory production environments worldwide," 3D Systems CEO Jeffrey Graves stated. "What we and many others in our space agree upon is that scale is increasingly necessary, not only to deliver sustainable profitability, but also to diversify end markets and smooth out quarterly results, such that one market, technology, or customer does not have an outsized impact on consolidated financial results."

"For our company, the dramatic success we have experienced in the dental orthodontics market over many years has now translated into an outsized negative impact as consumer discretionary spending on dental aligners has plummeted," he continued. "Over the last four quarters this has created a significant headwind to our performance, with total revenues from this market declining by over $50 million. While we are pleased to see this market now showing signs of stabilisation, the ultimate answer is to broaden market exposure and continue to expand the sales, service and technology expertise that our customers require. Unfortunately, our 3D printing industry today remains highly fragmented and, until this is rectified, all companies will be exposed to similar volatility over time."

The company reported a net loss of $28.8 million, with a diluted loss per share of $0.22, and a diluted non-GAAP loss per share of $0.07. The Adjusted EBITDA of negative $6.9 million improved over 30% sequentially, but declined year-over-year. This was primarily driven by lower total sales volume, inflationary impacts on input costs, and substantial investments in future organic growth.

Gross profit margin in the second quarter of 2023 was 39.0% compared to 37.9% in the same period last year. The non-GAAP gross profit margin was 38.9%, compared to 38.0% in the same period last year. Gross profit margin increased primarily due to favourable pricing, product mix and cost optimisation efforts in source production.

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Hexagon enhances its Additive Manufacturing offering with CADS Additive acquisition

Hexagon AB, headquartered in Stockholm, Sweden, has completed the acquisition of CADS Additive GmbH, a provider of specialised software designed to help companies prepare designs for metal Additive Manufacturing. Developed for those using the Powder Bed Fusion (PBF) process, CADS Additive software reportedly guides users through the build preparation, helping turn design files into build instructions and improve manufacturing productivity.

CADS Additive, based in Perg, Austria, has been a partner of Hexagon since 2021, integrating its build preparation and support structure creation capabilities with Hexagon's Simufact Additive process simulation software. Shared development roadmaps will reportedly look to further improve workflows, allowing users to adjust the orientation and support structure of their additively manufactured builds. This seeks to shorten the Additive Manufacturing workflow and provide easy steps to mitigate quality implications caused by changes to the orientation or support structure.

The AM Studio software from CADS Additive is reportedly already connected to Hexagon's Nexus digital reality platform, completing Hexagon's Nexus-enabled AM workflow by applying its extensive technology portfolio to computer-aided design (CAD) model preparation, build preparation, simulation-based optimisations, quality and production intelligence, and the automation of computer-aided manufacturing (CAM) to finish parts.

"Our investments reflect the growing importance of Additive Manufacturing, which has huge potential but has been held back by a fragmented ecosystem that means manufacturers are not getting the results they need fast enough. The acquisition of CADS Additive enables us to provide our customers with integrated tools that empower manufacturing teams to reduce waste and increase efficiency as they move from prototyping to production," said Paolo Guglielmini, Hexagon President and CEO.

"Opening up the Nexus platform to our ecosystem partners and providing building blocks like CADS Additive helps customers improve their processes throughout the manufacturing value chain and realise the potential of industrial Additive Manufacturing," Guglielmini added.

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SPEE3D brings its Cold Spray AM to Japan with defence partnership

SPEE3D, headquartered in Melbourne, Australia, has partnered with the Japan Ground Self-Defence Force (JGSDF) to introduce its Cold Spray Additive Manufacturing (CSAM) technology to Japan. This contract with the Japan Ministry of Defence is said to be a significant milestone as SPEE3D continues to expand into the Asia-Pacific region.

The Japanese Self Defence Force will receive a WarpSPEE3D and an XSPEE3D. The WarpSPEE3D is SPEE3D's first large-format metal Additive Manufacturing machine, capable of producing large metal parts quickly. The company's latest model, XSPEE3D, provides a deployable metal Additive Manufacturing capability with SPEE3D's patented Cold Spray AM technology and auxiliary equipment integrated within a single containerised shipping container unit. This enables industries operating remotely, such as defence, to build metal parts on-site and on-demand.

"We are grateful for the opportunity to expand our presence into Japan and the APAC region. It is indeed an honour to collaborate with the Japanese military," shared Byron Kennedy, CEO, SPEE3D. "Our aim is to train and prepare their forces to use the XSPEE3D printer in the field to address their most urgent supply chain issues through quickly manufactured on-demand parts."

The SPEE3D technology has been utilised by various defence forces worldwide, including field trials by the Australian, US, and UK militaries. With this technology, Japan's self-defence forces now possess the ability to manufacture critical replacement parts on demand in minutes or hours. This can be done using a range of materials, including aluminium 6061, aluminium bronze, copper, and stainless steel.

The XSPEE3D is a containerised and deployable cold spray metal Additive Manufacturing machine (Courtesy SPEE3D)

As part of the partnership, SPEE3D will provide the JGSDF with comprehensive training, support, and maintenance for both WarpSPEE3D and XSPEE3D. This includes field exercise programmes with the XSPEE3D, ensuring that Japan's forces are well-equipped to fully utilise the potential of this technology in the field and on base.

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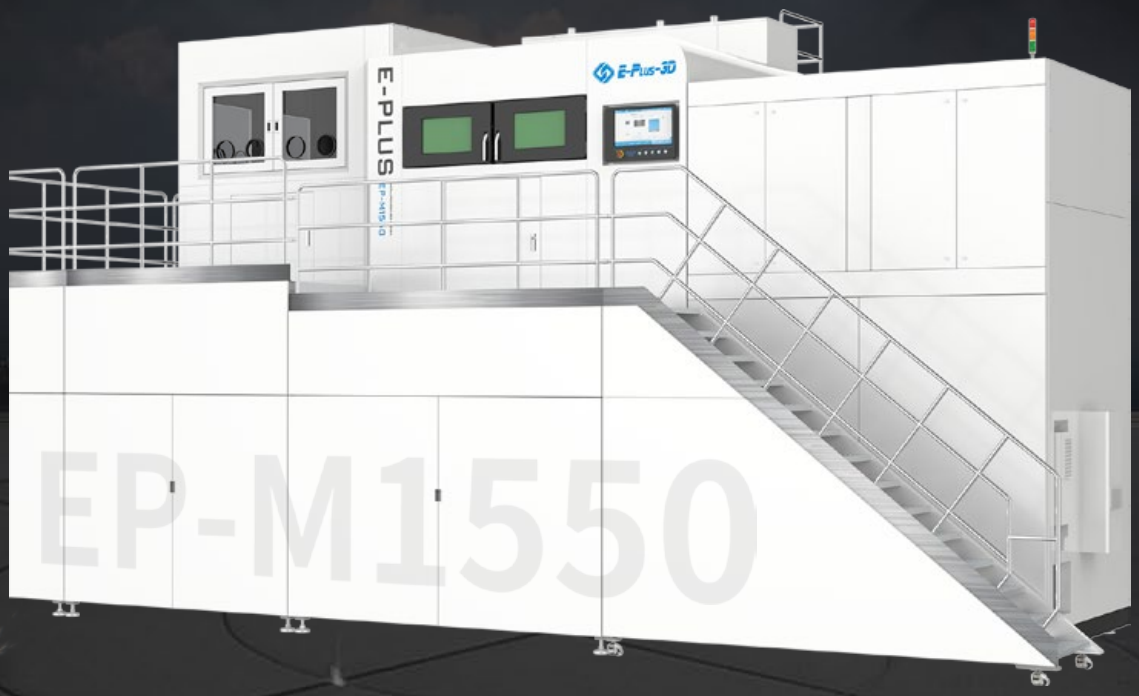

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BEAMIT and Constellium partner to advance aluminium Additive Manufacturing solutions

BEAMIT SpA, based in Parma, Italy, has signed a letter of intent to collaborate with Constellium, headquartered in Baltimore, Maryland, USA, to work on the development of advanced aluminium solutions. Together, the partners will focus on conducting extensive research and development activities to optimise the properties and characteristics of aluminium for Additive Manufacturing process.

This strategic partnership aims to leverage the expertise of both companies to advance the use of Additive Manufacturing and aluminium in various industries. The collaboration will involve the application of advanced design and engineering techniques, as well as the utilisation of cutting-edge technologies to ensure the highest quality and performance of aluminium materials.

The signing of this letter of intent is said to mark a significant milestone in the collaboration between BEAMIT and Constellium, demonstrating a shared commitment to driving innovation and pushing the boundaries of Additive Manufacturing.

"We are excited to work with BEAMIT in the development of advanced aluminium solutions, which have the potential to revolutionise Additive Manufacturing," said Ludovic Piquier, Chief Technical Officer of Constellium. "This collaboration aligns with our commitment to delivering innovative solutions to our customers and expanding the application of aluminium in the industry."

BEAMIT will collaborate with Constellium in an effort to further advanced aluminium solutions (Courtesy BEAMIT SpA)

Both companies have stated their commitment to sustainability and will prioritise environmentally responsible practices throughout the development process. By leveraging the inherent recyclability and lightweight properties of aluminium, the partners aim to contribute to the ongoing drive for a more sustainable future.

www.beam-it.eu
www.constellium.com

Freemelt receives multiple Freemelt ONE orders

Freemelt AB, located in Mölndal, Sweden, has announced sales of its Freemelt Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing machine to two new customers, with the Institute for Nuclear Research (ATOMKI) in Hungary and a Turkish university both placing orders.

The Institute for Nuclear Research has ordered a Freemelt ONE for research in nuclear material science, where the AM machine is well-suited for high-temperature materials commonly used in fusion and fission reactors. ATOMKI is a leading facility in the field of atomic and nuclear physics in Hungary. The Freemelt ONE machine has a periscope function that allows monitoring of the production process while a component is being made.

"We are happy that the collaboration with MTA Atomki now has resulted in an order of our Freemelt ONE machine," stated Daniel Gidlund, Freemelt's CEO. "We see an increased activity and interest from the energy sector, and this order is an important step and confirmation of the value that Freemelt and Additive Manufacturing technology can bring to the energy transformation."

Professor, Dr Kalman Vad, ATOMKI, added, "Freemelt ONE will be used for research in surface science, surface topology, which means creation of new surface structures and composite materials via non adiabatic alloying, based on opportunity of a fast-moving powerful electron beam. The open architecture and free parametrisation of the properties of the beam makes Freemelt ONE an ideal tool for research purposes."

The second order came courtesy of a Turkish university which will use the machine for Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing process development, application development and material characterisation. The Freemelt ONE is optimised for material research, enabling faster introduction of new materials and products in industrial applications. Delivery of the order is expected in Q1 2024.

"We are proud of this new order, which is our second in just a few days," Gidlund commented. "It is a strong confirmation of the value Freemelt's solutions brings to the research of materials development and to the Additive Manufacturing industry. Right now, we see an increasing interest for applications in various business verticals such as medical implants, electromobility, defence and renewable energy. It's very exciting to see how suitable Freemelt ONE is for various purposes. This customer will use the machine for academic purposes, material development and characterisation, process development, application development for composite technologies, Design for Additive Manufacturing (DfAM), smart and digital manufacturing as well as data-oriented smart productions."

www.atomki.hu | www.freemelt.com

Patent granted for use of oxalic acid powder for debinding POM feedstocks

XERION Berlin Laboratories GmbH, Berlin, Germany, has announced a patent for a new method for catalytically debinding polyoxymethylene (POM) based feedstocks, such as BASF's Catamold® for Metal Injection Moulding (MIM) or its Ultrafuse® filaments for Additive Manufacturing, using oxalic acid powder.

Both the Catamold and Ultrafuse materials see widespread use in MIM and metal Fused Filament Fabrication (FFF, also known as filament-based Material Extrusion (MEX)) thanks to the reduced time required for catalytic debinding compared to solvent based debinding methods. This is especially the case for parts with larger wall thicknesses and allows for faster batch processing and higher throughput for manufacturers.

Typically, nitric acid in varying concentrations is used to catalytically debind POM-based feedstocks in order to remove the polymer backbone before sintering. While advantageous for the aforementioned reasons, the challenges that nitric acid poses with regard to the environment, as well as safe handling, are well known within the industry. The new catalytic debinding method from XERION, used in its Fusion Factory XS system, alleviates these issues by using oxalic acid rather than nitric acid.

Oxalic acid is naturally occurring, found in various plants, leaves and even honey. As opposed to nitric acid, which is stored as in liquid form, oxalic acid can be stored as an odourless powder, which is safe to handle. It was stated that the amount of oxalic acid required for catalytic debinding in the Fusion Factory XS is comparable to the amount of oxalic acid that one would find in a handful of rhubarb leaves. The byproducts from the use of oxalic acid in the Fusion Factory XS system from XERION Berlin Laboratories present no harm to the environment and processing time is similar to debinding with nitric acid.

The Fusion Factory XS is an all-in-one metal FFF Additive Manufacturing, debinding and sintering system, built into multiple compact Pelican™ cases that are easily transported and can endure rugged conditions. The debinding unit and sintering furnace are housed together within one Pelican case, where the catalytic debinding unit consists of two independently heated interconnected chambers. Within the box chamber, 'green' AM or MIM parts are placed where they are heated to an elevated temperature.

The other chamber contains a pre-prepared oxalic acid cartridge, which is then heated so that the oxalic acid sublimates and is transported to the chamber with the green parts. The remnants of moved backbone polymer are then safely burned off within an electrical burner, therefore, posing no risk to anyone in the vicinity of the system.

The patented catalytic debinding solution from XERION Berlin Laboratories GmbH uses oxalic acid powder in a separately heated powder cartridge (Courtesy XERION)

The sintering furnace can achieve temperatures up to 1,550°C within an argon/forming gas atmosphere. The furnace utilises a cold-wall system, cooled by a chiller housed within a separate Pelican case. During thermal debinding, the same electrical burner as the debinding unit is used.

The custom-made dual extruder AM machine, specifically designed for the processing of powder-filled POM filaments, is housed within its own Pelican case. Filament is stored on compact spools that move on an independent linear rail, as part of a separate patent belonging to XERION. The overall solution, therefore, lends itself well to BASF Ultrafuse stainless steel in combination with its ceramic support interface.

XERION stated that it has considered the safety and environmental impact in every aspect of the Fusion Factory XS system, with its compact and transportable footprint enabled by this new method of catalytic debinding using oxalic acid.

www.xerion.de

Email:
info@hb3dp.com

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Tritone Technologies joins Bavarian Aerospace Association

Tritone Technologies, a provider of metal and ceramic Additive Manufacturing machines headquartered in Rosh Ha'ayin, Israel, has announced that it is now a member of the aerospace cluster Bavarian Aerospace Association (bavAIRia).

"We are delighted that Tritone Technologies have joined our association," stated Andreas Gundel, Managing Director, bavAIRia. "Tritone's MoldJet technology has the potential to revolutionise the way we can manufacture in the aerospace industry. Tritone's expertise will undoubtedly help open new horizons for innovation."

The aims of the association are to foster cooperation, drive innovation, and promote research in the aerospace sector, centred around Bavaria, a prominent hub for science, technology, aerospace, and space applications (LRFA). These efforts extend to various related technologies where the members possess specialised expertise.

"Joining bavAIRia is an exciting opportunity for us to bring our technologies to a wider audience and benefit from the diverse resources of this prestigious association," shared Steffen W Kuhn, General Manager Germany & Austria, Tritone. "We firmly believe that our membership in bavAIRia and the resulting collaboration opportunities will drive groundbreaking developments in the aerospace industry."

Tritone's MoldJet technology is a powder-free Additive Manufacturing process that allows for industrial production of high-quality metal and ceramic parts. Designed for producing large quantities of high-density parts with complex geometries and a wide variety of materials, the technology enables parallel manufacturing of parts of varying sizes, shapes, and applications.

www.tritoneam.com

Tritone's MoldJet technology is a powder-free Additive Manufacturing process that allows for industrial production of high-quality metal and ceramic parts (Courtesy Tritone)

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AFX

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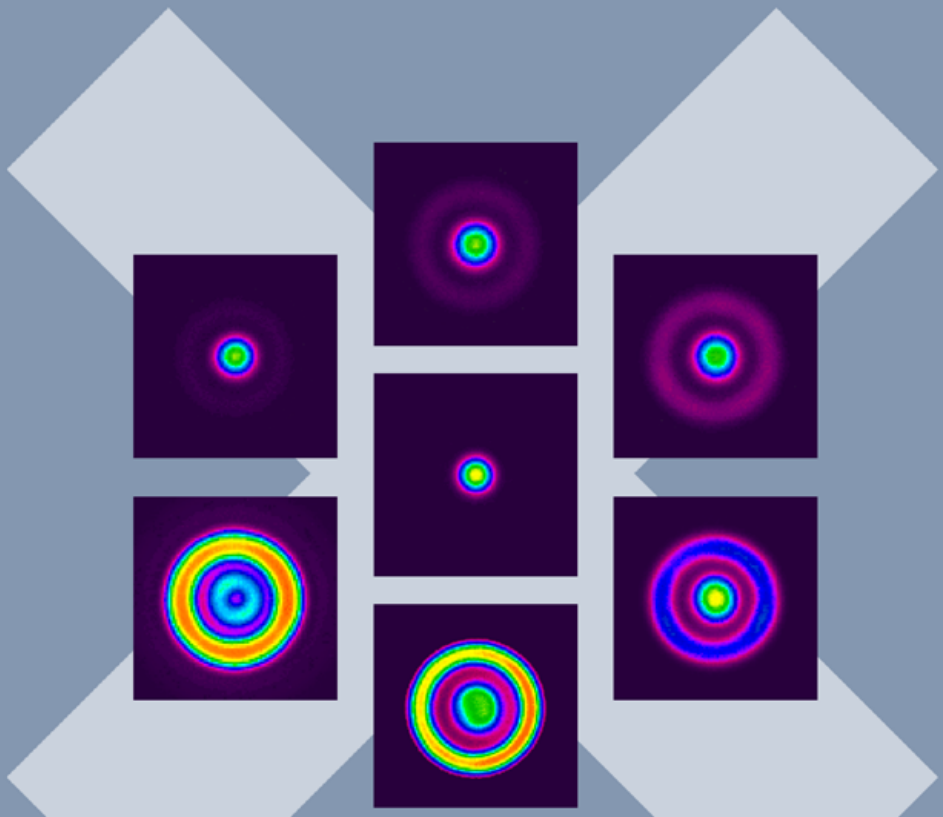

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Wallwork Group invests £10M in new UK-based Hot Isostatic Pressing facility

Wallwork Group, headquartered in Bury, Greater Manchester, UK, has announced it is establishing a £10 million, state-of-the-art Hot Isostatic Pressing (HIP) centre at its Bury site. Housed in a newly-prepared 2,500 m^2 facility, the first of the new HIP machines is expected to be fully operational in 2023.

"As the UK's premier independent heat treatment, vacuum brazing and advanced ultra-hard coatings company, this is a significant expansion of Wallwork's thermal processing services and is part of a commitment to invest £20 million over the next five years," stated Simeon Collins, Director. "It cements our position as the UK one-stop shop for component manufacturers. All secondary processes are easily accessible on this site or another Wallwork site and backed by our national pickup/delivery transport fleet."

James Bailey and David Loughlin are reportedly heading the new Wallwork HIP Centre, along with Andy Day in sales. Loughlin will be joining the company in the new role of HIP Business Manager, having extensive experience in managing a HIP facility in Europe.

"The demand for HIP is growing quickly, in part driven by the leaps forward in Additive Manufacturing technology," Loughlin explained. "HIP is extremely efficient at removing the porosity from AM parts made from metal powders – this densification process is often the only way for AM builds to fulfil their safety critical potential. With the Quintus URC system to reduce cycle times and high-pressure capability, we are set to meet customer demand and expectations in these developing areas. Compared to the US and Europe, the UK has been lagging behind in HIP capacity. This investment, and those planned by Wallwork, will go a long way to rectify that. In addition to Wallwork's focus on quality, service and value added, I'm looking forward to developing some new relationships for the company."

Quintus has over 2,000 systems working worldwide in industries including aerospace, energy, medical implants, space, automotive, Additive Manufacturing, Powder Metallurgy, castings and food processing.

Bailey added, "The Quintus Technologies' HIP operates at pressures from 40 to 207 MPa (5,800 to 30,000 psi) and temperatures up to 1,250°C. The new unit being installed has the latest technology capable of rapid cooling and also the ability to increase cycle pressures to aid with new engineering advances particular in Additive Manufacturing. This requires some major engineering and civil works, hence the high investment we need to make to enter this growing market. The ability to improve material fatigue properties, ductility, structural integrity and fracture toughness applies to AM, castings, forgings and subtractive engineered components. Components with complex geometries can also be processed to near-net shape, saving customers additional machining steps and therefore cost."

The design phase for the new HIP centre began during the pandemic and presented many unforeseen challenges for Wallwork and the team at Quintus Technologies. "This has forged a solid working relationship and gives us great confidence in their support for the technology going forward as we continue to invest," Collins added. "As the Bury site is already the largest single-site UK heat treating facility with an aerospace scope covering nine Nadcap check sheets, we expect to be adding new certifications and approvals for HIP as quickly as possible. We also have a dedicated online customer portal in development that will aid load scheduling."

As well as its Bury facility, the company also has sites in Cambridge, Birmingham and Newcastle.

www.quintustechnologies.com
www.wallworkht.co.uk

Additive Manufacturing drives spherical powder development at PSI

PSI Ltd, based in Hailsham, UK, is probably best known for the design, manufacture and installation of gas atomisers to make spherical powder for use in metal AM and other Powder Metallurgy applications. Atomisers supplied range from small laboratory ones, processing a few kilograms, up to large, sophisticated plant delivering multi-thousand tonnes per year.

What is less well known, however, is that PSI is also active in designing plant for a diverse range of other processing technologies. In the field of advanced engineering materials, these are often complementary to its PM activities. These technologies include Chemical Vapour Deposition (CVD) used to coat powders, Electron Beam Physical Deposition (EBPVD) to coat aerospace turbine hot section components, melt spinning and strip casting to make high performance (FeNdB) magnetic powders and several other processing technologies. These all relate to gas atomisation in that they have rapid solidification science in common, generating high performing material microstructures.

For the R&D team at PSI, metal Additive Manufacturing has, over the past five to ten years, thrown up a whole series of interesting and unique challenges. PSI has developed process equipment with specific advantages to the AM industry.

Fluidised Bed Reactors (FBR)

PSI has been working in fluidised bed technology for several years in the processing of metal and ceramic powders. In very simple terms an FBR is a container of powder, generally housed in a pressure or vacuum containment vessel. At the base of the container is a porous plate through which a whole variety of heated gases may be passed, inert or reactive in nature. The gas flow energises the powder (fluidises) so it appears to the naked eye as a pot of boiling liquid.

Heat treatment of metal powders and FBRs are not new but, in combination, offer a range of intriguing opportunities to produce powders with sophisticated properties targeted at the advantages and challenges that metal AM presents. These include the use of coatings that can modify the behaviour of powders when being introduced to the build zone, during melting and the mechanical, electrical and magnetic properties of the finished part. Another use is for the heat treatment of powders to modify their rheological properties to suit a range of different AM powder flow requirements.

The recycling of AM powders is another advantage of FBR. Regardless of the particular AM technique employed, powder not incorporated in the build may become oxidised or experience modified flow properties. FBRs can be used to regenerate such powders.

PSI has also used its in-house FBR to process aluminium powders for a non-AM process, namely Cold Spray, where a novel alloy composition and heat treatment resulted in enhanced properties in the coatings. Here, the powders were extracted from the FBR and subjected to a cold gas quench, thus retaining the soft, solution heat treated structure. The advantage of FBRs in contrast to other powder modification processes is that the fluidising action gives a very uniform process environment in terms of temperature and process gas distribution. Furthermore the process can be scaled up to tonnage quantities and can be operated on either a batch or continuous basis.

Gas Classification

Generally, after atomisation, metal powders are graded into the familiar size fractions depending on the requirements of each particular AM technique, whether it be PBF-LB, typically at 15-45 µm or 15-60 µm or coarser cuts for PBF-EB use.

Sieving at the finer cuts (in the size range 10-25 µm) can be particularly problematical. It is true that advances in sieve technology have occurred over past years leading to shorter process times and reduced incidence of sieve 'blinding'. However, the problem still essentially remains. A solution exists in the use of gas classifiers to remove the undesirable fines in a powder distribution whilst retaining a sieving operation at the coarser cuts where sieving rates are much faster.

Gas classifiers are cyclone-like devices which are a standard method of separating a powder distribution into coarse and fine fractions. However, simple cyclones are not capable of precisely dividing atomised metal powder into the desired fractions and rejecting oversize and undersize. Gas classifiers generally have a slotted rotor inside a cyclone body which rotates at high speed and greatly enhances the sharpness of cut and, therefore, improves the economics of production and allows powder producers to meet the exacting specifications of those using the powder.

Such classifiers are generally fed with very large volumes of air to suspend and transport the powder. This has no cost consequence if a powder is not sensitive to oxidisation in the air flow. However, when reactive and possibly explosive powders are required to be processed, argon is the process gas of choice. Here, the cost can become prohibitive.

To solve this, PSI has extended its range of gas classifiers from lab scale to those handling hundreds of kilograms per hour under inert gas. Operating in a highly-automated way, these efficiently recycle the argon, limiting the cost to just the initial charging of the system.

External melt delivery

As with most manufacturing processes, when efficient use of feedstock within the process is approaching optimum, the focus turns to reducing the input cost of metal.

PSI has introduced the 'Contipour' atomising process whereby two furnaces alternatively feed molten metal to a central holding tundish that supplies the atomising zone. Rather than using the pouring furnaces to melt the desired alloy, those furnaces merely act as holding devices into which metal from an external source. These are adjacent to, but operationally separate from, the atomisation unit which then operates on a continuous basis. Thus when one furnace is empty it is removed and refilled while the other furnace continues to top up the tundish.

This technology is particularly attractive to operators of large melting equipment, such as steel electric arc furnaces, where existing use of melt is currently directed towards other processes such as casting. Here, having already invested in the melting plant, the operator may wish to divert part of the output to the relatively high value adding operation of metal powder production.

Analysis of the CAPEX and OPEX components of powder cost when liquid metal is introduced in this way shows a disruptive reduction in those costs.

www.psiltd.co.uk

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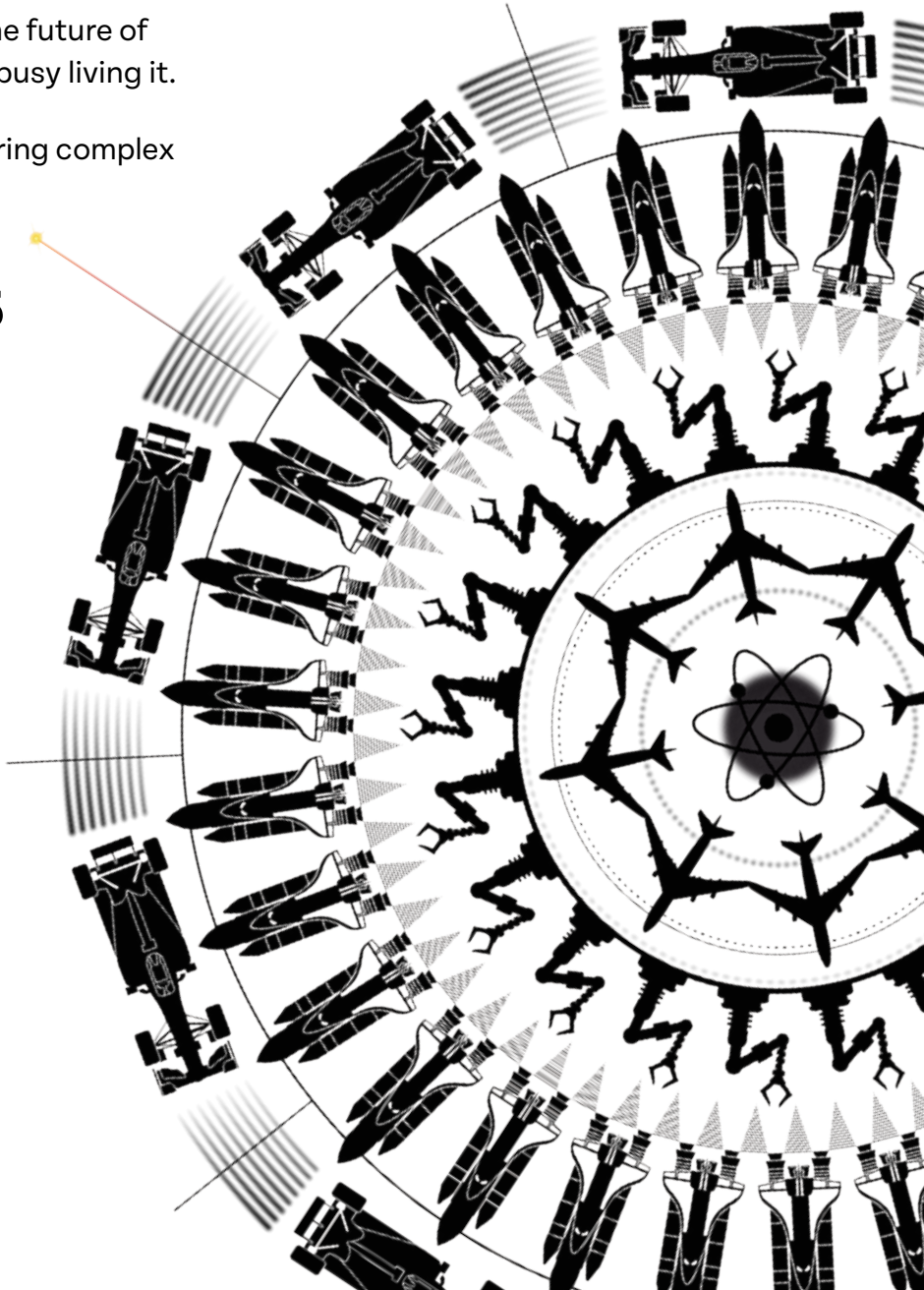

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National Physical Laboratory adds Indentation Plastometer for mechanical testing of metal AM parts

The National Physical Laboratory (NPL), a public sector research establishment which serves as the UK's National Metrology Institute, has added an Indentation Plastometer from Plastometrex for the mechanical testing of metallic materials, including those produced by Additive Manufacturing. Initially, NPL will use the system to test the strength of complex lattice structures and small parameter cube samples made by Laser Beam Powder Bed Fusion (PBF-LB).

The Plastometer is powered by advanced algorithms that allow it to extract metal stress-strain curves from a five-minute indentation-based test. The process is reported to be ideally-suited to Additive Manufacturing due to its unique ability to test small and complex shapes quickly and affordably. This provides users with the necessary data to make confident and informed engineering decisions.

Tony Fry, Principal Scientist at NPL, shared, "The Indentation Plastometer allows us to characterise the properties of finely structured parts in an entirely new way. The data allows us to build up a more comprehensive picture of the properties of parts made via Additive Manufacturing, deepening our understanding of the process."

Plastometrex and NPL are working on several projects. These include supporting the standardisation of the technology, utilising the tool in the AM market, and the development of Plastometrex's upcoming high-temperature system, HotPIP.

NPL will use the new Indentation Plastometer for the mechanical testing of metal additively manufactured parts (Courtesy Plastometrex)

Professor Bill Clyne, Chief Scientific Officer at Plastometrex, added, "We are delighted to be working with NPL, a world-leading organisation in this field. We are looking forward to collaborating with them on several projects that push the frontier of measurement technology for the benefit of the economy and the environment."

www.plastometrex.com
www.npl.co.uk

US Army looks to expand use of additively manufactured parts in Humvees

The US Army is planning to expand the use of additively manufactured parts in its M998 High Mobility Multipurpose Wheeled Vehicles (HMMWV, or Humvee), reports *Breaking Defense*, having recently produced a replacement battery bracket using Fused Filament Fabrication (FFF) Additive Manufacturing technology.

Following Additive Manufacturing, the bracket underwent a post-annealing stage to strengthen the part. The development process used two approaches aimed at eliminating slump and creep during annealing in addition to preserving part geometry. The US Army Research Lab (ARL) tested the deployment of a high-temperature support shell and building the components out of a filament that includes both a low-temperature, annealable phase, and a higher-temperature phase to stabilise the part during annealing.

The study, which began three years ago, aimed to design and produce components for the Humvee using three filament types and three different AM machines to make the comparative quarter-sections. Trials were then conducted in eight processing conditions with the AM parts. The evaluations indicated that annealing was an effective strategy to increase the mechanical robustness of AM parts. Additionally, shell annealing was found to be an effective approach.

As a result of these tests, the components will be installed on Humvees for field testing with the Maryland Army National Guard.

In addition to producing the AM battery bracket, the Army is now reportedly interested in exploring the use of AM for other components. "We are looking for more using cases. We are looking for manufacturing partners. Our plan is to expand consideration to other parts," stated Eric Wetzel, team leader for the project at the US Army Research Lab, at the 15th Annual Ground Vehicle Systems Engineering & Technology Symposium, in Novi, Michigan.

www.army.mil

The M998 Humvee at the 7th Army Training Command's Grafenwoehr Training Area, Germany (Courtesy Gertrud Zach, US Army)

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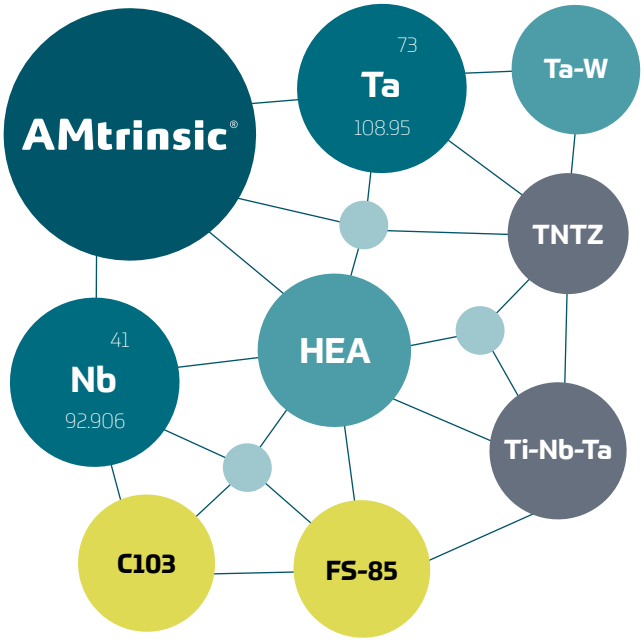

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Kennametal's additively manufactured toolholder wins R&D 100 Award

Kennametal Inc, based in Pittsburgh, Pennsylvania, USA, has been named a winner of a 2023 R&D 100 Award for its new additively manufactured toolholder developed for machining large engine and transmission housings. Made using Kennametal's KENionicTM technology, the tool is 50% lighter than conventional tooling and is reported to reduce machining time by around 50%.

"This is an outstanding example of our industry-leading expertise in materials science, precision machining, bionics-inspired design and Additive Manufacturing that fuels Kennametal's innovation," shared Dr Carlonda Reilly, Vice President and Chief Technology Officer. "We welcome opportunities to leverage our core capabilities to continuously innovate for our customers and are thrilled our KENionic technology has been recognised with this award."

Developed to produce machine precision components for transportation applications, KENionic technology is part of a new class of additively manufactured tools that feature a design that mimics the most effective and efficient organic shape adaptations found in nature.

The light-weighted PBF-LB steel cutter body enables easier tooling changes, as well as more rapid acceleration and deceleration in use. The AM route also allows multiple channels to feed coolant exactly where it is most effective.

The dimensional stability of the Additive Manufacturing process is such that, when combined with finish machining of the insert pockets and the cutting inserts' own tolerance levels, very tight machined component tolerances are achieved.

www.kennametal.com

Kennametal received a 2023 R&D 100 Award for its additively manufactured toolholder developed for machining large engine and transmission housings (Courtesy Kennametal)

The PBF-LB steel cutter body enables easier tooling changes. The AM design also allows multiple channels to feed coolant exactly where it is most effective (Courtesy Kennametal)

ATI to establish AM facility for US Navy's nuclear propulsion programme

ATI Inc., located in Dallas, Texas, USA, has been granted a contract by Bechtel Plant Machinery Inc. (BPMI) to provide assistance in developing highly-engineered part solutions for the US Naval Nuclear Propulsion Program. As part of this contract, ATI will establish a specialised Additive Manufacturing facility outside Fort Lauderdale, Florida, to support advanced manufacturing methods, including metal Additive Manufacturing.

ATI will expand its traditional capabilities by bringing its expertise as a global producer of high-performance materials and solutions to Additive Manufacturing for aerospace and defence. ATI's Additive Manufacturing, heat treating, machining, and inspection capabilities are located within a secure facility designed for expansion as ATI continues to extend its Additive Manufacturing technologies to the assembly of finished components.

The new operation combines the expertise of ATI Forged Products, known for producing mission-critical finish-machined forgings, with the powder alloy leadership of ATI Specialty Materials. "With this facility, ATI will maximise its ability to deliver advanced Additively Manufactured materials and components by turning them into parts that further the defence industry," shared Kim Fields, president and Chief Operating Officer of ATI. "Our customers increasingly require more robust and versatile materials and components, produced in an ecologically sustainable manner. This facility will deliver both." It is projected to come online in mid-2024.

"Within one facility, we're combining the latest additive and advanced manufacturing technologies and ATI's novel powder alloys. We bring decades of experience delivering solutions that power and protect. We're well-positioned to deliver the next generation of manufactured components," continued Fields.

"Additive Manufacturing offers tremendous advantages to our Program, including accelerating ship construction, improving operational readiness, reducing costs, and an increase in warfighting capability," Barb Staniscia, president and General Manager of BPMI added. "Metal Additive Manufacturing is driving necessary improvements in lead time, design, and performance for the US Navy."

"As our customers blaze the trail of what's possible, ATI is honoured to partner with BPMI in developing and producing the materials and components that make these extraordinary achievements possible," Fields concluded. The investment is included in the company's existing capital expenditure guidance.

www.atimaterials.com
www.bpmionline.com

Amaero to establish US titanium powder facility

Amaero International Limited, headquartered in Notting Hill, Victoria, Australia, has announced that it will locate its flagship titanium powder manufacturing facility in Cleveland, Tennessee, USA, following a campaign by the state's government to attract the company. Amaero also intends to relocate its R&D and corporate headquarters to the Tennessee location, which is convenient to the Oak Ridge National Laboratory and the University of Tennessee, Knoxville.

Amaero has reportedly received commitments for economic incentives from the Tennessee Department of Economic and Community Development, the Cleveland-Bradley Chamber of Commerce, the Tennessee Valley Authority and the Oak Ridge National Laboratory. It has also received a long-term commitment from the Tennessee Valley Authority (TVA) for investment credit and a long-term electricity rate subsidy. The TVA's proposed investment credit includes a ten-year commitment for electricity rates that will be lower than the subsidised rates in the UAE and 85% less than the prevailing rates in Victoria.

The decision to locate in Tennessee was made with the belief that it has the strategic advantage of a highly efficient and pro-growth business environment, as well as close proximity to primary customers, research and development partners, the supply chain, highly skilled employees and robust capital markets. Locating in the US looks to give Amaero more business development flexibility from an export control and technology transfer perspective.

The primary facility at the Spring Branch Industrial Park in Cleveland was set to be completed in August 2023. A high bay extension is due to be designed and purpose-built for the installation of four electrode inert gas atomisers (EIGAs). The lease has a primary term of fifteen years, including an allowance for tenant improvements and an Option to Purchase. The lease payments are said to be approximately 75% less than the proposed built-to-suit facility at KEZAD in the UAE. It is expected that Amaero will occupy the main facility in April 2024 and the high-bay extension in July 2024.

The facility with a prepared pad for the high-bay extension is intended to enable Amaero to install the titanium powder production plant sooner than the proposed 'build-to-suit' project in the UAE. Amaero now expects to accelerate breakeven operations by twelve months and to reduce working capital by $22 million as a direct result. In November 2022, it estimated that the required working capital for the first three years (2023-2025) would equate to $78 million; the facility in Tennessee also looks to reduce the required working capital for the same three-year period to $56 million and allow the company to achieve positive cashflow in 2026. Amaero expects that required funding for capital expenses (facility, tenant improvements and equipment) will remain unchanged from the previously proposed project at KEZAD.

"This is a seminal event for Amaero and a cornerstone development for Amaero's shareholders, our employees and our customers. With this development, we expect the cadence of material announcements and tangible milestones to accelerate," stated Hank J Holland, Amaero Chairman and CEO. "Amaero is appreciative of the many stakeholders in Tennessee who quickly mobilised resources and proactively developed a compelling business case and competitive value proposition for the re-location of our flagship titanium powder manufacturing, research & development and corporate headquarters."

"After nine months of all consuming efforts in the UAE, after advancing the build-to-suit planning at KEZAD and after recent receipt of the Term Sheet from Emirates Development Bank, it was difficult to consider last minute advances for alternative locations in Tennessee or other States in the Southeast US. At the same time, circumstances are fluid and we have a fiduciary duty to decisively pursue opportunities that are in our shareholders' best interest. We appreciate the efforts and support of so many stakeholders in the UAE and remain interested in pursuing other strategic opportunities," Holland concluded.

www.amaero.co.au

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Safina defines green laser exposure parameters for copper on Prima Additive machines

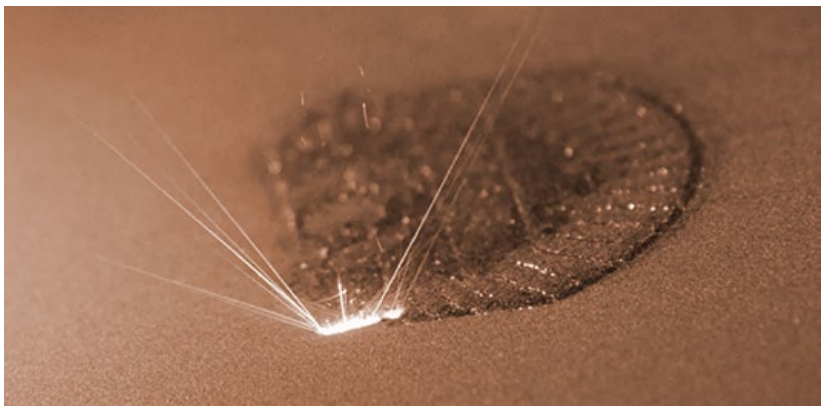
Established in 1860 and based in Vestec, Czech Republic, Safina has a long tradition in the complex processing and manufacture of products from precious and nonferrous metals. Among other areas, Safina is a well-known supplier of gas atomised non-ferrous materials for Additive Manufacturing.

In the last few years, Safina has focused on materials development with Additive Manufacturing technology manufacturers. Recent projects include the development of process parameters for Prima Additive machines equipped with a 532 nm wavelength laser (known as a green laser). These are suitable for melting highly reflective materials such as pure copper or copper alloys. Unlike some competitors, the Prima Additive system uses a green IPG laser with a very small spot size.

Using relatively standard pure copper with PSD -15-45 and purity of 99.95% and higher, smaller parts with complex, highly detailed geometries can be produced while maintaining thermal and electrical conductivity at the level of conventionally-produced pure copper. In terms of numbers, this means thermal conductivity at 388 [W m-1 K-1] and electrical conductivity at 97-100% IACS across the build chamber. As a result, even on a machine with a relatively small chamber, parts can be produced that find use in industrial applications such as smaller heat exchangers or smaller induction hardening coils.

Depending on the type of application, it is possible to decide whether or not to apply heat treatments to fabricated parts, unlike copper alloys. Homogenisation annealing at high temperature will allow any defects to be eliminated, but the properties of the copper will change to some extent and a change in the mechanical properties of the copper must be taken into account (e.g. yield strength is reduced by about 30-40 Mpa compared to untreated copper). Conversely, electrical conductivity typically benefits from this treatment and sample builds then show values up to 100% of the IACS standard for pure copper.

Parts can be produced that find use in industrial applications such as smaller heat exchangers (Courtesy Safina)



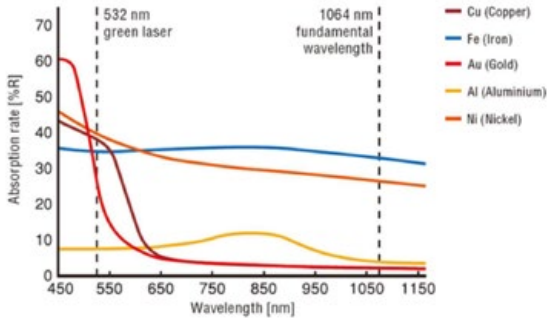
Relatively standard pure copper powder with PSD -15-45 and purity of 99.95% and higher, produces parts with highly-detailed geometries (Courtesy Safina)

Safina is now working on the development of exposure parameters on green laser systems for other manufactured materials including the popular copper alloys CuCr1Zr, bronze and Grcop-42. All of these materials today find their applications in various segments ranging from the automotive and energy industries to aerospace.

www.safina.eu

Electrical Conductivity (IACS)	97 - 100 % IACS
Thermal Conductivity	> 388 [W m-1 K-1]
Porosity	< 0.5 %
Elongation at break	5 %
Yield strength (without heat treatment)	170 MPa
Tensile strength (without heat treatment)	200 MPa

Table 1 Measured results of additively manufactured samples with green laser form pure copper (Courtesy Safina)



The absorption rate of a green laser to copper is 35-40% (Courtesy Safina)

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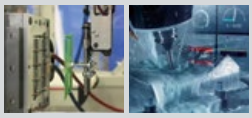

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C01P
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Wear resistant

W

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High strength maraging alloy

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H

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Bosch Nuremberg and Nikon SLM Solutions look to further the adoption of AM in the auto sector

Nikon SLM Solutions (formally SLM Solutions) reports that it has formed a strategic alliance with Bosch Nuremberg as the companies look to further the adoption of Additive Manufacturing in the automotive sector. The Bosch Group, a leading global technology and services provider and a tier 1 automotive supplier, employs over 400,000 associates with subsidiaries and regional companies in some 60 countries. A move towards greater use of AM is expected to send the message that this technology is the future of automotive production, rather than just an experimental venture.

Bosch Nuremberg's journey into Additive Manufacturing was not without its hurdles, reported Nikon SLM Solutions. In the beginning, the technology was seen as just another tool in its manufacturing arsenal. However, when this didn't yield the expected results, a paradigm shift occurred.

"Our transformation was defined by a transition from a solely technology-driven mindset to one that places paramount importance on the distinct advantages of the product," stated Kai Kuhlmann, Director of Technical Functions at Bosch Nuremberg's facility. "The heart of our revamped strategy is to utilise AM's unparalleled design capabilities, thereby enhancing product performance, optimising cost management, and setting a gold standard for quality."

The relationship between the two companies isn't just transactional, it is said to be a melding of minds and expertise, resulting in a synergistic drive toward innovation. Having already established a number of metal and plastic AM centres, Bosch Nuremberg is ready to integrate AM within its global operations

Bosch Nuremberg operates multiple AM machines, including the SLM®500 Laser Beam Powder Bed Fusion (PBF-LB) machine from Nikon SLM Solutions. The large build volume, swappable build cylinders, and open architecture are intended to make quick work of the prototyping phase, whilst still being production-focused.

Sam O'Leary, CEO of Nikon SLM Solutions, stated that the cornerstone of this collaboration is its "open-architecture philosophy" - a philosophy that focuses not only on the technology itself but also on its integration into tried-and-tested production processes.

OEMs, always on the hunt for innovation and differentiation, may stand to gain from this shift to Additive Manufacturing, added Nikon SLM Solutions. Furthermore, as OEMs grapple with the distinct challenges of EVs, solutions offered by AM may become increasingly relevant.

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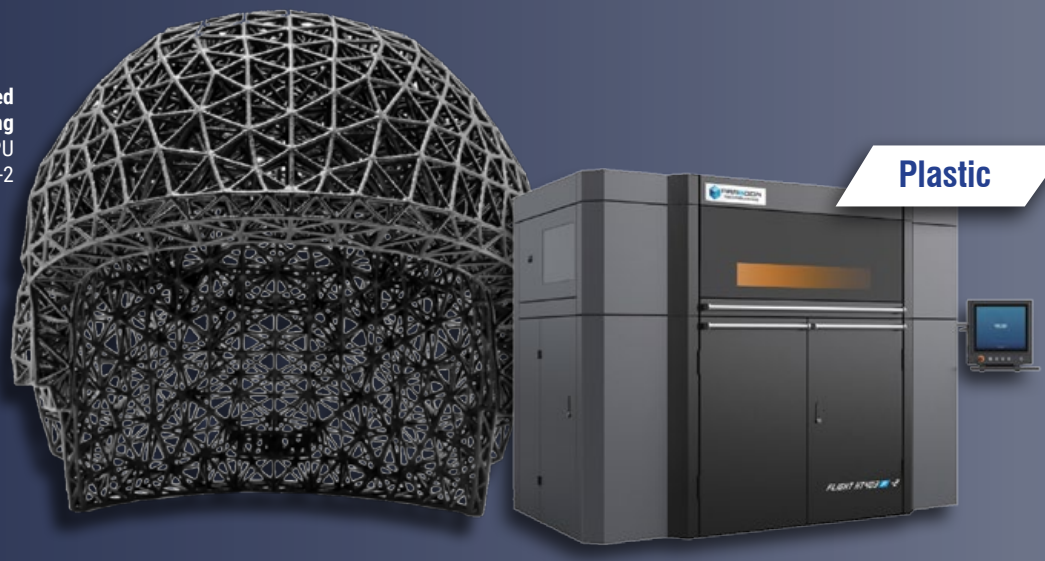

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Sigma sells its Additive Manufacturing quality assurance software business

Sigma Additive Solutions, Inc., based in Santa Fe, New Mexico, USA, has announced plans to sell the assets of its Additive Manufacturing quality assurance software business to an unnamed strategic buyer. The company also announced it will acquire 100% of NextTrip Holdings, Inc., a travel technology company based in Sunrise, Florida.

"With our focus on increasing shareholder value as we explored a variety of strategic alternatives, we believe a transaction with NextTrip provides a significant opportunity to participate in a leading travel brand with an array of product offerings and concierge services," Jacob Brunsberg, president and Chief Executive Officer of Sigma, stated. "The transaction would imply a solid valuation for Sigma and good positioning in public markets. As well, we have a clear path to add value from the sale of Sigma's current assets in the business of process monitoring with our signed letter of intent from a strategic buyer to acquire the assets."

NextTrip has recently formed a new management team with extensive experience in key areas of the travel industry, including online travel distribution, wholesale distribution, and travel technology. With the company's relationship network and industry knowledge, the team is believed to be well-positioned to establish NextTrip as a major player in the travel space.

As of 2023, NextTrip has established over 200 direct relationships with blue-chip travel organisations and major industry suppliers for air, hotel, and other travel-related services. This ensures a robust product offering of more than 2 million hotels worldwide.

"NextTrip's recently acquired scalable booking engine and platform offers numerous proprietary booking solutions allowing travellers to customise itineraries to meet their needs. We believe NextTrip's leadership team is addressing a clear underserved demand for a differentiated and tailor-made approach in the online travel space. Our ambition is to allow NextTrip the ability to amplify its growth plans and expand its reach into new markets for the benefit of Sigma equity holders, while tying the issuance of additional equity to clear business objectives for NextTrip," added Brunsberg.

Lyndsey North, president of NextTrip, commented, "The transaction with Sigma will establish a partnership and path forward to accelerate growth. As NextTrip continues to roll out key technology developments and grow our footprint in the travel space, we believe the relationship with Sigma will bring additional leverage and momentum. The efforts of the NextTrip team to drive the business forward have established the brand and positioned it to be a disruptive force in the industry. We look forward to continued growth and product development. NextTrip's commitment to customer service, our deep supplier relationships and proprietary technology uniquely position us for a strong trajectory across multiple segments of the travel market."

The transactions are expected to be completed in the fourth quarter of 2023, subject to the negotiation and execution of the definitive acquisition agreement, regulatory and shareholder approvals, and other customary closing conditions. As part of the transactions, Sigma is expected to change its name to NextTrip, Inc. and be listed on Nasdaq under a new trading symbol reflecting the NextTrip name.

Until the NextTrip transaction is finalised, Sigma Additive Solutions and NextTrip will remain separate, independent companies, and will continue to operate as such.

www.sigmaadditive.com
www.nexttrip.com

Mantle delivers its first production metal AM machine to Westec

Mantle Inc., San Francisco, California, USA, has delivered its first production-specification metal AM machine to Westec Plastics, a custom plastic injection moulder and tool builder in Livermore, California. Having completed multiple beta deployments, Mantle is now shipping production versions of its P-200 manufacturer and F-200 furnace, incorporating additional hardware and process refinements.

"Having the Mantle equipment in-house enables Westec to complete prototype and production steel tooling inserts with a much shorter lead time than standard mould builds," stated Tammy Barras, president of Westec Plastics. "This will benefit our customers by providing production-quality steel tooling with aluminium tooling lead times."

Mantle uses its proprietary TrueShape technology – a hybrid material extrusion (MEX), CNC and sinter-based process to refine the shape of AM tools and deliver accuracy as well as good surface finish and properties. The P-200 Additive Manufacturing machine is built on a CNC platform that integrates building and machining to produce parts with the accuracy and surface finish required for tooling. The P-200 machine has a build volume of 200 x 200 x 150 mm.

A sintering stage follows using the company's F-200 furnace. This furnace can sinter multiple parts and will support multiple AM machines. Mantle offers two tool steel materials, H13 and P2X (a steel comparable to P20), said to be durable, stable, and perform like traditional tool steels with secondary operations like machining, polishing, coating, and laser welding.

www.westecplastics.com
www.mantle3d.com

Xometry launches cloud-based collaboration tool to streamline project management

Xometry Inc, Gaithersburg, Maryland, USA, has introduced a new cloud-based collaboration tool that enables employees within the same company to manage projects using Xometry's AI-powered platform. The new dashboard provides engineering, procurement, and supply chain colleagues with visibility into existing projects. Seen as an important addition to Xometry's online marketplace, the dashboard looks to help streamline order management, increase efficiency, and drive data-based decision-making.

"Our new dashboard further accelerates Xometry's continued adoption into the enterprise and supports a growing number of clients who rely on us to strengthen their supply chains and provide additional capacity for large-volume production runs," said Randy Altschuler, Xometry CEO. "With it, our customers can manage the production of individual parts to entire supply chain projects, empowered by data and insights that help them drive real-time decision-making."

Xometry's cloud-based collaboration tool enables employees within the same company to manage projects using the AI-powered platform (Courtesy Xometry Inc)

The dashboard was announced during the company's second quarter 2023 earnings call in early August and is currently in beta with large companies. It will be widely available later this year. The introduction of the dashboard follows other recent innovations, such as the continued expansion of Xometry's AI-powered marketplace.

Xometry's two-sided marketplace aims to connect enterprise buyers with manufacturers who build the big ideas that fuel the global economy. Xometry's proprietary technology looks to shortens development cycles, drives efficiencies within corporate environments, and helps stabilise supply chains to make them more resilient.

Xometry's product portfolio includes its digital marketplace, the Thomasnet.com industrial sourcing platform, and cloud-based tools. These tools include Workcenter, a manufacturing execution system that helps small and medium manufacturers digitise every aspect of their shop.

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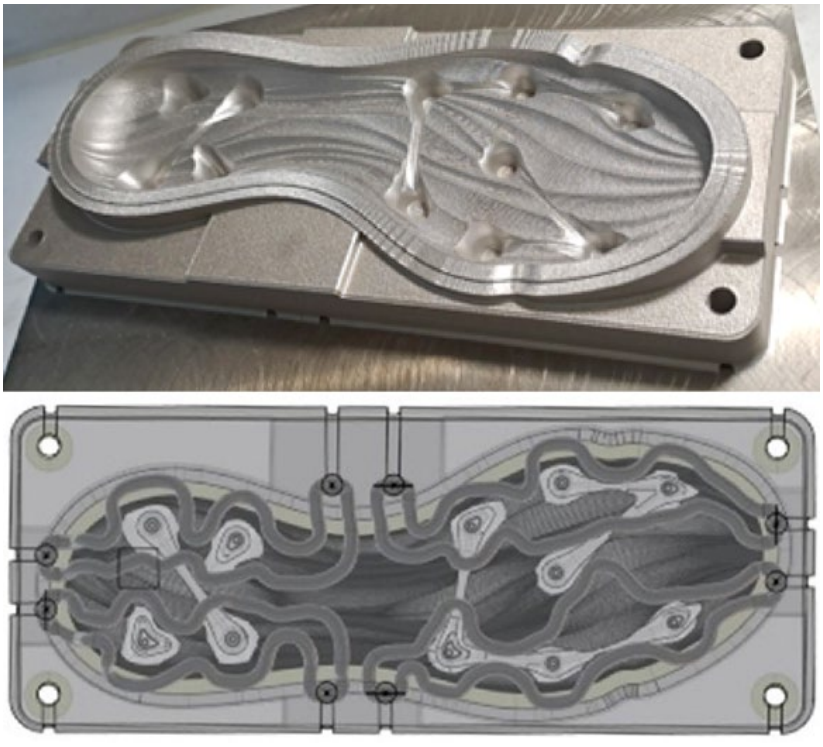
Metal Additive Manufacturing for tool makers highlighted by AddUp and WBA

AddUp SAS, headquartered in Cébazat, France, has partnered with WBA Aachener Werkzeugbau Akademie (WBA), in Aachen, Germany, to demonstrate the advantages of metal Additive Manufacturing for the mould making industry. After launching a Tooling Study in January 2023, the team found six tool-making companies that each identified existing moulds to be tested. AddUp and WBA have now produced the first prototypes of these injection moulds, all with optimised internal cooling channels.

Traditionally, manufacturers using injection moulding must contend with certain constraints that are inherent to the moulding process. Specifically, the mould's performance is directly related to its ability to cool the injected parts. However, AM technology can be used to create complex cooling channels that are positioned as close as possible to the mould walls. By adapting the shape of these channels to cool the surface of the part more homogeneously, manufacturers can improve the quality of their products and experience higher productivity, as well as reduced cooling and cycle times.

The companies selected for the Tooling Study were Pöppelmann, Siebenwurst, Harting, Zahoransky, GIRA, and Framas. They were given the opportunity to test the introduction of Additive Manufacturing into their workflow, and specifically implement the technical and economic advantages that AM technology brings to their injection moulds.

Once selected, AddUp and its partners evaluated each injection mould to determine how it could be optimised with Additive Manufacturing. Each part was then redesigned for AM, optimised for conformal cooling, and manufactured on AddUp's four-laser FormUp 350 Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machine at AddUp's AM Tooling Competence Centre in Aachen.



The complex cooling channels for the new mould can be seen. This mould was chosen by Framas (Courtesy AddUp)

AddUp established its AM Tooling Competence Centre in Aachen, in partnership with WBA, in early 2023. This facility, which also serves as AddUp's German subsidiary, gives tooling manufacturers access to AddUp's Additive Manufacturing machines. Users can also submit application cases for evaluation and study of all aspects of their project, from the design when applied to PBF-LB, to profitability analysis and study of series production.

AddUp explained that the choice of material is critical for tool makers, as moulds must meet high requirements, especially in terms of corrosion resistance, heat conductivity, and fatigue. Leveraging its twenty years of experience in AM, AddUp used Maraging 300, a material successfully used in series production by Michelin to manufacture over a million tyre mould sipes per year. In addition to Maraging 300, AddUp recently announced build parameters for AISI 420, a corrosion-resistant tool steel also known as 1.2083 in the German standard. It is expected that this new material will enable tooling manufacturers to produce even more complex and efficient moulds.

For the project, post-processing was completed by the tooling company itself or by the WBA. Each of these ready-to-use moulds is now being sampled on the respective tooling company's production lines, and the comparative data will be provided to WBA. The final results of the Tooling Study will be presented and published at the WBA's General Assembly in late 2023.

This study was also supported by companies including iQTemp, Deutsche Edelstahlwerke, 3D Laser BW, and Siemens NX, as well as institutes, such as Fraunhofer ILT and ACAM.

AddUp plans to launch a follow-up Tooling Study this autumn, and is inviting any tool makers interested to get in touch.

www.werkzeugbau-akademie.de
www.addupsolutions.com

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Ariane 6 launcher sees successful hot-fire test for upper stage

Teams from ArianeGroup, Issy-les-Moulineaux, France; the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR), and the European Space Agency (ESA) have successfully completed a further hot-fire test of the upper stage of the new Ariane 6 launcher. Metal Additive Manufacturing has been used in the production of the thrust chambers for the rocket's Vinci engine, used in the upper stage.

The test took place in Lampoldshausen, Germany, where the upper stage test sequence simulated the operating phase of Ariane 6's inaugural flight. It required eleven minutes (680 seconds) of Vinci re-ignitable motor operation in two boosts, including two boosts of the Auxiliary Power Unit (APU) in parallel with the Vinci engine, as well as propellant pressure and temperature control in the tanks during non-propulsive phase. The Auxiliary Power Unit (APU) was in operation for a cumulative period of almost thirty minutes. The complete test results are currently being analysed and should lead to the Ariane 6 upper stage being declared 'flight-ready.'

"This success for the Ariane 6 teams brings us closer to the final qualification of the upper stage. This crucial test has demonstrated the perfect simultaneous operation of the Vinci re-ignitable engine and the APU, which are two key technologies for the versatility of our new European launcher, allowing it to complete highly diverse missions," explained Martin Sion, CEO of ArianeGroup.

ESA Director of Space Transportation Toni Tolker-Nielsen added, "Ariane 6 represents a dramatic increase in our launch capability, and the upper stage with its re-ignitiable Vinci engine will be transformative. The results from these tests gives us great confidence in the flexibility of this launch system to satisfy all mission requirements. Together with our partners we are making significant progress, and I look forward to the next stages of our Ariane 6 journey."

Assembled at ArianeGroup's site in Bremen, Germany, the Ariane 6 upper stage incorporates some of the launcher's main innovations. These enable it to carry out a wide range of launch missions, including complex ones such as the large-scale deployment of satellite constellations in low-Earth orbit (LEO), or the successive injection of payloads into different orbital planes.

The Ariane 6 launcher underwent its second hot-fire test (Courtesy ESA/DLR/ArianeGroup)

The stage includes two main tanks for cryogenic propellants (liquid hydrogen and oxygen) to power the Vinci engine, which can be re-ignited up to four times.

While upper stage tests are taking place in Germany, combined tests of the entire launch system, including the first-ever built Ariane 6 launcher called CTM (Combined Test Model), and the new launch base continue in Kourou. The test launcher includes an upper stage used for launcher electrical and fluids tests, such as cryogenic propellant filling and draining sequences, and the operation of the cryo-arms in fully representative conditions, along with the launch base.

The Ariane 6 programme is managed and funded by ESA. ArianeGroup, as the industrial lead contractor and design authority for the launcher, is responsible for its development, production, and marketing through its Arianespace subsidiary, with the help of its industrial partners. Meanwhile, CNES and its contractual partners are in charge of constructing the launch pad in Kourou, French Guiana.

www.ariane.group

Both Additive Manufacturing and Powder Metallurgy are used to manufacture components in the Vinci engine (Courtesy DLR)

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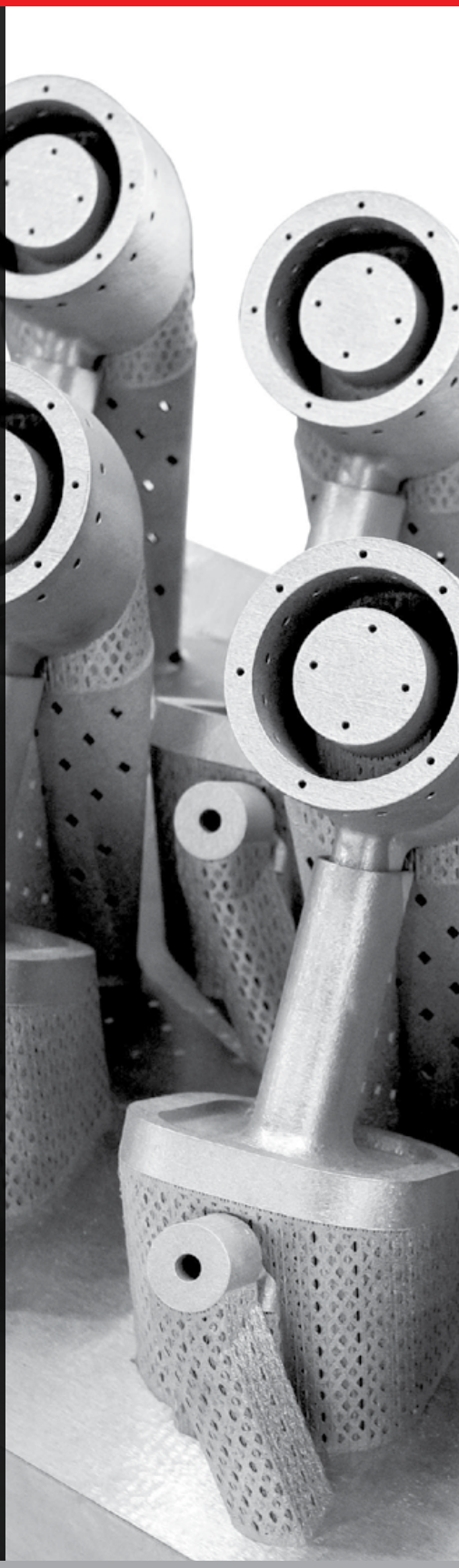

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Meltio launches toolpath software; names Snowbird as sales partner

In separate announcements, Meltio, headquartered in Linares, Spain, released its new Meltio Space toolpath generator software for robotic AM and reported a new sales partner in the USA.

Meltio Space integrates with the Meltio Engine Robot and is said to feature an easy-to-use interface for creating planar, non-planar, and variable extrusion toolpaths. Additionally, it includes two-axis workpiece positioner interpolation, kinematics simulation, collision checking, and cell configuration. The toolpath generator software was developed specifically for accelerating the adoption of Meltio technology, allowing users to quickly adapt to and leverage the benefits of robotic AM, without requiring expertise in robotics or programming.

Integrating a six-axis robotic manipulator and two-axis workpiece positioners is expected to open up a realm of possibilities for metal Additive Manufacturing. With comprehensive coordination, multi-axis toolpath generation, and enhanced design freedom, Meltio Space enables users create intricate, customised, and highly-detailed metal parts.

"Meltio Space makes it possible to design very reliable parts as quickly as possible and with a wider range of possibilities for our industrial customer," explained Alejandro Nieto, Engine Product Manager at Meltio. "Meltio Space also includes preset and recommended material profiles and 3D printing parameters and a series of specific processors for robot arms from ABB, Kuka, Fanuc, and Yaskawa including collision detection, and simulation."

Snowbird Technologies

Snowbird Technologies, based in Jacksonville, Florida, USA, was also announced as a sales partner. The move will see Meltio's Directed Energy Deposition (DED) print head offered as a standard component on the Snowbird Additive Mobile Manufacturing Technology platform (SAMM Tech).

"The SAMM Tech platform with Meltio components offers an impressive, high-performing solution for in-the-field parts manufacturing," stated Jeremy Heerdink, VP of Business Development at Snowbird Technologies. "Our goal in expanding our sales partnership of Meltio products is to provide solutions facilitating efficient and accurate Additive Manufacturing capabilities in the most remote and harshest environments around the world."

SAMM Tech is a newly-released and patented AM machine that is built and operates inside a shipping container. Designed to be transportable and deployable to any location in the world, SAMM Tech aims to support soldiers and industrial operators by advancing in the-field production of large-format metal parts for equipment repairs onsite and on demand.

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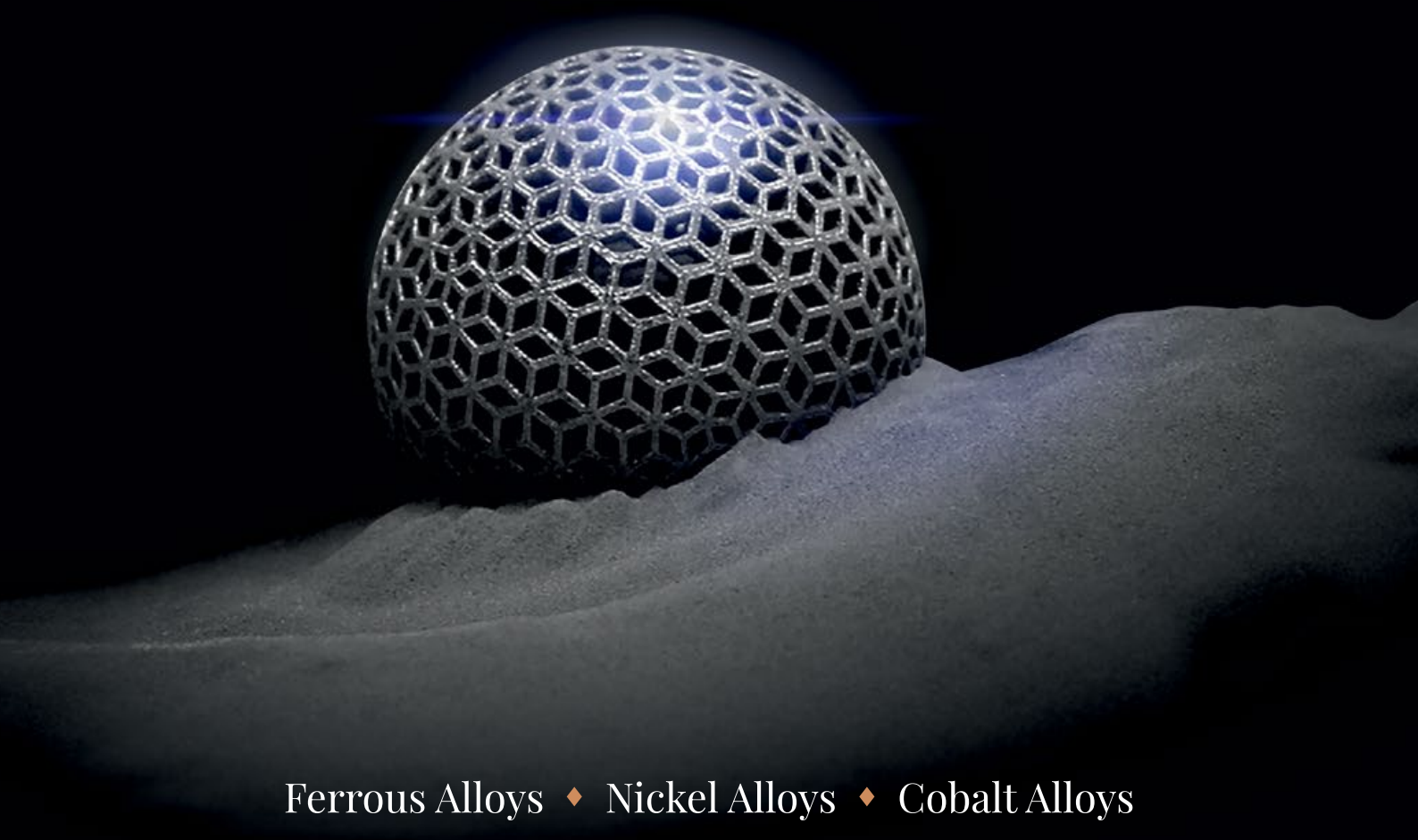

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ISO 9001:2015 / IATF 16949:2016 / AS 9100:Rev D / ISO 13485:2016 / ISO 14001:2015

Dubai Electricity and Water Authority R&D centre files patent for metal Additive Manufacturing extrusion device

The Dubai Electricity and Water Authority (DEWA)'s Research and Development Centre (R&D), headquartered in Dubai, United Arab Emirates, has filed a patent for a novel extrusion device that reportedly enhances the process of melting and extruding raw metal materials to the build plate, while maintaining the optimum temperature required to handle raw metal materials. The extrusion device, said to improve the performance of AM machines by reducing the cost of manufacturing and energy consumption, can be attached and detached from the AM machine as required.

Further details of the patent or process developed at DEWA were not disclosed, however, HE Saeed Mohammed Al Tayer, MD & CEO of DEWA, said that these patents support DEWA's efforts to develop an advanced infrastructure, with the investments helping to overcome challenges in the energy sector.

"The R&D Centre's achievements consolidate DEWA's effective role in realising the Dubai 3D Printing Strategy, launched by His Highness Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai, to exploit this technology for the service of humanity and promote the status of the UAE and Dubai as a leading hub of 3D printing technology in the region and the world by the year 2030," Al Tayer stated. "The Centre hosts leading researchers and creative minds who effectively support the sustainable economy and enrich the scientific community everywhere. At DEWA, we adopt 3D printing as one of the innovative solutions in our internal operations to print spare parts for devices and equipment, in addition to extending the lifespan of the equipment."

DEWA uses Additive Manufacturing to produce prototypes and spare parts for its generation, transmission, and distribution divisions, and to support the digitisation of its inventory.

Waleed Bin Salman, Executive Vice President of Business Development and Excellence at DEWA, added, "The research papers and patents registered by the Centre have enhanced its position as a global platform providing innovative solutions and technologies that enhance the operations and services of the utility sector. This maintains DEWA's worldwide leadership and consolidates Dubai's global position in research and development in solar energy, smart grids, energy efficiency and water, and capacity building in these sectors."

www.dewa.gov.ae/en

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Material Options (Ceramics)	Alumina 99.5%, Zirconia
Build Envelope	~ 300 grams max, Footprint equivalent of baseball size or less, 0.02" (0.50 mm) wall thickness minimum
Quantity	10~50 samples based on footprint. Larger quantities up to 1,000 pcs welcome depending on the part size.
Tolerance capability	Within 2% of the feature size, 2~3 Ra Surface finish, Option of finishing to closer tolerances available.

CONTACT FOR MORE DETAILS

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I-Break project aims to grow UK's aerospace presence via DED AM

A new £22.5 million project known as I-Break (Landing Gear Industrial Breakthroughs) has launched to develop lower-emission technology and increase the UK's share of the global aerospace market. The project is led by Airbus Operations Ltd and involves collaboration between fifteen other partners, including industry leaders, small businesses, academics, and research organisations.

The project aims to develop and manufacture major landing gear structural components using innovative techniques such as metal Additive Manufacturing, Hot Isostatic Pressing, and composites, which are expected to reduce aircraft time to market as well as industrial CO_2 footprint by 30%. This is believed to be the first time such components will be produced using these techniques, with current methods using large-scale forging.

I-Break is being delivered through the Aerospace Technology Institute (ATI) Programme and is being funded from a larger UK government initiative in which £218 million has been allocated to ground-breaking R&D aerospace projects, supporting jobs and growth across the country. The joint commitment with industry to invest in new aircraft and manufacturing technologies is set to help secure at least £20 billion of further private investment in aerospace in the UK and support over 100,000 jobs.

Gary Elliot, CEO of the Aerospace Technology Institute recently said, "The investment through the ATI Programme that the Industry Minister, Nusrat Ghani announced at the Paris Air Show will support a range of world-class research projects in technologies to improve the sustainability of aerospace, from new design processes to new materials."

Metal Additive Manufacturing company WAAM3D is a partner in the project, and its role will involve the industrialisation of higher productivity Wire DED Additive Manufacturing variants; control of microstructure and mechanical properties for high-integrity structural applications; industrialisation of online non-destructive-testing (NDT) techniques; and production of demonstrator parts of relevant size and complexity on its upgraded RoboWAAM machines.

The I-Break project consists of several work packages; partners working with WAAM3D include:

- Cranfield University is working on novel Wire Arc Additive Manufacturing processes and solutions, as well as the validation of deposition of new alloys of key interest
- The University of Strathclyde is working on innovative on-line non-destructive testing techniques.
- Peak NDT, is working on online NDT hardware systems

The I-Break project is currently due to be completed in 2026.

www.waam3d.com

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Ursa Major extends America Makes partnership for the AM of rocket engines

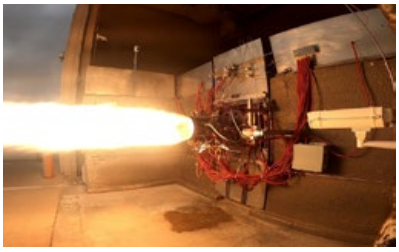
Ursa Major Technologies Inc, headquartered in Berthoud, Colorado, USA, has received additional funding from America Makes, an Ohio-based organisation that aims to accelerate US manufacturing competitiveness through the adoption of Additive Manufacturing.

Ursa Major and America Makes initiated their partnership in 2021 by establishing the Ursa Major Advanced Manufacturing Lab in Youngstown, Ohio. The lab created an Additive Manufacturing capability for GrCop-42, a copper-chrome-niobium alloy developed by NASA, with Ursa Major's first large-scale Additive Manufacturing machine and produced prototype thrust chambers for the vacuum variant of the Hadley liquid rocket engine.

Ursa Major and America Makes have now entered into a new agreement that will extend their partnership through mid-2024. During this time, they will transition from building prototypes to manufacturing production and engine qualification hardware.

"Our Advanced Manufacturing Lab is critical to Ursa Major's Additive Manufacturing capabilities, which accelerate engine production timelines," said Brad Appel, Chief Technology Officer at Ursa Major. "With our resources in Youngstown, we can reduce the production and delivery cycle for combustion chambers from six months to one month."

John Wilczynski, Executive Director of America Makes, added, "Ursa Major has been a great addition to our Youngstown ecosystem. We are excited to continue our collaboration on improving producibility and lead time reduction of defence industrial base relevant parts."



A Hadley engine with an AM copper combustion chamber during a hotfire test (Courtesy Ursa Major)

GRCop-42 is utilised in high-heat applications such as liquid rocket engine combustion devices, due to its high conductivity and strength. Additive Manufacturing enables Ursa Major to accelerate engine production and incorporate real-time testing improvements, resulting in reduced costs. Furthermore, Ursa Major's rocket engines are more than 80% additively manufactured by mass.

www.ursamajor.com
www.americamakes.us

BLT's Additive Manufacturing enables successful launch of world's first liquid oxygen-methane rocket

Bright Laser Technologies (BLT), located in Xi'an, China, reports that it has provided metal Additive Manufacturing support in the development of critical components used in the ZhuQue-2 (ZQ-2 Y2) methane-fuelled rocket. Built by LandSpace, the two-stage rocket has a diameter of 3.35 m and a total length of 49.5 m, with a launch weight of 219 tons and takeoff thrust of 268 tons.

The ZQ-2 Y2 is reported to be the world's first liquid oxygen-methane carrier rocket to successfully reach orbit. During its development, the BLT team conducted a comprehensive analysis of the service conditions for a number of parts, selecting materials such as superalloys and stainless steel to meet the required mechanical properties. Parts were manufactured on machines such as the BLT-S310 and BLT-S400 Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing machines. Certified by Airbus, the BLT-S310 has a maximum build dimension of 250 × 250 × 400 mm. The BLT-S400, primarily used for aerospace industry applications, has a larger build area and is capable of manufacturing parts with dimensions of up to 400 × 250 × 400 mm.

According to BLT, the Additive Manufacturing process not only met performance requirements, but also enabled the creation of complex structures resulting in further optimisation. This capability significantly reduced prototyping and validation time, enhanced efficiency, and facilitated weight reduction.

www.xa-blt.com/en

The ZQ-2 Y2 rocket was launched from the China Jiuquan Satellite Launch Centre (Courtesy LandSpace)

Xometry sees Q2 boost driven by strong marketplace growth

Xometry, an AI-enabled marketplace for on-demand manufacturing that offers AM services, headquartered in Gaithersburg, Maryland, USA, has shared its second quarter 2023 results including a revenue increase of 16% year-over-year. This was reportedly driven by strong marketplace growth of 24% year-over-year and 8% quarter-over-quarter. Supplier Services revenue impacted by approximately $1.7 million, driven by the discontinuation of sales of supplies in the US in Q2.

The company reported a 16% year-over-year increase in gross profit, driven by a 34% growth in marketplace gross profit. The marketplace gross profit was up 19% quarter-over-quarter. Adjusted EBITDA experienced a loss of $8.7 million, which was a $3.1 million improvement from the previous quarter, due to higher revenue, gross profit, and improved operating leverage.

"In Q2 2023, Xometry delivered stronger-than-expected 24% marketplace growth year-over-year, delivered 19% growth in marketplace gross profit quarter-over-quarter and significantly improved operating leverage," said Randy Altschuler, Xometry's CEO. "Driven by Artificial Intelligence, the underpinnings of marketplace growth are robust with 44% active buyer growth and continued strong order growth. Xometry is empowering our customers to build parts that are critical components in next-generation industries from spacecraft and electric vehicles to medical devices and robotics. Our digital marketplace and suite of cloud-based solutions are enabling the long tail of the internet to finally reach the thousands of small- and medium-sized manufacturers in the United States and around the world. We expect to continue to rapidly gain market share fuelling robust marketplace revenue growth in 2023 and continuing on our path to Adjusted EBITDA profitability in Q4 2023."

Xometry is an AI-enabled marketplace for on-demand manufacturing (Courtesy Xometry)

www.xometry.com

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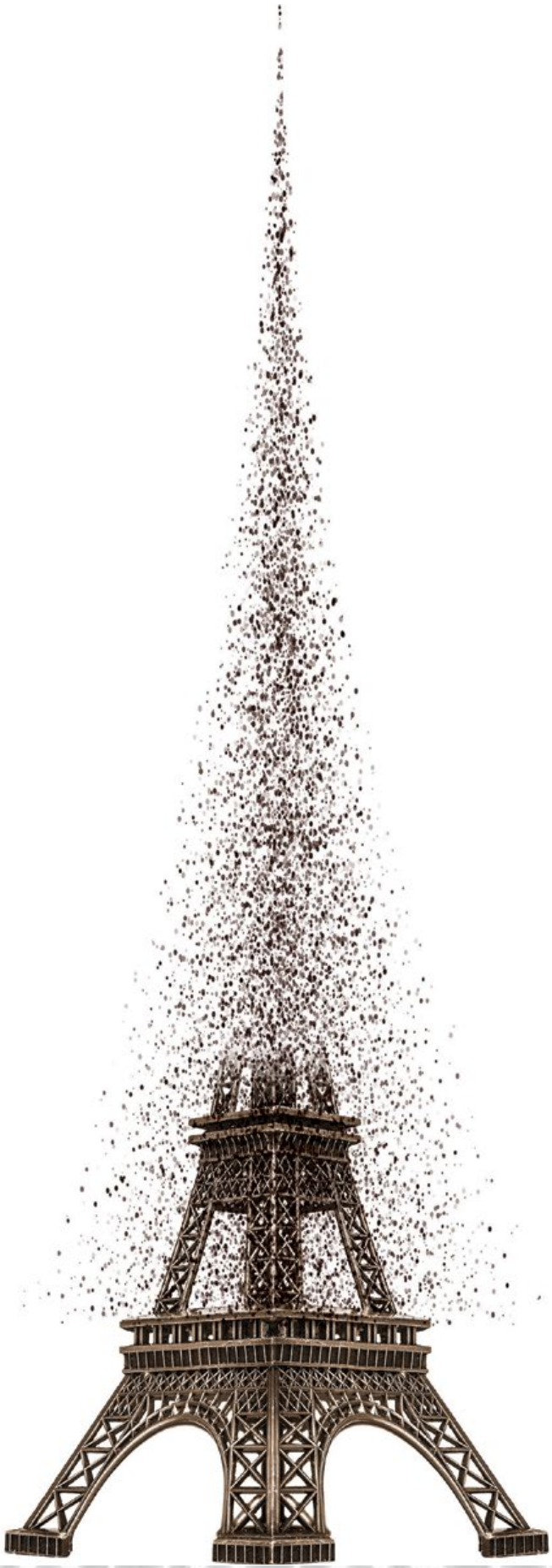

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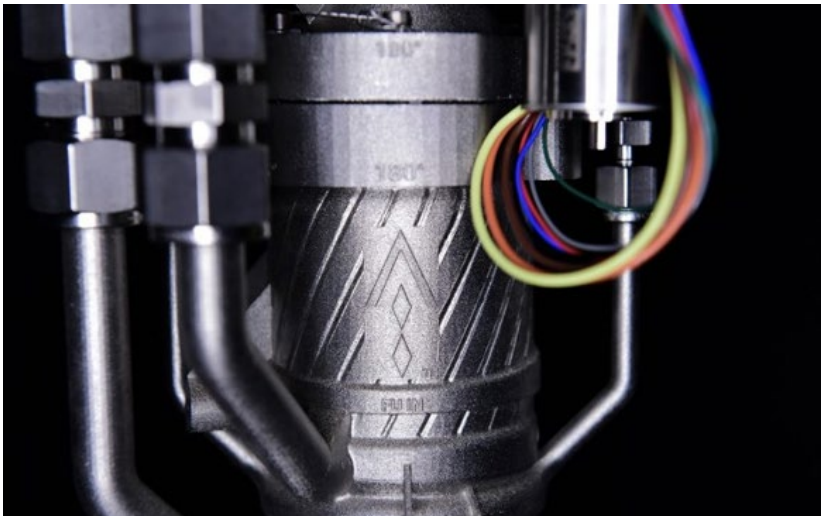
6K Additive and Agile Space Industries partner to advance lunar mission with Ni625 powder certification

6K Additive, a division of 6K Inc. headquartered in Andover, Massachusetts, USA, and Agile Space Industries, a space propulsion technology company headquartered in Durango, Colorado, USA, have announced that Agile is seeking certification of Ni625 powder produced by 6K Additive for use in customer space applications, including critical rocket components.

6K Additive's Ni625 powder is currently undergoing certification for use at Agile's manufacturing facility. The first parts to be produced using this powder will be used in Agile's A2200 bipropellant hypergolic engine. The engines are powered by a pressure-fed hypergolic biorepellant, which does not require ignition as the hydrazine derivative fuel, M20, and MON3 oxidiser combust on contact. By leveraging Additive Manufacturing, the engine was designed to weigh only 5.9 kg, while still producing 500 lbf of thrust, highlighting the benefits of lightweighting using AM technology, without compromising on power.

Kyle Metsger, Director of Additive Technology at Agile, explained, "By weight, 85% of our engine components are Additively Manufactured, meaning we rely heavily on AM powders that can withstand the extreme temperatures and forces generated during take-off and flight. 6K Additive allows us to additively manufacture using high-quality powders that are required for our critical applications, while also helping us meet our environmental goals through their recycling program and sustainably manufactured powders. 6K Additive can deliver extremely consistent powder that allows our production line to run the long build times required for these complex components."

Traditional development cycles for aerospace components can take more than two decades. However, by harnessing the speed and flexibility of AM, Agile can compress development time to just twelve months. "A year-long development cycle still sounds like a very long time in many industries, but we are showing the primes in the aerospace industry what the future looks like. Moving to the larger TruPrint 5000 machine gave us the ability to qualify the new parameters for the machine and material simultaneously. In this way, AM allows us to be 'Agile' in name and practice," continued Kyle Metsger.



Using an integral pintle sleeve throttling mechanism, the engine is capable of deep throttling, providing a smooth ride and fine control for a variety of missions (Courtesy 6K Additive)

6K Additive's Ni625 powder is being certified for use at Agile's manufacturing facility (Courtesy 6k Additive)

Agile's A2200 engines will power a Lunar lander vehicle. Developed for high-performance on demanding missions, the A2200 engine provides a specific impulse of over 318 seconds. Its integral pintle sleeve throttling mechanism allows for deep throttling, ensuring precise control and a smooth ride for a range of missions. The engine can adjust thrust from 50 to 100% in under 650 milliseconds, making it ideal for the demanding manoeuvring sequences required for lunar missions.

Frank Roberts, president at 6K Additive, commented, "We are always excited to partner with customers like Agile who leverage our high-quality powders to produce critical rocket parts to land on the moon. The fact that we can enable space exploration while continuing to lead the way with sustainability at home on Earth is the best of both worlds. Agile has a cradle-to-grave mentality around its products, and having 6K Additive supply the company with high-quality, sustainably produced Ni625 and provide an established waste stream to help with its environmental stewardship speaks to our mission of going beyond expectations for our customers."

www.agilespaceindustries.com
www.6kinc.com

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Spherene announces Adaptive Density Minimal Surfaces tech in sphereneRHINO public beta

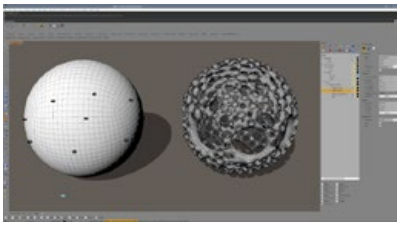
Spherene AG, based in Zurich, Switzerland, has announced the upcoming launch of sphereneRHINO Public Beta, a cloud-based plugin for the Rhino 7 design and 3D modelling software. Expected in Q3/4 2023, the plugin is the first integration of ADMS (Adaptive Density Minimal Surface) technology in the software, and looks to provide designers with the opportunity to experience a new kind of parametric structure firsthand.

The cloud-based solution will allow users to easily design parts while simultaneously specifying where to integrate ADMS, resulting in a significant reduction in design time and highly efficient parts for manufacturing.

"Integrating spherene's ADMS into my Pedorthic Information Modeling workflow was remarkably straightforward. This underlines the significance of interconnected computational design systems, driving my enthusiasm to explore further possibilities in my field," shared Daniel Petcu (@ PedorthicArt).

ADMS are a family of aperiodic minimal surfaces that can be configured to create versatile components with maximal strength and minimal material usage. The architecture enables users to control various complex structural features.

One use case of the ADMS algorithm is spherene's earlier design of a qualitative interpretation of a femur's intricate internal structure with the sphereneRHINO plugin, before building the part on a Rapidia Conflux 1 metal Additive Manufacturing machine.



sphereneRHINO Public Beta is a cloud-based plugin for the Rhino 7 design and 3D modelling software (Courtesy spherene AG)

ADMS components are efficient and adaptable to any enveloping geometry and multi-physics boundary conditions. They exhibit excellent heat exchanger characteristics, controllable elasticity, and can be made open-pored or closed.

www.spherene.ch

EOS Additive Minds and 3YOURMIND launch Rapid Part Identifier

EOS North America's Additive Minds team has partnered with 3YOURMIND, Berlin, Germany, to accelerate the adoption of Additive Manufacturing through the launch of Rapid Part Identifier software. Organisations can use the system for the screening of 2D and 3D files, enabling them to identify viable strategies for successful Additive Manufacturing production.

"We are providing a path for organisations to leave the whiteboard and Excel spreadsheet world by creating a faster, more professional approach to building a digital parts warehouse ready for AM production," shared Fabian Alefeld, senior manager, Additive Minds. "We partnered with 3YOURMIND to help unlock AM's potential by eliminating what historically required months of analysis, and quickly generate business cases for on-demand, highly-engineered applications."

Through this agreement, Additive Minds now utilises 3YOURMIND's software and its capacity to digitally optimise the part screening methodology across the entire AM value chain, including part identification, qualification, order management, and production scheduling.

The jointly developed Rapid Part Identifier software now enables faster part screening for customers, and provides end-users with a comparative digital inventory of uploaded and evaluated parts, enabling data-driven decision-making based on results. Ultimately, customers can achieve greater success in their AM programmes by scanning their existing inventories, identifying strong AM business cases, exploring practical AM applications, and making quicker decisions.

"EOS has always been a strong supporter of 3YOURMIND and our vision of streamlined, intuitive Additive Manufacturing workflows," Aleksander Ciszek, co-founder and CEO of 3YOURMIND, commented. "By collaborating with Additive Minds, we look forward to showcasing to EOS customers how simple additive manufacturing can be when it's backed by strong part business cases from day one."

www.na.eos.info | www.3yourmind.com

Organisations can use the system for the screening of 2D and 3D files, enabling them identify viable strategies for successful Additive Manufacturing production (Courtesy EOS/3YOURMIND)

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4WEB launches additively manufactured cervical spine plating solution

4WEB Medical, an orthopaedic implant company based in Frisco, Texas, USA, developing implants using its proprietary Truss Implant Technology™, has announced the full commercial launch of its Cervical Spine Plating Solution (CSTS-PS).

Geoff Bigos, Vice President of 4WEB's Spine Division, commented, "By adding the Cervical Spine Plating Solution to 4WEB's existing inter-body device offering, the company continues to demonstrate its commitment to investing in further development of a comprehensive cervical portfolio."

The Cervical Spine Truss System (CSTS) utilises an advanced structural design that incorporates 4WEB Medical's proprietary Truss Implant Technology. During normal loading conditions, the struts in the truss implant transfer strain to adjacent cellular material, which stimulates a mechanobiologic response.

In addition to launching the cervical plate, the company plans to expand its cervical product line in early Q4 with an integrated anchor fixation system and a stand-alone integrated plate. These products will complement the stand-alone cervical option that is currently available, providing surgeons with a variety of cervical fusion construct options.

"The launch of the Cervical Spine Plating Solution is a significant milestone for 4WEB. The company's cervical portfolio is currently 4WEB's fastest growing product line and with the addition of cervical plating, anchor fixation, and integrated plates, 4WEB will continue its rapid growth trajectory in 2023 and beyond," shared Jessee Hunt, president of 4WEB Medical.

www.4WEBMedical.com

4WEB has announced the commercial launch of its Cervical Spine Plating Solution (CSTS-PS) (Courtesy 4WEB Medical)

Atherton's metal AM bikes win gold and silver at World Championships

Atherton Bikes, a specialist bike producer that utilises metal Additive Manufacturing in its frame construction, has won both gold and silver medals at the UCI Downhill Mountain Bike World Championships (Elite) men's competition held in Fort William, Scotland.

Atherton Bikes is a specialist bike producer that utilises metal Additive Manufacturing in its frame production process (Courtesy Atherton Bikes)

Atherton Bikes celebrated both first and second place, with the UK's Charlie Hatton taking first place with a time of 4.26.74, and Austria's Andreas Kolb coming second, just +0.599 behind Hatton.

"To win the World Championships is unreal!," stated Hatton. "But to win in front of the home crowd, on a British-built bike designed by my friends on the team, with my training partner taking the silver… it just hasn't sunk in yet, I'm lost for words."

Hatton's bike, an AM.200, is custom built by Atherton Bikes at its facility in Machynlleth, Wales. The company has its own in-house metal Additive Manufacturing capability, with a Renishaw RenAM 500Q Laser Beam Powder Bed Fusion (PBF-LB) machine being used to produce the titanium nodes that are integral to the bike frame. The nodes are used to connect the carbon fibre tubing of the bike frame, and are joined using aerospace grade adhesives.

www.athertonbikes.com

JEOL installs JAM-5200EBM at Cumberland Additive

JEOL USA Inc, based in Peabody, Massachusetts, USA, has reported the installation of a JAM-5200EBM Electron Beam Powder Bed Fusion (PBF-EB) Additive Manufacturing machine at Cumberland Additive, located at the Neighborhood 91 advanced manufacturing production campus at Pittsburgh International Airport.

Prior to its arrival in North America, the JAM-5200EBM AM machine underwent an operational qualification at JEOL's manufacturing facility in Japan. The results of this qualification demonstrated that the machine meets the minimum requirements specified in AMS 7011 for PBF-EB machines. Once at the Cumberland facility, the machine was reported to be fully operational within six days.

Cumberland Additive CEO Dawne Hickton, stated, "This collaboration with JEOL signifies a new era in advanced Additive Manufacturing at Neighborhood 91. We look forward to harnessing the capabilities of the JAM-5200EBM E-Beam system and unlocking new possibilities in the world of materials science and 3D printing."

The JAM5200EBM machine at Cumberland Additive will initially focus on processing titanium alloy, although a second hopper and feeder system can be added to enable a seamless transition to produce components in pure copper and Nickel 718 alloy, for example.

"JEOL has been the leading supplier of electron-beam based imaging instruments and manufacturing tools for seventy-five years and has a well-established global customer service organisation. However, we are a relative newcomer to the Additive Manufacturing machine market," explained Robert Pohorenec, JEOL USA President.

A JAM-5200EBM machine has been installed at Cumberland Additive (Courtesy JEOL)

"The opportunity to collaborate with an Additive Manufacturing leader like Cumberland Additive in the Neighborhood 91 Additive Manufacturing campus provides us the perfect partner and location to introduce the JAM-5200EBM electron beam system in North America and to demonstrate our commitment to customer service."

www.jeolusa.com

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www.vdm-metals.com

ORNL receives six R&D 100 Research Awards for 2023

Researchers at the Department of Energy's Oak Ridge National Laboratory (ORNL), based in Oak Ridge, Tennessee, USA, have received six 2023 R&D 100 Awards. The winners of the renowned science and innovation competition were announced by R&D World magazine, whose judging panel comprised forty-five professionals from across the globe. Entries to the competition were received from fifteen different countries and regions.

"ORNL strives to deliver technological solutions for the nation's toughest problems," said interim ORNL Director Jeff Smith. "This year's R&D 100 Awards are a reminder of how hard our scientists and engineers work to accomplish that feat."

The winners at ORNL included a number of Additive Manufacturing processes, as well as other technologies. These included the following:

- Additively manufactured thermally conductive collimators for neutron instrumentation – ORNL and PolarOnyx
- OpeN-AM: A platform for operando neutron diffraction measurements of Additive Manufacturing – ORNL
- Physics-informed, active learning–driven autonomous microscopy for science discovery – ORNL
- Precise, continuous, & high-speed manufacturing of thermoplastic composites using Additive Manufacturing-Compression Molding (AM-CM) – ORNL
- SuperNeuro: An accelerated neuromorphic computing simulator – ORNL
- CANDLE (CANcer Distributed Learning Environment)

www.ornl.gov

Australian Strategic Materials appoints Chris Jordaan as Chief Operating Officer

Australian Strategic Materials (ASM), headquartered in West Perth, Australia, has appointed Chris Jordaan as Chief Operating Officer (COO), effective August 24, 2023.

Jordaan joined ASM with thirty-one years of experience in operational and corporate leadership roles in the petrochemical, processing, and mining industries in South Africa, Australia, and Papua New Guinea. Prior to accepting the role of COO, he was the President CEO of Superior Gold, a gold mining company listed on the Toronto Stock Exchange. He has also held senior leadership positions within Newcrest Mining, BHP, and several South Africa-based companies.

Australian Strategic Materials has appointed Chris Jordaan as Chief Operating Officer (Courtesy Australian Strategic Materials)

"With Stage 1 of our EPC Definition work for our Dubbo Project now complete, and early establishment activities for the project underway, Chris is joining us at a crucial and exciting time in ASM's operational development," shared Rowena Smith, ASM CEO and Managing Director. "Chris has a substantial depth of experience and the leadership qualities required to progress our Dubbo Project, lead the ramp-up of ASM's Korean Metals Plant and advance our metallisation technologies, particularly our innovative LK Process."

"His skills and experience are perfectly suited to further develop and execute ASM's mine to metals strategy," Smith concluded.

www.asm-au.com

MakerVerse obtains ISO 27001 certification for information security

MakerVerse, located in Berlin, Germany, has obtained ISO 27001:2017 certification for information security. This certification is a globally-recognised standard that outlines the requirements for establishing, implementing, and improving an information security management system (ISMS). The criteria for this certification heavily emphasise information security controls, data protection, and continuous improvement of the overall ISMS.

The certification process involved an in-depth evaluation of MakerVerse's ISMS, which covered the policies, procedures, and processes for safeguarding services and customer data. This process entailed a meticulous audit performed by TÜV SÜD to examine MakerVerse's security controls, for example its secure development practices, access controls, and cryptography.

"This recognition underscores our dedication to maintaining the highest data security and privacy standards," said Tim Schark, MakerVerse CFO. "It further emphasises our commitment to offering unparalleled services to our customers while ensuring robust security measures are in place."

MakerVerse, founded in 2022, provides over twelve manufacturing technologies, including Additive Manufacturing. The company also offers a comprehensive suite of production services, guiding customers through detailed manufacturing and quality plans. MakerVerse is also ISO 9001 certified for its quality management system.

www.makerverse.ai

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Build Volume:

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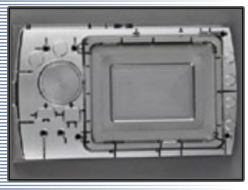
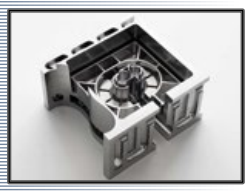
(D)250mm x (W)250mm x (H)300m *

(* Option)





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LUMEX Avance-60

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More information at www.lumex-matsuura.com

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matsuurausa.com

Element receives GKN Aerospace approval for testing of AM powders

Element, headquartered in London, UK, has received approval from GKN Aerospace Sweden AB to test metal powders at its Antwerp facility. The approval is seen as a significant milestone, and follows investment in a comprehensive suite of metallic testing services for Additive Manufacturing at Element's Antwerp and Teeside laboratories, in accordance with ISO/ASTM 52907 standards.

These laboratories are equipped with state-of-the-art technology and offer customers from various industries, including aerospace and medical devices, an extensive array of techniques and services for powder characterisation. These services encompass crucial aspects such as chemical composition, particle size distribution, morphology, contamination, flowability and characteristic densities.

Accurately determining powder properties is essential for quality assurance, as the quality of the powder significantly impacts the build process and the properties of the manufactured material. Element's investment in these services enables the laboratory to ensure compliance and adhere to specification limits in an effort to guarantee the quality of the final parts produced.

With the growing industrial application of Powder Bed Fusion (PBF), and Additive Manufacturing in general, Element reports its laboratories are witnessing an increasing percentage of work dedicated to this technology, transitioning from research and development to active production.

Matt Hopkinson, EVP of EMEAA at Element, shared, "We are thrilled to receive approval from GKN Aerospace Sweden AB, a respected leader in the aerospace industry. This milestone highlights our commitment to advancing Additive Manufacturing and our dedication to providing exceptional testing services."

"As 3D printing and Additive Manufacturing continue to expand across industries, our Antwerp and Teesside laboratories are well-positioned to meet the evolving needs of the industry and contribute to the success of our customers," Hopkinson continued.

Both laboratories offer comprehensive testing for products throughout their entire lifecycle, including pre-service, post-service, and manufacturing stages. Element Antwerp is accredited by BELAC (NEN-EN-ISO/IEC17025) as a testing laboratory, while Element Teesside is intended to serve as the European centre of excellence for Additive Manufacturing.

www.element.com

Nikon SLM Solutions acquires Adira AddCreative's large format AM technology

Nikon SLM Solutions is expanding its solutions portfolio to meet diverse customer needs for all applications, from standard to ultra-large-format Additive Manufacturing applications, through the acquisition of Adira AddCreative's technology. Based in Vila Nova de Gaia, Portugal, Adira AddCreative offers large format Laser Beam Powder Bed Fusion (PBF-LB) technology based on the Fraunhofer ILT moveable process head solution.

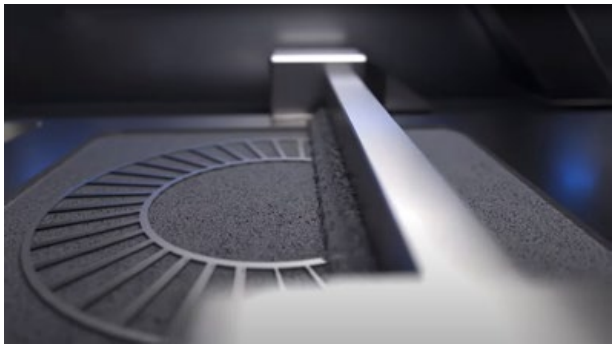
Capable of supporting up to twelve lasers and operating on a 1 x 1 m build platform, the technology is believed to perfectly fit into SLM's existing line-up, positioned between the NXG XII 600 family and the recently announced SLM-developed large-scale AM system.

Adira AddCreative's technology reportedly brings added flexibility, scalability, and cost-effectiveness, making it an attractive option for a variety of applications across industries such as aerospace, energy, and defence. "Integrating this advanced technology into our portfolio helps complete our offering, bridging the gap between our current systems and our future large-scale AM system," stated Sam O'Leary, CEO of Nikon SLM Solutions. "It is another testament to our relentless innovation aimed at overcoming our customers' manufacturing challenges and altering the manufacturing landscape forever."

Adira's AddCreative team in Vila Nova de Gaia has played a crucial role in developing the technology. It will now join Nikon SLM Solution's global team to continue the work on advancing Additive Manufacturing systems.

Miguel Gil Mata, Adira's Addcreative Chairman and CEO of its parent company, added, "I'm thrilled to see this innovative technology, in-house invented and nurtured from the very beginning by our team, being integrated into one of the leading players in the 3D printing landscape. This is the best recognition for the breakthroughs we have achieved, and an excellent opportunity for our team and product to further develop within SLM."

www.slm-solutions.com
addcreative.tech



Adira AddCreative large format PBF-LB technology is based on the Fraunhofer ILT moveable process head solution (Courtesy Adira AddCreative)

Brain4Industry Innovation Centre brings AM to Czech industry

The Brain4Industry Innovation Centre, led by the FZU – Institute of Physics of the Czech Academy of Sciences, has officially opened its new campus. Established with the strategic goal of supporting industry development in the Czech Republic, the new facility offers industrial metal and polymer Additive Manufacturing with Laser Beam Powder Bed Fusion (PBF-LB) machines from Farsoon Europe GmbH.

The Brain4Industry facility aims to bring together scientific research, design, and industrial manufacturing under one roof. It implements advanced manufacturing, digital transformation, and artificial intelligence at small and medium-sized companies. Supported by a team of experts in design, materials, application, manufacturing, and post-processing, the new facility will act as a comprehensive service for Additive Manufacturing, including product design, topology optimisation, mathematical simulations, and manufacturing. By utilising Additive Manufacturing, the Brain4Industry Centre aims to develop its position as a technology incubator in the region.

"The interest of the private sector in cooperation with scientists from the Institute of Physics is steadily growing, which has already led to a number of interesting results," stated Michael Prouza, Director of the Institute of Physics of the Czech Academy of Sciences. "Industrial cooperation gives a new dimension to the work of our scientists, with our research immediately serving the public interest. I am glad that the Brain4Industry Innovation Centre will significantly develop this line and help Czech companies to become more competitive and will thus support the entire Czech economy."

Eva Zažímalová, president of the Czech Academy of Sciences, added, "The scientists of the Czech Academy of Sciences frequently cooperate with the private sector, we have about 400 joint projects and direct contracts between institutes of the Czech Academy of Sciences and Czech companies. I am glad that the imaginary doors of further cooperation are opening with this newly-established innovation centre. For both science and industry, mutual contacts bring new perspectives and inspiration for research and development in the long term. Forward-thinking businesses and scientists across disciplines have long been aware of this."

www.brain4industry.cz
www.fzu.cz
www.farsoon.com

SPEE3D's Cold Spray AM to be installed at US Naval Postgraduate School

SPEE3D, headquartered in Melbourne, Australia, has partnered with CAMRE (Consortium for Additive Manufacturing Research and Education) at the Naval Postgraduate School, Monterey, California, USA, to bring its Cold Spray metal Additive Manufacturing technology to the Tri-State Maritime forces in the US, including the Navy, Marine Corps, and Coast Guard. The US Naval Postgraduate School's XSPEE3D metal AM machine will be utilised by military graduate students, PhD candidates, as well as research and development professionals.

CAMRE plans to leverage the XSPEE3D machine and its proprietary Cold Spray Additive Manufacturing (CSAM) technology to explore its role in Maintenance, Repair, and Operations (MRO) for ships, vessels (both surface and undersea), aircraft, and ground equipment. The technology will be tested and evaluated during contested military trials and exercises, both on the ground and onboard an amphibious warfare ship.

"The Naval Postgraduate School chose the XSPEE3D metal 3D printer because of its expeditionary nature that allows it to be contained inside a rugged and deployable metal container and deployed anywhere, including harsh field conditions. Uniquely, it runs on heated compressed air and does not require inert gasses or lasers, reducing risk to the operator. We were also impressed with its capabilities relating to build speeds and maximum part size and its lineup of current and future materials," shared Chris Curran, Program Manager for CAMRE.

This announcement follows the successful field trial of SPEE3D technology at the Marine Corps Annual Integrated Training Exercise (ITX) 4-23 where SPEE3D participated alongside CAMRE to deploy WarpSPEE3D in order to manufacture crucial parts that ere either broken or unavailable from ground support. SPEE3D was the only AM company invited to the exercise.

Warfighters and maintainers need technology that can quickly produce metal repair and replacement parts on-demand, minimising downtime and keeping them in the fight. XSPEE3D offers a containerised, ruggedised, and deployable Additive Manufacturing capability that can function in austere environments, even when exposed to the elements. While the WarpSPEE3D is not containerised, it is reportedly well-suited to shop or depot use and has been proven to be expeditionary capable in field trials with the Australian, US, and UK militaries.

"We're thrilled to partner with CAMRE to bring access to our CSAM technology that allows them to integrate efforts with our company further, as well as with NAVSEA and Penn State University's Applied Research Lab," added Chris Harris, SPEE3D Vice President of Defense, Americas.

www.spee3d.com

Trumpf highlights the advantages of 500 and 700 W lasers

The optimisation of laser power in Laser Beam Powder Bed Fusion (PBF-LB) Additive Manufacturing has become an increasingly critical consideration. Trumpf recently explained the case for increased laser power and how this can be leveraged to increase efficiency.

The company has expanded the lineup of its TruPrint Series 3000 to now offer both a 500 and 700 W laser across the series to better match the varying productivity needs of customers. The 700 W model is, the company states, able to reduce part build time by 1.4 X compared to the 500 W model, thus reducing cost per part, making it well suited to markets which face increasing demand for mass-produced products.

Roland Spiegelhalder, Additive Manufacturing Production Manager at Trumpf, stated, "This means less time per part. Output is increased by more than a third, and the cost per part is drastically reduced. In some cases, it is even better to use just one 700 watt machine than two with 500 watts each. This saves a lot of space and personnel."

This increase in power, however, can raise concerns about higher build temperatures and, thus, material compatibility. Nevertheless, Spiegelhalder, however, that all powders suitable for use with the 500 W laser machines are also suitable for the 700 W laser machine through 'downward compatability', which enables users to lessen the power levels as necessary. It was emphasised that this does not negate the use cases for the less expensive 500 W TruPrint3000 machines; if speed and higher power levels aren't of the utmost concern, the 500 W machines remain ideal.

"All powders used in 500 watt laser printers can also be processed in 700 watt machines without difficulty. Sometimes they can be processed even more productively: for example, materials such as aluminium cast alloy or high-strength titanium alloys. Furthermore, there are now powders on the market that cope particularly well with the high power levels and enable even faster build rates and better part quality than standard powders, for example, Equispheres' AlSi10Mg aluminium powder," he stated.

A safety-relevant component manufactured with the TruPrint 3000 (Courtesy Trumpf)

"You need to ask very basic questions when making an investment decision," Spiegelhalder explained. "Most importantly: What does the machine cost per part? But also: Is it possible that I will have to produce more parts in future than I am aware of at the moment? How variable does my production have to be? Am I at risk of losing orders due to a lack of speed?"

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America Makes announces largest ever funding with two project calls worth nearly $12M

The National Center for Defense Manufacturing and Machining (NCDMM), headquartered in Johnstown, Pennsylvania, USA, and America Makes, based in Youngstown, Ohio, have announced two new open project calls worth a total of $11.75 million. These projects are funded by the Office of the Under Secretary of Defense, Research and Engineering Manufacturing Technology Office (OSD (R&E)) and the Air Force Research Laboratory (AFRL).

This is the largest funding opportunity that America Makes has launched since its inception in 2012. Each project call has two areas of focus, and one award is anticipated for each topic area. The maximum funding request varies depending on the project topic.

The first project call, Powder Alloy Development for Additive Manufacturing (PADAM), is worth $6 million and is being funded by the AFRL. America Makes, its members, and government stakeholders have assessed the benefits and strategic opportunities offered through the development and scaling of novel Additive Manufacturing materials at the Alloy Development Workshop in 2021. This project call aims to accelerate the maturation of high-temperature metals for AM, in order to demonstrate measurable improvements in application-specific performance criteria.

The PADAM request for proposal (RFP) is separated into two topic areas:

- Topic 1: High-Temperature Refractory Alloys ($3.6 million)
- Topic 2: High-Temperature Nickel-Based Superalloys ($2.4 million)

"For the better part of a decade, the additive community has been advocating for funding to direct research and development to establish proven methods for applying the best attributes of novel AM materials. The materials that project partners will be working with are incredibly important to the future of the applications used in the aerospace and defence communities," shared Brandon Ribic, Technology Director at America Makes. "Our organisation is incredibly fortunate to have the support of the Under Secretary of Defense and AFRL and the engagement of the brightest minds in the country who will be collaborating to revolutionise this technology."

The second project call, Proliferation of AM Material Datasets, offers a total of $5.75 million in funding through OSD (R&E) and the AFRL. Recognising that there are additional material systems beyond Ti-6Al-4V that can benefit the AM industry, this project aims to increase the number and type of pedigreed, statistically-based, and industrially-relevant Additive Manufacturing material datasets. The RFP also encourages the growth of these learnings, practices, and data to a more expansive cross-section of the AM supply chain by requiring partnerships with small businesses.

The Proliferation of AM Material Datasets RFP is also separated into two topic areas:

- Topic 1: Aluminum Alloy Material Dataset ($2.875 million)
- Topic 2: High-Temperature Nick-Based Superalloys ($2.875 million)

"This project is a great opportunity for America Makes and our members to lay the foundation for groundbreaking development and incorporation of alloy-based refractory metals, which are extraordinarily resistant to heat and wear, into AM applications used in the aerospace, defence, and energy industries," stated John Martin, Additive Manufacturing Research Director at America Makes. "Additionally, data and best practices formulated and shared as a result of this project will help expand the AM supply chain through the inclusion of smaller businesses from across the country."

Proposers for the project calls are advised to reference the RFP for full details and guidelines.

www.ncdmm.org
www.americamakes.us

Aurora Labs receives ISO 9001:2015 certification for Quality Management System

Aurora Labs Limited (A3D), headquartered in Canning Vale, Australia, has announced ISO 9001:2015 certification for its Quality Management System. Aurora's Quality Management System was independently auditited by ECAAS Pty Ltd, and internationally recognised certification body. The scope of the certification covered provision of design, engineering and Additive Manufacturing of bespoke parts, which are key activities under Aurora's AM offering.

Peter Snowsill, CEO of A3D, stated, "This certification is a mandatory requirement for many of our partners, and we look forward to growing our AM Solutions business, leveraging our in-house developed metal 3D printing technologies."

Aurora 3D is developing a suite of technologies for its flagship Laser Beam Powder Bed Fusion (PBF-LB) machine: a high-power, multi-laser system that is set to be commercialised in 2023. The machine is designed, it is stated, to serve the market with a more affordable, industrial-grade, high-productivity, and high-accuracy solution that can compete with traditional metal manufacturing.

www.auroralabs3d.com

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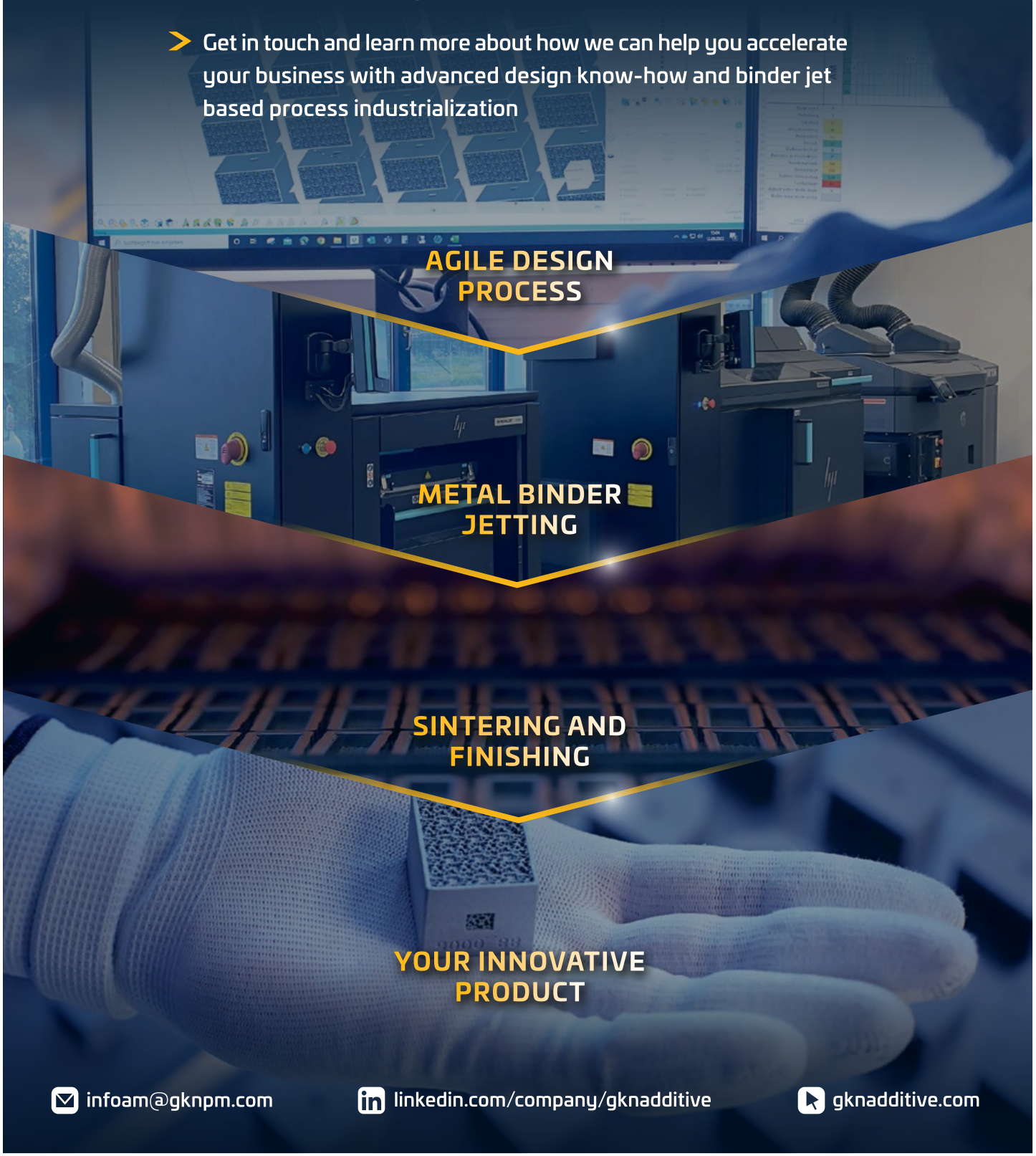

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Schoeller-Bleckmann Oilfield Technology adds Velo3D Sapphire XC

Velo3D, Inc, based in Campbell, California, USA, has announced that Schoeller-Bleckmann Oilfield Technology (SBOT), an Austrian provider of high-precision components for the oil & gas industry, has purchased a large-format Sapphire XC Laser Beam Powder Bed Fusion (PBF-LB) machine to expand its Additive Manufacturing capabilities.

The new Sapphire XC machine is calibrated to manufacture parts in Inconel 718 and looks to enhance production capabilities, delivering high-volume parts at a reduced cost. Furthermore, it supports the manufacturing of large-scale components up to 600 mm in diameter and 550 mm in height.

SBOT has expertise in manufacturing high-quality components for the oil & gas industry, including more than a decade of experience offering its customers Additive Manufacturing capabilities. In addition to its operations in Europe, SBOT's subsidiary, Knust-Godwin, operates a fleet of Velo3D machines in its Katy, Texas, facility. In November 2021, SBOT became the first Velo3D contract manufacturer in Europe with the purchase of a standard Sapphire machine calibrated to manufacture in Inconel 718. The addition of the Sapphire XC machine looks to enable SBOT to easily scale the production of parts previously additively manufactured and qualified on the Sapphire machine.

"Additive Manufacturing continues to see growing adoption and through Velo3D's Sapphire XC 3D printer, our team can scale up the production of parts for customers with the Sapphire XC's 400% throughput increase over the original Sapphire," said Campbell MacPherson, SBO EVP of Advanced Manufacturing. "It will also increase the addressable use-cases for metal Additive Manufacturing by unlocking the capability of producing larger parts, allowing us to maintain our position as a leader in the industry."

It is stated that the Sapphire XC machine will provide SBOT with the geometric design freedom to precisely and efficiently produce highly complex, mission-critical parts with a large build volume. The contract manufacturer also offers conventional manufacturing capabilities such as CNC milling and turning, heat treatment, material testing, and polishing. This aims to allow SBOT to deliver finished, ready-to-use parts to its customers.

Schoeller-Bleckmann Oilfield Technology has acquired a Sapphire XC (Courtesy Velo3D)

"We are thrilled to partner with SBOT and expand our presence in Europe with our first Sapphire XC installation at a contract manufacturer," shared Benny Buller, founder and CEO of Velo3D. "SBOT's commitment to delivering high-quality components aligns perfectly with our mission to enable manufacturers to unlock the full potential of their products through Additive Manufacturing. We are confident the Sapphire XC's advanced capabilities will empower SBOT to achieve new heights of innovation and excellence in their manufacturing processes."

www.velo3d.com
www.sbo.at

Shapeways launches MFG Materials to provide discounted raw materials to manufacturers

Astro Mechanical Testing Laboratory, headquartered in Los Angeles, California, USA, has selected NSL Analytical Services, Inc, Cleveland, Ohio, to be its collaborative outsourcing partner for chemical composition, trace analysis and metal powder characterisation testing. NSL Analytical Services was reportedly chosen because its metals chemicals experience and turnaround time aligns with Astro's mission to streamline the qualification, validation and certification process for its Additive Manufacturing customers.

Astro provides certified testing and qualification services to aerospace primes and advanced space companies, streamlining the process for products in space flight hardware, rockets and satellites. NSL Analytical is an independent commercial materials testing business, maintaining several quality approvals across multiple industries. It is said that both companies look forward to a partnership that provides the very best in advanced testing services for the Additive Manufacturing industry.

"We are excited to have NSL as part of our one-stop shop for additive testing. NSL is key in allowing us to cover the entire gamut of testing and analytical capabilities, which will hugely benefit our additive customers," shared Humna Khan, CEO and founder of Astro.

www.nslanalytical.com
www.astrotestlab.com

Laser Additive Solutions adds TruPrint 3000 as it targets UK space sector

Laser Additive Solutions Ltd (LAS), a provider of laser processing and Additive Manufacturing services based in Doncaster, UK, is targeting customers in the UK's rapidly growing space sector, following its purchase of a TruPrint 3000 metal AM machine from Trumpf, headquartered in Ditzingen, Germany.

Established in 2015, the team at LAS has over fifty years of combined experience in precision laser repair, manufacture and joining processes. Customers include those operating in the general engineering, fusion energy, aerospace and military sectors, among others. The company is ISO9001-accredited and is reported to have close ties with a number of UK universities and research organisations.

"Our core expertise is LMD [laser metal deposition], although like most in the industry we're now referring to this process as laser DED [direct energy deposition]," Managing Director, Peter Brown, explained. "We have two very good systems that undertake laser DED, both of which use Trumpf lasers. While these machines can support our steady growth moving forward, to drive faster progress I felt we needed a complementary process, hence our interest in a powder-bed machine."

The UK space sector

"Our number one target for the TruPrint 3000 is the UK's space sector," stated Brown. "The space sector is constantly seeking manufacturing solutions for lightweight structures that are not easy to build with other technologies."

High-strength aluminium is a crucial material for many of these lightweight structures. Fortunately, the TruPrint 3000 is already configured to use this material.

"We'll continue with this material initially, maybe introducing others at a later date," Brown added. "The TruPrint 3000 is the start of a journey for us, but we don't expect it to be vastly different to how we work with our laser DED systems. We're familiar with developing machine parameters for new components, performing trials and experimenting with different build techniques. We can also assist with design suggestions to suit additive manufacture and help minimise costs for customers."

LAS has experienced robust business growth, which today occupies three industrial units. The company is currently bidding for its biggest ever contract valued at over £1 million. "If we win, we'll invest in another laser DED system and hire more people," Brown concluded.

www.laseradditivesolutions.co.uk
www.trumpf.com

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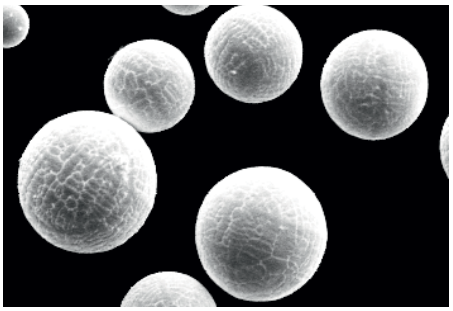

Fig.1 PtRh spherical powder

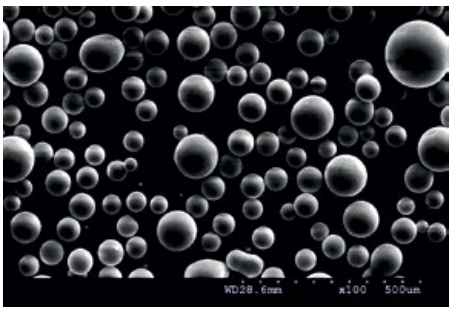

Fig. 2 MgLi custom alloy powder

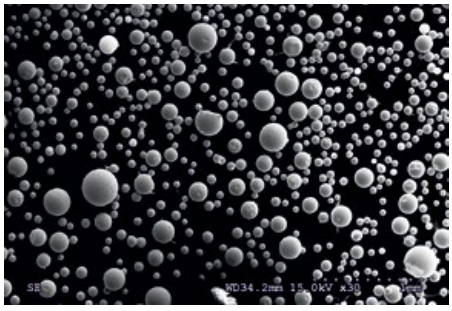

Fig.3 Zr-based metallic glass

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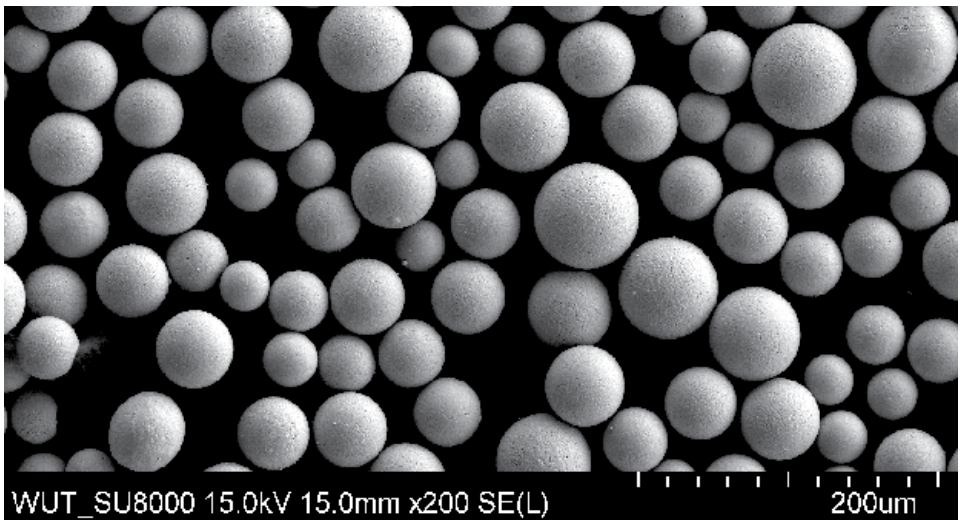

Fig.4 C103 alloy powder - aerospace and defense propulsion application

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Panerai and Brabus unveil PBF-LB titanium watch

Panerai, a luxury watch brand headquartered in Geneva, Switzerland, has unveiled its latest timepiece, the Submersible S Brabus eTitanio PAM01403. This watch features an additively manufactured watch case, produced as part of the company's partnership with Brabus, a German luxury engineering group specialising in high-performance vehicles. This collaboration is said to illustrate the growing trend of luxury brands incorporating Additive Manufacturing into their production processes.

The watch features a 47 mm case that was additively manufactured using Laser Beam Powder Bed Fusion (PBF-LB). It was made from eTitanio, a 100% recycled titanium powder derived from pre-consumer titanium alloy scrap. The PBF-LB process ensures a lighter structure, with the watch case weighing just 23.6 g – 30% lighter than a standard titanium case.

"When we speak about partnership, it's not just about a logo; it extends to the highest levels and smallest details. We offer each other complementary skill sets and synergies in terms of products, sales and key markets. The ideas, materials and technologies of our brands will be a vehicle for developing concepts that are both disruptive and spectacular. All of these elements will come together to create results and added value to the benefit of our clients, in terms of service, retail concepts and calibers," shared Jean-Marc Pontroué, CEO, Panerai.

Brabus CEO, Constantin Buschmann, added, "When put side by side, the similarities in regard to

The Submersible S Brabus eTitanio PAM01403 features an AM case (Courtesy Panerai)

design language and overall character of the Panerai Submersible and the Brabus Marine line of dayboats are obvious and striking. Both are made to be functional and stylish tools for life in the marine environment and therefore this combination just makes sense."

www.panerai.com
www.brabus.com

AddUp approves Constellium's Aheadd CP1 alloy for high-performance aluminium applications

AddUp Inc, headquartered in Cébazat, France, has approved Constellium's Aheadd CP1 alloy for use in its AddUp FormUp® 350. This aluminium alloy was developed specifically for high-performance and lightweight applications in Additive Manufacturing using Laser Beam Powder Bed Fusion (PBF-LB).

The Aheadd CP alloy serves as an alternative to traditional grades such as AS7 and AS10 (alloys of aluminium, silicon and magnesium, originally created for the foundry industry). Constellium, headquartered in Baltimore, Maryland, USA, provides an aluminium-iron-zirconium alloy that is said to offer better solderability, allowing for increased laser power and scan speed, resulting in improved productivity.

"To obtain the best mechanical properties using AS7 and AS10 grades, several long and expensive post-build treatments must be carried out, such as Hot Isostatic Pressing and, solution and ageing etc," explained Frédéric Sar, Materials Officer at AddUp. "With Aheadd CP1, very similar material properties can be achieved with a simple heat treatment at 400°C."

Saving time and money on post-build operations, which represent up to 40-50% of the cost of PBF-LB parts, can significantly improve the profitability of an application.

The mechanical properties of parts manufactured by AddUp using Aheadd CP1 (particle size 20-63 µm) are similar to those of AS7 in terms of hardness. They are at least equal in fatigue resistance and higher in ductility. Additionally, these parts can be subjected to anodising treatments to enhance their corrosion resistance.

The higher thermal conductivity of Aheadd CP1 compared to traditional aluminium alloys makes Constellium's alloy a more suitable candidate for all heat exchanger applications. This alloy remains stable up to 250°C without degrading its microstructure. Thus, parts made from this material can withstand higher temperatures than those made from AS7, paving the way for lightweight applications in the aerospace industry.

All of these characteristics make Aheadd CP1 a potential alternative for AS7 and AS10 alloys for Additive Manufacturing. The material was recently approved in the field of motorsports. Combining this material with the performance of the AddUp FormUp 350 machine increases productivity without compromising part quality. This material could quickly gain significant interest in many other industrial sectors, including aeronautics and aerospace.

www.addupsolutions.com
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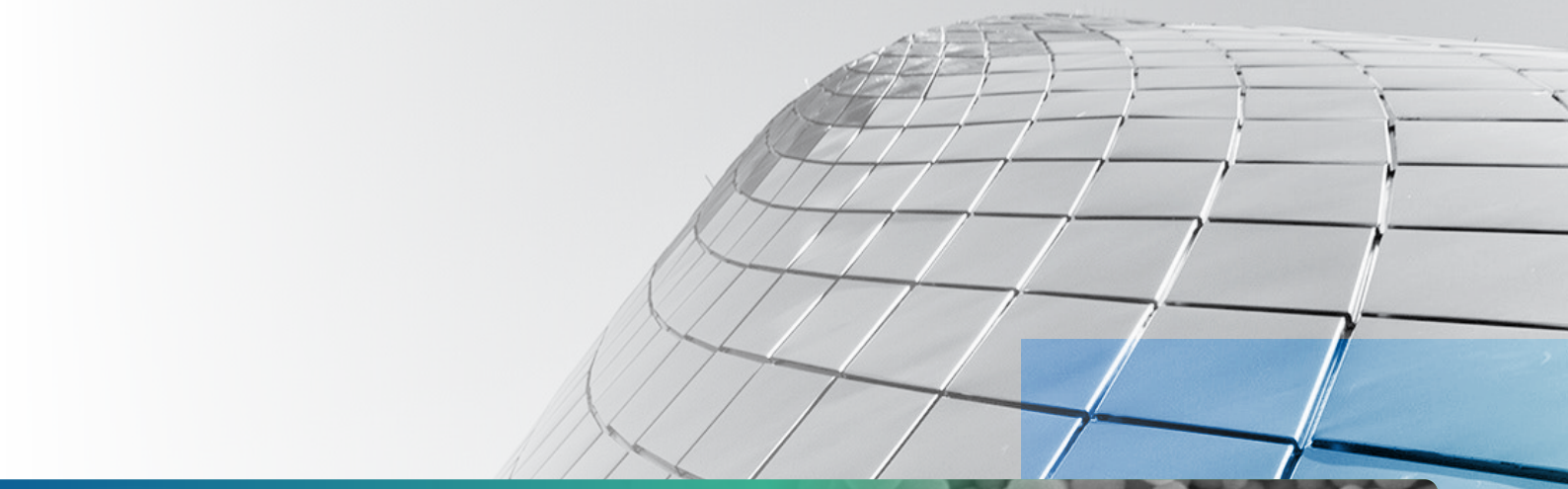

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Pulsed electrochemical machining for post-processing metal AM parts

Voxel Innovations, based in Raleigh, North Carolina, USA, is an advanced manufacturing company specialising in the use of pulsed electrochemical machining (PECM). The company is recognising a growing opportunity for PECM in the Additive Manufacturing sector, being well suited for materials that are difficult to machine using conventional methods, such as superalloys.

The exponential growth of Additive Manufacturing technology has provided unique advantages to manufacturers, such as reducing manufacturing costs associated with consolidating operations/eliminating complex assemblies, as well as reducing material waste in comparison to conventional subtractive manufacturing, explains Voxel. Furthermore, the advent of metal AM has allowed rapid prototyping and faster design iteration of a wide range of metal parts, including some critical components. However, as part volumes grow as a result of increased demand for AM, minor limitations of the technology are exacerbated.

For example, when considering both design and material requirements of parts within critical applications (environments with high temperature flux, or extreme stress), certain tolerances and features may not be achievable with AM by itself. High-volume demand of these AM parts incentivises companies to find innovative ways to reduce manufacturing expenses – sometimes even at the cost of quality. To lower costs, additive manufacturers are sacrificing surface finish, resolution, and feature size to improve production capabilities by using faster laser scan strategies, larger powders, thicker layer lines, and more. Ultimately, this has created a need in the AM industry for affordable, repeatable postprocessing methods for metal parts.

Before-and-after photo of PECM as both a finishing and a secondary machining operation for an additive turbine part (Courtesy Voxel Innovations)

Metal AM companies are seeking a secondary machining/post-processing operation that can attain higher resolution and surface quality whilst reducing production costs in high volumes, adds Voxel. Here, PECM can provide superfinished surfaces, small features, and high repeatability on metal AM parts.

How PECM works

PECM is a non-contact, non-thermal material removal process capable of machining superfinished surfaces and unique geometries on high-volume metal parts and, alternatively, can act as a secondary machining – or post-processing operation.

Rather than utilising friction or heat, PECM uses electrochemistry to dissolve the workpiece material into the desired shape. A charged electrolytic fluid is flushed within a microscopic gap between the tool (cathode) and workpiece (anode), dissolving the workpiece material at a rate proportional to its proximity to the cathode.

The process is best understood by learning four key terms:

- **Cathode:** The cathode, or tool, is a custom-machined part that is shaped as the inverse of the desired geometry on the workpiece;
- **Anode:** The anode, or the workpiece, must be a conductive material, meaning PECM cannot machine plastics or polymers. The anode can take on many forms, such as an AM part, a near-net shape, or even wrought stock;

PECM's finishing capabilities on Inconel 738 (Voxel Innovations)

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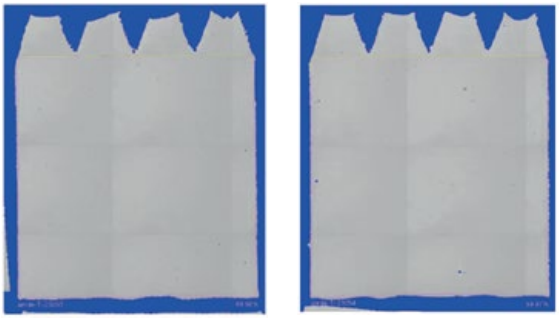

Density	SPL_1[23053]	SPL_2[23054]	SPL_3[23055]	SPL_4[23056]	AVG	DOM [≥99.90%]
	99.98%	99.97%	99.98%	99.97%	99.98%	OK

TC4

Note: The information is provided by a third party medical customer.
Test results might subject to test methods. Please contact us for further information.

Chemical Composition		O	N	H	C	Fe	Al	V	D10	D50	D90	Density
Receiving Standard	<	0.1	0.03	0.008	0.08	0.25	5.5~6.5	3.5~4.5	22~32	34~44	49~61	/
JSJW	Powder	0.08	0.003	0.003	0.02	0.15	5.8	4.2	24.2	36.6	55.6	2.46
	Parts	0.14	0.04	0.001	0.02	0.15	5.87	4.3				
A Foreign Brand	Powder	0.082	0.006	0.002	0.02	0.17	6.05	3.778	24.5	36.9	54.6	2.28
	Parts	0.11	0.034	0.0013	0.032	0.18	5.92	3.92				

Typical Mechanical Properties	Tensile Strength (Mpa)	Yield Strength (Mpa)	Elongation (%)	Reduction of Area (%)	Density (g/cm³)	Hardness (HV10)
≥	895	825	10	25	4.40	/
JSJW	1072	1010	16.2	48.8	4.52	355
A Foreign Brand	1080	1033	17.1	37.4	4.51	/

Finished Fusion Mechanical Properties	Stiffness/MPa	Yield Load/MPa	Max Load/MPa
JSJW	79045	37098	45099
A Foreign Brand	66958	28952	35887

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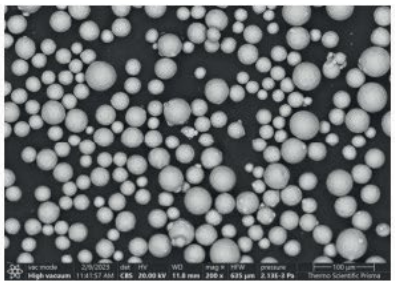

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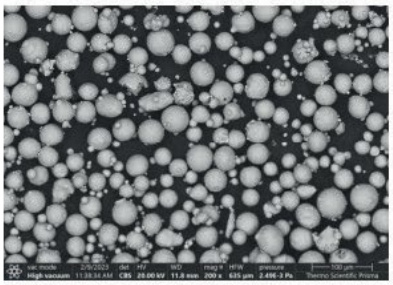

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PECM machining and finishing bars of Inconel 718 (Courtesy Voxel Innovations)

- **Electrolytic Fluid:** The electrolytic fluid performs two vital roles simultaneously. The fluid is both the conductor for the electrochemical reaction itself and is the flushing agent that removes the waste product from the workpiece area;
- **Inter-electrode gap:** The microscopic gap between the tool and workpiece where the fluid runs is a crucial variable that helps determine the precision of the process; as this gap shrinks, PECM's precision capabilities improves. Currently, this gap can be as small as 10-100 um Ra (.0004-.004 in)

PECM is said to be capable of high repeatability due to its significantly reduced tool wear; there is no heat or contact in the process. Furthermore, as PECM is only concerned with the conductivity of a given part (rather than its material hardness) it can machine tough alloys like Inconel at a similar rate to copper or aluminium.

The process is primarily used to machine critical aerospace and medical device components, including Inconel heat exchangers, nitinol bone fixtures, molybdenum X-ray components, and turbine blades. However, another crucial application of PECM is for post-processing additively manufactured parts.

PECM as a secondary machining process

For most applications, the average wall thickness, resolution, and surface quality produced by Additive Manufacturing wouldn't significantly affect the part's fit, form, or function. However, within critical environments that require parts, have increased fatigue resistance, surface quality, and tolerances, AM alone cannot produce ideal parts directly from the AM machine. To improve these features, AM generally requires a secondary machining process for critical applications.

For example, most metal AM processes can only achieve a minimum wall thickness of around 0.3-0.5 mm without a secondary process. However, a dedicated PECM tool can reduce that wall thickness down to less than 50 um (<0.05 mm). As there is no heat-affected zone or tool vibration in PECM, it can machine areas of a part otherwise very sensitive to heat or tool vibration – including ultra-thin walls. PECM could subsequently repeat these features hundreds, or even thousands, of times without tool wear.

Consider an additive nickel alloy turbine blade. Without a secondary process, the extra blade thickness, resolution, and surface quality (especially on downskin surfaces) would impact the blade's functionality, aerodynamic performance, and susceptibility to corrosion and microcracks.

PECM should be considered as a viable secondary machining process on similar parts; by creating thinner trailing edges on turbine blades and vastly improving its surface quality, PECM could potentially improve the performance, durability, and safety of additive turbine blades. PECM could also complement lower-resolution, higher-volume metal-AM operations.

PECM as a surface finishing method

Surface abnormalities inherent to AM can cause significant problems for critical parts (e.g. introducing microcracks on aerospace parts or diminishing the sterility of medical devices) continues Voxel. These surface irregularities can take on many forms including support structure remnants, layer lines, lower resolution on downskin surfaces, and re-melted material. Each of these issues directly impact a given part's functionality, corrosion resistance, sterility, and lifespan.

PECM, however, is capable of machining and finishing AM parts simultaneously. According to data from Voxel Innovations, PECM reduced the surface quality of metal AM parts from 5-10 µm (196-393 µin) Ra to >0.5 µm (19.6 µin) and even 0.1 µm (3.9 µin) Ra. This operation was relatively quick compared to more conventional methods, such as CNC milling, and is highly repeatable, able to create identical superfinished features in hundreds, or thousands, of parts without incurring tool wear.

In summary, PECM's secondary machining and post-processing capabilities for metal additive parts provide a variety of unique advantages additive manufacturers should consider. These advantages include, but are not limited to, the ability to machine thin-walled or thermally sensitive areas, remove a variety of surface irregularities, and, crucially, the ability to repeat these features hundreds or thousands of times on tough materials without incurring tool replacement costs.

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ONE STEP AHEAD.

Canada funds Additive Manufacturing technology (AAMTECH) prototyping hub as part of $20.8M investment

PacifiCan is the Government of Canada's new economic development agency, dedicated to promoting growth and diversification in British Columbia's economy. Its mission is to enhance innovation, improve business competitiveness, and promote inclusive growth. As part of this mission, Harjit S Sajjan, Minister of Emergency Preparedness and Minister responsible for the Pacific Economic Development Agency of Canada (PacifiCan) and Terry Beech, Minister of Citizens' Services, have announced funding of over $20.8 million to seven Burnaby-based businesses and organisations in the life sciences, manufacturing, and technology sectors. This funding looks to help the recipients commercialise new products, acquire advanced technologies, and increase sales.

Minister Sajjan shared, "Across British Columbia, organisations and businesses are working hard to propel BC forward. PacifiCan is supporting these innovators to reach their goals to expand to new markets, create jobs, and even access new technologies like 3D printing. PacifiCan is proud to be a partner in helping Burnaby build a thriving, inclusive economy, one that leverages the diverse skills of these talented entrepreneurs and others throughout BC."

Ministers Sajjan and Beech announced the funding at the Centre for Applied Research and Innovation at the British Columbia Institute of Technology (BCIT). While at BCIT, the ministers also announced over $1.9 million in support for the establishment of AAMTECH, an advanced Additive Manufacturing prototyping hub. This funding is intended to address the financial barrier faced by many businesses seeking to develop and commercialise new concepts.

The project aims to provide small- and medium-sized enterprises in the local area with access to state-of-the-art technology and expertise. This will enable them to build prototypes using advanced Additive Manufacturing technology, with a wide variety of materials including advanced composites, metals, foods, and bio-manufacturing. The hub will support approximately sixty businesses, help bring ninety products or services to market, and provide training opportunities.

"Today's announcement furthers the important work of the BCIT Centre for Applied Research and Innovation – creating practical learning opportunities for BCIT students, while providing practical solutions to industry challenges. With the PacifiCan funding for the new Advanced Additive Manufacturing Technology (AAMTECH) 3D Printing Hub, BCIT continues to grow our breadth of support across multiple manufacturing sectors including metals, composites, foods, and bio-manufacturing. Businesses, organisations, and BCIT researchers and students now have a truly state-of-the-art space to build innovation in the 3D printing arena," added, Dr Jeff Zabudsky, president, BCIT.

This funding is being provided through three PacifiCan programmes: the Regional Innovation Ecosystems program, Business Scale-up and Productivity programme, and the Jobs and Growth Fund. These programmes support advanced manufacturing, digital technology, clean technology, and business growth.

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KEY FEATURES

- Options for CMT / STT / Laser technology DED head
- 150 Nm machining head to perform both additive and subtractive operations
- Eight axis capability enables to 3D print complex shapes
- 3D Print large parts (1 m+) and machining
- Ability to process Stainless Steel, Nickle base alloys, Tool Steel and many more..
- Customization options for Metal Powder or Wire feed stock.
- Close loop process control
- In build process camera

KEY FEATURES

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- Close loop process control
- In line process camera
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Metal AM in the aerospace sector: from early successes to the transformation of an industry

Across the world, a new wave of aerospace engineers are designing and building the next generation of aero engines and systems around the revolutionary capabilities of Additive Manufacturing. Twenty years ago this was a vision, but today it is a reality. From fuel nozzles to Stage 5 and Stage 6 low pressure turbine (LPT) blades, housings to structural elements, in this article *Metal AM* magazine's Technical Consultant Martin McMahon reviews the progress that has been made, shining a light on selected applications that offer insight to those in the aerospace industry who want to get up to speed with progress.

Cast your mind back twenty years and imagine a list of all the companies capable of producing parts for the aerospace sector using Additive Manufacturing. That list would not be very long at all. However, there are now suppliers on every continent and entire programmes where Additive Manufacturing is at the heart of innovation and development – as well as being responsible for keeping ageing fleets airborne. Although, in reality, metal Additive Manufacturing has been in development for a considerable amount of time, it is only in the past two decades that it has made headway as a groundbreaking technology. This development has transformed the aerospace sector's ability to produce lightweight, intricate and high-performing parts in ways that were not previously deemed possible.

The ability to create complex geometries with the internal features required for cooling effects and to reduce weight through newly optimised designs has started to enable improved efficiency and enhanced performance in numerous areas of aircraft and satellite technology. This now ranges from engine components to structural assemblies in safety-critical applications. In the past three to five years, the industry has experienced a huge increase in the number of use cases where AM parts have been designed to replace conventionally manufactured parts.

Following a truly rapid expansion of the adoption of AM technologies, the sector is starting to report on lower costs, faster lead times, and, in the new era of digital manufacturing, vast improvements in flexible design and development methods based on simulation and generative algorithms. With this use of metal AM, the avia-

Fig. 1 The GE9X turbofan is the ultimate demonstration of the capabilities of AM, containing more than 300 metal additively manufactured parts. The engine has been selected by Boeing for its 777X airliner (Courtesy GE Aerospace)

Fig. 2 GE Aerospace's LEAP fuel nozzle, produced for the CFM International LEAP 1A and 1B engines. Each engine uses 18 or 19 additively manufactured fuel nozzles, depending on the specific engine model. The engines are used on the Airbus A220, A320neo, A321neo, Boeing 737 MAX and COMAC C919 airliners. In 2021, it was reported that the parts have achieved over 10 million flight hours and more than 100,000 nozzles had been manufactured (Courtesy GE Aerospace)

tion sector anticipates reporting on lower levels of CO_2 emissions, both in manufacturing processes and end use through lower fuel consumption, and views attractive pathways for greater sustainability. GE Aerospace's LEAP fuel nozzle (Fig. 2), which will be covered here in greater detail, can be regarded as the first high-volume application to prove these claims true.

All this has not happened overnight, and the aerospace industry's steady adoption of 'disruptive' metal AM processes, such as Powder Bed Fusion (PBF), Directed Energy Deposition (DED), and Binder Jetting (BJT), has paved the way for unprecedented innovation in part design and alloy development. The world has already witnessed the first tentative steps by the major OEMs and Tier 1 suppliers. In this article, we explore the remarkable successes achieved through these technologies, highlighting key examples such as turbine blades in engines and complex communication devices in satellites. No mean feat given the deep insecurities that exist within the sector, and the armour-like protection placed around any new use of AM. This in itself is very puzzling, even to many that work with the sector, or are part of the AM value chain.

We won't dwell on explanations for each of the AM processes that are mentioned as there is an abundance of information elsewhere. Similarly, even though there are now many new alloys that have been developed for the purpose of AM in the aerospace sector, there is insufficient space to include detail about these here. In fact, there is sparse information in the public domain to support this. Instead, the ability of metal AM to deliver mass produced airworthy parts is brought into focus through a review of those parts that are already approved and in use today. We will also broadly limit our scope to aircraft applications, with the rapid growth of AM for space applications being regularly featured on the pages of *Metal AM* magazine.

Laser and Electron Beam Powder Bed Fusion: the technologies that led the revolution

Laser Beam Powder Bed Fusion (PBF-LB) and Electron Beam Powder Bed Fusion (PBF-EB) are the dominant metal AM technologies used in the aerospace sector. Very simply, the process takes advantage of the ease to rapidly scan a 2D image with a laser or electron beam to selectively melt metal powder one layer at a time from a 3D CAD model.

Parts produced this way are nominally fully dense and most undergo significant post-process finishing operations and the most rigorous quality checks. Hence, it is PBF processes that have caused the greatest revolution in aerospace manufacturing over the past twenty years. This group of technologies, for which there is an ever-growing number of machine suppliers across the world, has truly enabled the production of more complex geometries, and lightweight structures, whilst improving component performance – all at lower overall production costs. Chief amongst the successes has been the ability to eliminate complex assembly and joining techniques by combining multiple parts into a single part design.

Fig. 3 This warm air mixer from Northrop Grumman, built using PBF-EB technology, dates back to 2007 (Courtesy Northrop Grumman)

Northrop Grumman's early success

Before looking in detail at more recent examples of flying, or soon to be flying, parts, it is worth acknowledging the earliest PBF parts to have been qualified and flown. That honour would appear to go to Northrop Grumman, known for its work in solving the toughest problems in aerospace and defence using advanced technologies that now regularly include Additive Manufacturing. Tayelor McKay, Principal Additive Manufacturing Systems Engineer, stated, "As pioneers of advanced manufacturing capabilities, we have more than twenty years of experience with Additive Manufacturing of metallics. Northrop Grumman has taken advantage of AM's many benefits, such as increased design flexibility, consolidated parts, improved performance, and has been able to reduce cost by up to 70% and reduced lead time up to 90%."

It is quite difficult to find many other stories that date back before 2010, and Northrop Grumman reported that it performed its first flightworthy validation in 1999 using a laser/powder DED process, and then went on to establish its first flightworthy PBF-EB Ti-6Al-4V component in 2007; a warm air mixer used on a US Navy X-47B Unmanned Combat Air System (Fig. 3).

"This group of technologies, for which there is an ever-growing number of machine suppliers across the world, has truly enabled the production of more complex geometries, and lightweight structures, whilst improving component performance – all at lower overall production costs."

McKay explained how Northrop Grumman went on to produce what is believed to be the first PBF titanium aircraft component to have been used in real flight, when it supplied four parts for the X-47B which successfully launched off a US Navy carrier in 2011. What is clear from Fig. 3 is that it was already known and accepted that AM parts could exist with relatively rough non-machined surfaces, post-process machining surfaces just where they are required.

The fact that this last point may seem logical to many, in much the same way as it is for a huge variety of castings, remains a hurdle more than fifteen years later. Amongst the growing number of companies in the aerospace sector that are new to AM technology, and who are still only starting to investigate the possibilities of series production, the issue of surface roughness is still a common question. For many decision makers, this remains a source of doubt about the efficacy of metal AM parts. It is suspected here that the reason lies in the availability of published use cases of metal AM in aerospace. Hence, we hope that this highlighting of just one of many success stories, in which metal AM parts have seen service for much more than a decade, reduces concerns: X-47B parts really account for a significant number of flight hours.

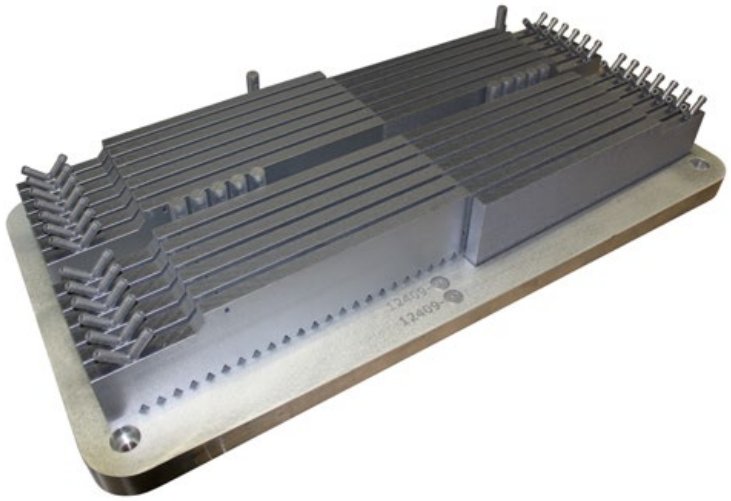


Fig. 4 AlSi10Mg PBF-LB parts prior to removal from the build plate (Courtesy Northrop Grumman)

> *"In a testament to how metal AM has changed the product design cycle, Northrop Grumman completed drawings for this part in January 2022 and delivered functional hardware by August 2022."*

In the years that followed this first qualification of PBF-EB Ti-6Al-4V, Northrop Grumman has gone on to certify numerous components on several air and space programmes, with one of the most recent being a sensor coldplate used in its Mission Systems Sector and produced in AlSi10Mg via PBF-LB (Fig. 4). Caleb Martin, a Mechanical Design Engineer, remarked, "The agility made possible by AM allowed us to design, iterate, and deliver coldplates in a quarter of the time of traditional manufacturing."

In a testament to how metal AM has changed the product design cycle, Northrop Grumman completed drawings for this part in January 2022 and delivered functional hardware by August 2022. It has since delivered sixteen of these complex parts that are assembled into multi-function apertures which consolidate multiple functional parts into a single sensor, decreasing both the number of apertures needed and the size, weight, and power requirements that are normally associated with such advanced capabilities.

It is clear how metal AM has enabled Northrop Grumman to quickly leverage technology developed for other programs and adapt them to multiple capabilities, such as in Electronically-Scanned Multifunction Reconfigurable Integrated Sensors (EMRIS). These critical devices are used to perform functions in radar, electronic warfare, and communications simultaneously. It is perhaps the first company to adopt and integrate metal AM into product lifecycles, and continues to develop metal AM further on various platforms.

GE: The fuel nozzle and beyond

Of course, in that period of twenty years, Northrop Grumman wasn't alone in developing metal AM, and everyone is by now familiar with the widely publicised fuel nozzle produced by GE Aerospace for CFM International in the LEAP 1A and 1B engines. Each of these engines, now popular on several single-aisle aircraft, uses eighteen or nineteen additively manufactured fuel nozzles, depending on the specific engine model.

CFM International, a joint venture between GE Aerospace of the USA and Safran of France, has stated that its additively manufactured fuel nozzles are up to five times more durable than the previous designs, which has been attributed to the way in which Additive Manufacturing technology has allowed them to create a simpler design with a reduced number parts in the nozzle, vastly reducing the amount of brazing and welding required in the finished assembly.

GE Aerospace took on the responsibility for the production of this fuel nozzle, made using PBF-LB and a cobalt-chrome alloy, at its Auburn, Alabama, site, which began full scale production in 2015. In the following year it entered into revenue service and now it is used on the Airbus A220, A320neo, A321neo, Boeing 737 MAX and COMAC C919 airliners. The airline operators are reportedly experiencing 15% better fuel efficiency than previous generation engines, lowering the overall environmental impact of commercial flights.

During the summer of 2021, the partnership announced that the metal AM parts had achieved 10 million flight hours and that the Auburn site had produced it's 100,000th metal

Fig. 5 The final assembly of LEAP engines at Safran's Villaroche, France, location. The GE Aerospace metal AM fuel nozzles used in the engines contribute to a reported 15% better fuel efficiency than previous generation engines, lowering the overall environmental impact of commercial flights (Courtesy Adrien Daste/Safran)

AM fuel nozzle. It is by no means an exaggeration that this does indeed herald the first mass production of aerospace parts using metal AM technology. With an output of several hundred parts per week since 2019, and taking into account the reduced part count into a single piece part, it is very strong evidence that metal AM has been accepted as an economically viable production method.

GE Aerospace has also been on several other development journeys using metal AM and now produces more than 300 metal additively manufactured components for the GE9X turbofan, which was selected for use by Boeing for its 777X airliner (Fig. 6). This latest generation of aircraft engines include AM parts that have evolved to combine multiple components into single designed units, such as the fuel nozzles, heat exchangers, sensor housings, combustor mixer, and inducer, as well as being used to produce large critical parts like the Stage 5 and Stage 6 low pressure turbine (LPT) blades.

These unique blades are made from titanium aluminide, chosen for its exceptional high temperature performance, and have been produced by Avio Aero (acquired by GE in August 2013) at its plant in Cameri, Novara, Italy, since 2014. Using PBF-EB, to date Avio Aero has produced all the LPT blades that

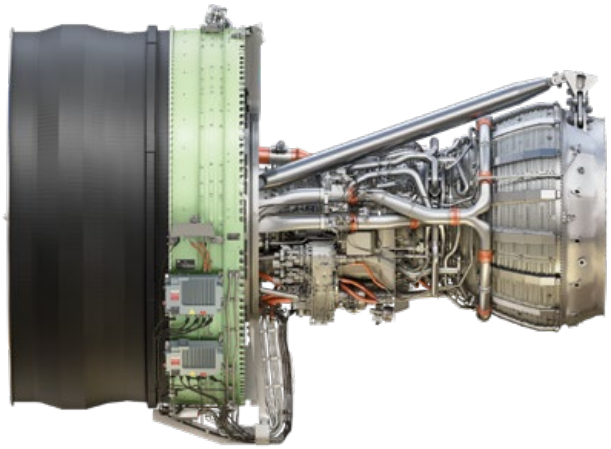


Fig. 6 The GE9X turbofan uses metal AM for parts including fuel nozzles, heat exchangers, sensor housings, combustor mixers, inducers and Stage 5 and Stage 6 low pressure turbine (LPT) blades (Courtesy GE Aerospace)

Fig. 7 An Avio Aero turbine blade made on a GE Additive Arcam PBF-EB machine and used in the GE9X engine (Courtesy GE Additive)

have been required to achieve the FAA certification of the GE9X engine (achieved in September 2020), and to support the certification process of the Boeing 777X aircraft.

The development of these TiAl LPT blades, as shown in Fig. 7, has also resulted in them being half the weight of traditional nickel alloy turbine blades. Dave Abbott of GE Aerospace stated, "For the GE9X engine, this means a fuel consumption reduction of 10%, and therefore lower emissions." Abbott also went on to explain how Additive Manufacturing has provided Avio Aero engineers with more creative freedom, resulting in a change to how it approaches new designs and allowing more complex components.

Furthermore, the new Catalyst turboprop engine, a product of GE's Avio Aero, is the first to be conceived, designed, and produced with additively manufactured parts. This engine was always intended to be a 'game changer' for its segment in the industry. In terms of performance, GE introduced two stages of variable stator vanes, cooled high-pressure turbine blades and a FADEC (Full Authority Digital Engine Control). It performs at an industry-best 16:1 overall pressure ratio, enabling the engine to deliver up to 20% better fuel efficiency and 10% higher cruise power compared to a competing turboprop engine.

MTU Aero Engines

MTU Aero Engines come very close to the top of the list of the early adopters as well. It leveraged PBF-LB Additive Manufacturing to manufacture a borescope boss for the Pratt & Whitney PurePower PW1100G-JM engine that powers the A320neo (Fig. 8). The application was developed over several years before production commenced back in 2013.

"...the new Catalyst turboprop engine, a product of GE's Avio Aero, is the first to be conceived, designed, and produced with additively manufactured parts. This engine was always intended to be a 'game changer' for its segment in the industry."

Liebherr

Less known is that Liebherr used PBF-LB to produce flight control parts used on the Airbus A380. Sadly, while the longer term MRO sector may still plan to use AM for this application, the withdrawal of the A380 from production will not lead to the mass production of these particular parts (Fig. 9). The company also produced a landing gear nose bracket for the A350 XWB, reported to be the first Airbus parts to be qualified for Additive Manufacturing in titanium.

Fig. 8 An additively manufactured borescope boss from MTU Aero Engines for the high speed, low pressure turbine of the Geared Turbo Fan engine PurePower® PW1100G-JM, which powers the A320neo (Courtesy MTU Aero Engines)

Airbus

Further success for metal AM was achieved by Airbus on its A350 XWB aircraft, and it has been using metal Additive Manufacturing to produce a door latch shaft and other components since 2019. Through its own internal supply chain, parts have been produced by a sister company, Airbus Helicopters in Donauwörth, Germany. Made from Ti-6Al-4V in batches of up to twenty-eight at a time it has, so far, produced more than 1,000 parts using multi-laser PBF-LB, and has recently started fitting these to the passenger aircraft in service (Fig. 10). Philippe Emile, an Additive Manufacturing expert at Airbus in France, offered, "Printed latch shafts are 45% lighter and 25% cheaper to produce than traditional ones."

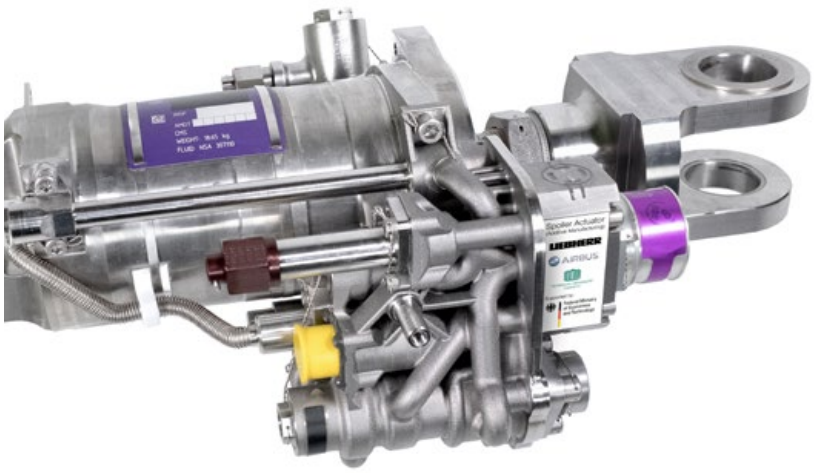


Fig. 9 A PBF-LB part on a spoiler actuator flight control system used on the Airbus A380 (Courtesy Liebherr)

Safran

Each of the CFM International joint owners separately continued to explore and develop metal production parts within its wider group companies, as have most of the other significant players in the industry. Today, metal AM has been integrated into a significant number of product development and production cycles. In 2019, Safran Aero Boosters announced that it had been working since 2015 on an alternative to the cast casing for a lubrication

Fig. 10 Finished metal AM latch components (in silver) for the A350 XWB (Courtesy Airbus)

Fig. 11 An additively manufactured thrust reverser cascade array (Courtesy Collins Aerospace)

unit destined for use on the LEAP engine, and optimised for Additive Manufacturing. Safran Aero Boosters has produced the new parts in the same F357 aluminium alloy as the original casting, and achieved TRL 6 with PBF-LB when one of the lubrication units was first used on a LEAP-1A engine. However, unlike GE Aerospace, Safran had no internal production capability at that time and instead chose to develop an external supply chain, entrusting the manufacture of parts to external metal AM service providers.

"Through the application of the principles behind 'Design for AM', Collins reports that it now routinely achieves weight savings of between 10 and 30%, with corresponding part count reductions of 50 to 80%."

Collins Aerospace

RTX group company Collins Aerospace has also been very active in the deployment of AM and has, to date, produced more than seventy-five different parts. As a major Tier 1 supplier, it has the opportunity to seek out many different applications for AM, and successes include parts for thermal management, engine, nacelles, and various nozzles, housings and sensors. Through the application of the principles behind 'Design for AM', Collins reports that it now routinely achieves weight savings of 10-30%, with corresponding part count reductions of 50-80%. Perhaps more significantly, the company is seeing lead time reductions of 60-80%. One of its key successes has been the large additively manufactured structural thrust reverser cascade array on a nacelle used on a business jet (Fig. 11).

Fig. 12 An AM tail bearing housing (TBH) used on the first Rolls-Royce UltraFan® demonstrator engine (Courtesy of ITP Aero)

Rolls Royce

Whilst Rolls-Royce is yet to declare any mainstream use of metal AM, it did announce in 2015 that it had successfully produced a large titanium front bearing housing for the Trent XWB-97 engine. This 1.5 metre diameter structure assembled from multiple metal AM parts made by PBF-EB was, at the time, the largest load-bearing structure to have flown on a commercial airliner when it was used on a test flight of an Airbus A350.

Although this part was never destined to enter into production, it did prove that AM was capable of producing safety-critical parts. Its continuous assessment of AM technologies has given Rolls-Royce the confidence to go on to develop parts for the next-generation UltraFan® engine. The results of this are yet to be publicised, but this AM component is destined to be even larger than that used on the Trent XWB-97.

"...the TBH is designed to withstand operational loads under all conditions. Part of the bearings that support the shaft for the fan, the main propulsion system of the engine, are included in the housing, as well as removable sound attenuation panels; these were also made by AM for the demonstrator engine."

Rolls-Royce has also been working with its supply partners in Spain, ITP Aero. There is a possibility that the new engine will include an additively manufactured tail bearing housing (TBH), already included in the demonstrator engine that was presumably assembled and tested in Derby last year (Fig. 12). Being a key structural component, the TBH is designed to withstand operational loads under all conditions. Part of the bearings that support the shaft for the fan, the main propulsion system of the engine, are included in the housing, as well as removable sound attenuation panels; these were also made by AM for the demonstrator engine.

Other recent developments to come out of Rolls-Royce have included an additively manufactured low emission combustor for the Pearl

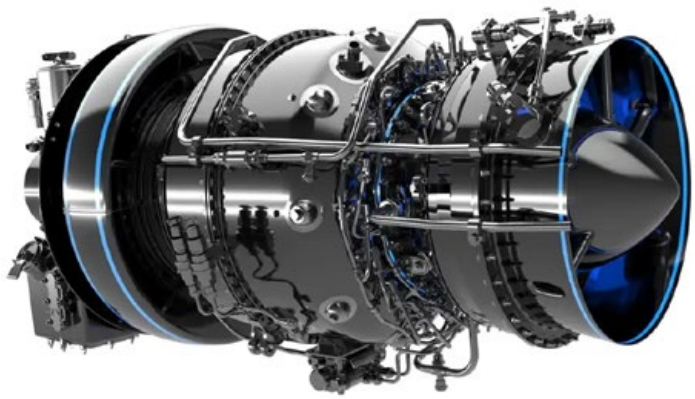


Fig. 13 United Engine Corporation (UEC), Moscow, intends to produce up to 70% of the VK-1600V helicopter engine using Additive Manufacturing (Courtesy UEC)

Fig. 14 An additively manufactured fuel scavenge jet pump and, inset, an exploded view of the conventionally manufactured pump (Courtesy Eaton Aerospace)

10X engine that has been developed for Dassault's Falcon 10X business jet. This part has been produced on a multi-laser PBF-LB system and consists of AM tiles that are then assembled to form the body of the combustor unit. The advantage that AM is said to have provided to Rolls-Royce relates to previous engine combustors, produced by casting, that required cooling holes to be drilled into them. AM provided more freedom to design the required holes directly into each component, all of which could be fully optimised for the flow of the cooling air required by the combustor unit. In terms of performance, the new design is claimed to have a reduced number of temperature hotspots which enhances the output from the engine's high-pressure turbine, which in turn should lead to greater fuel efficiency whilst reducing nitrous oxide emissions at the same time.

United Engine Corporation

Engine development using metal Additive Manufacturing has also become a global priority. United Engine Corporation (UEC) based in Moscow has declared that it intends to produce up to 70% of the VK-1600V engine, its first fully 3D modelled and designed engine, using Additive Manufacturing (Fig. 13). The engine will be used on the Ka-62 helicopter, and when combined with other components in the airframe, the company says around 10% of the Ka-62 helicopter will then be additively manufactured. The VK-1600V was said to be planned to go into service this year, with mass production of metal AM parts to start in 2024.

Eaton

Elsewhere in the very widespread supply chain of the aerospace sector, critical parts suppliers like Eaton have been developing their own AM capabilities. Over a number of years, the company has been developing AM processes with titanium, Inconel, stainless steels and aluminium alloys, and recently teamed with Airbus to develop an internal qualification framework for Eaton's manufacturing fuel scavenge jet pumps using PBF-LB technology (Fig. 14). The process also had to demonstrate that Eaton's newly manufactured pumps would perform in accordance with original component specifications, customer requirements and EASA and FAA airworthiness standards.

Mike York, Director of AM and Digital Engineering at Eaton said, "Eaton Aerospace is leveraging the power of AM to produce superior product and system solutions for our customers leading to increased market share. In addition, we have harnessed the technology to dramatically reduce the weight, number of components and assembly required leading to significant operational savings."

Following an extensive qualification period, Eaton's additively manufactured fuel scavenge jet pump has been approved by EASA for commercial flight and is in service today. In its additive process the company not only reduced pump weight by 30%, but also decreased component assembly time and eliminated potential leak paths, such as seals and threaded joints, resulting from the consolidation of eleven parts into a single part (Fig. 14).

Fig. 15 DED Ti-6Al-4V structural components in the as-deposited and finish machined state produced in high volumes for the Boeing 787 Dreamliner by Norsk Titanium (Image courtesy of Boeing)

Following on from its longstanding pedigree in casting and machining, Eaton is now incorporating AM technology across the business to complement its existing manufacturing processes, as well as using additive processes such as Cold Spray to improve repair options for of older and more unique parts for aftermarket customers. "These examples show that the aerospace primes and the supply chain are now actively working together to implement metal AM solutions, and we should only see more of this in the future", York added.

Opportunities for Directed Energy Deposition (DED)

Directed Energy Deposition encompasses a wide variety of metal AM technologies that melt either wire or metal powders to effectively form 3D objects by overlaying welds, layer by layer. DED offers the advantage of high deposition rates and can be used either in free-form from an initial build platform, or applied directly to pre-existing parts. This makes this group of AM technologies particularly suitable for repair and large-scale production applications.

However, despite being one of the oldest AM technologies, first developed in the 1980s as laser cladding, there have been fewer integrations into mainstream production. Instead, repair has been the dominant use, particularly for the laser-based deposition processes developed by the likes of Trumpf and Optomec. The latter has claimed that they have installed hundreds of systems in many countries with certified processes for the repair of turbine blades using DED and, to date, there have been a great number of repairs, perhaps tens of millions. Instead, it is the wire-based technologies that have seen the most take up by the aerospace sector for new production, and several companies are developing products and processes.

Norsk Titanium and Boeing

Norway's Norsk Titanium is reported to be the first company to receive approval from the FAA to manufacture AM components using DED, but only as recently as 2017. This came as a consequence of being tasked by Boeing to produce the parts for the 787 Dreamliner (Fig. 15).

Metal AM magazine recently spoke with Matthew Crill, Associate Technical Fellow for AM at Boeing, to learn more about the outcomes from the story that was originally reported in January 2018. Crill explained that as AM started to gain traction in the sector, Boeing looked to its supplier base for a solution for the 787 passenger floor galley diagonal fittings. There are four parts per shipset and Norsk Titanium became its qualified supplier, with industry success recognised in 2018 with the Aviation Week Network 2018 Laureate Award for the first structural titanium AM parts to be included in any commercial aircraft.

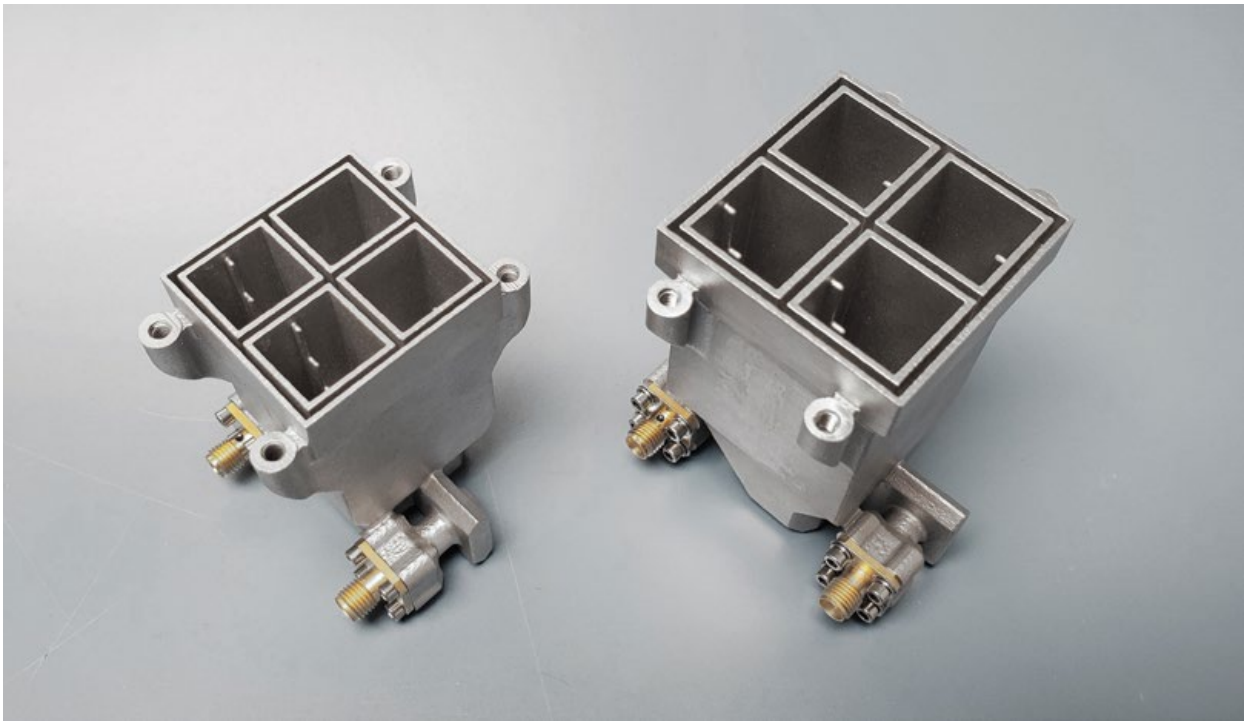


Fig. 16 RF antenna parts made by PBF-LB for Low Earth Orbit (LEO) usage (Courtesy of Optisys)

These parts were installed on the first aircraft in June 2017 and have since been in full-rate production. Crill stated, "Where many have sought to radically change designs, this part intentionally kept the same final geometry, whether machined from plate or from a near-net wire-DED preform." For Boeing, the main focus was on buy-to-fly reductions for both cost and sustainability benefits. Following on from this success, Boeing has implemented several other wire-DED parts produced using the Norsk Titanium technology, and all fitted on the 787 programme through its sub-tier suppliers.

Crill added, "The proven benefits have come from the typical 80% reduction in buy-to-fly ratios when comparing machining the part from a near-net preform opposed to machining it from plate. This reduction has provided benefits in terms of part cost and sustainability by reducing waste."

Perhaps the most comprehensive investigation and development of DED has been conducted by NASA, and experts like Paul Gradl, Senior Propulsion Engineer at NASA Marshall Space Flight Centre, have frequently presented and published their findings. However, despite a staggering amount of research and development activity, there is limited information available on launched parts used on missions by NASA.

Satellite and antenna solutions

Further afield, in the space sector, Additive Manufacturing has almost become the norm. With rocket engines aside as a subject in its own right – components that have been routinely produced include the oxidiser valves in the Merlin 1D engines used on SpaceX's Falcon 9 rockets, the Super Draco engines that provide a fault-tolerant propulsion system for the escape system of the SpaceX Dragon 2 rocket capsule, and turbines supplied by GKN to Ariane Group for the Prometheus engine on the Ariane 6. NASA has also been at the forefront in the adoption of metal AM, and the Perseverance rover sent to Mars has eleven metal AM components used in two of its instruments.

However, metal Additive Manufacturing was first used in less-challenging space applications and the AlSi10Mg alloy has been used on several satellite programmes. In these instances, it is the supply chain that seems to have responded well to using metal AM for these advanced applications, supplying the likes of Airbus Defence and Space (AD&S) various passive structural and active communication devices. The UK-based company has contracted external AM service providers to produce parts like the well-publicised TMTC antenna bracket from 2015, probably the first fully-qualified part to be used on a launch mission on the Eurostar E3000 satellites and, more recently, over 500 radio frequency waveguide components for two Eurostar Neo-series satellites, HOTBIRD 13F and 13G. These satellite programmes have all been successfully launched prior to 2022 to support Eutelsat's TV relay services over Europe, the Middle East, and North Africa. The TMTC bracket

represented a landmark moment for the company as it achieved a 35% weight saving, and reduced the design of the previous bracket, which comprised four parts and forty-four rivets, to a single piece. However, by applying generative design software it was also able to produce a part that was 40% stiffer than the previous manufactured component.

The above example alone provides adequate proof of the readiness of the emerging Additive Manufacturing supply chain to respond to the needs of the aerospace sector. This includes companies like Optisys which has developed a whole range of products via AM (Fig. 16). Chief Innovation Officer, Rob Smith, stated that they have seen all these benefits by implementing AM, "Fast turnaround on development and production for custom combinations and mounting options. As well as being able to design much smaller packages that are lighter in weight, have higher reliability through reduced part-count, and a more consistent pattern of performance."

The company has been developing AM antenna solutions since 2016 and has already delivered more than forty space parts to various customer platforms, mostly aimed at Low Earth Orbit (LEO) usage. Several parts have been included in successful launch programmes, like the horn array antenna parts delivered to the International Space Station (ISS) in November of 2018, and several other commercial satellite programmes through to 2022.

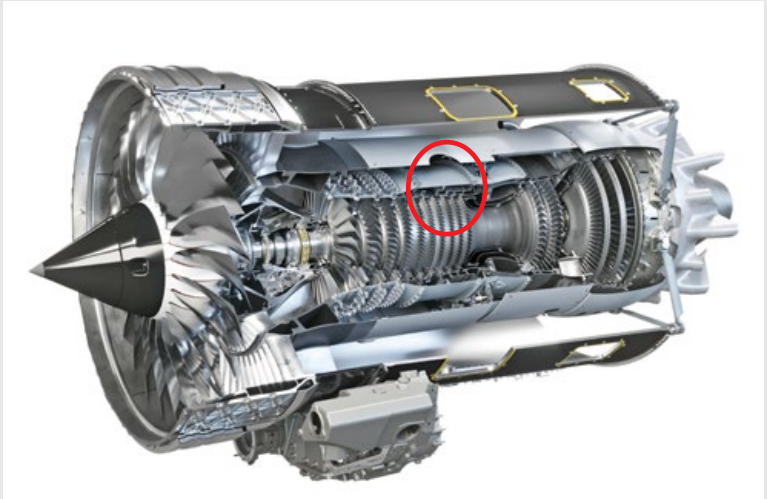
The company exclusively designs these parts with AM as the intended production process, and has achieved some extraordinary performance gains. Compared to one historical device that used to be 4-5 kg in weight, they are now able to deliver equivalent functionality in a device that weighs just 40-50 g. Even its more typical designs have had a huge impact and Smith said, "We reduce weights by an average of 50-80% from my general feel of this industry." The best weight saving comes from the dramatic reduction in part count, and elimination of screws, washers

Binder Jetting for aerospace? How MIM's success highlights the potential of sinter-based technologies

The aerospace sector has long been recognised as an important potential market for the Metal Injection Moulding (MIM) industry. However, extended application development cycles, combined with a lack of fundamental process understanding and rigorous validation requirements had held back the technology.

A milestone was reached in 2017, with Rolls-Royce using Inconel 713LC single-ended stator vanes, produced by Schunk Sintermetalltechnik GmbH, into service in the Pearl 15 business jet engine. Whilst MIM is a more established technology than Binder Jetting, the processes are closely related.
Full article: https://bit.ly/45ZlK4J

MIM IN713LC single-ended compressor stator vanes shown after injection moulding (right), debinding (centre) and sintering (left) (Courtesy Schunk/Rolls-Royce)



The Pearl 15 engine – the circled area marks the position of MIM compressor vanes (Courtesy Rolls-Royce)

"Though much of its time is spent on design verification, which isn't unique to AM processes, it is working with fewer parts, meaning the design, documentation, release, and assembly steps are greatly reduced."

and adapters. He added, "I'd say we replace 100:1 quite typically on our passive waveguide networks, and in many cases our resulting designs simply cannot be built with traditional processes."

This is an industry that really benefits from the aspect of mass customisation without having to change any manufacturing processes. In the example from Optisys shown in Fig. 16, the company has been able to create a product line family where parts are similar but operate at slightly different frequencies. This would normally require significant changes in conventionally designed and produced parts. It also benefits from vastly reduced lead times. Though much of its time is spent on design verification, which isn't unique to AM processes, it is working with fewer parts, meaning the design, documentation, release, and assembly steps are greatly reduced. Due to its unique approach, the company claims to be able to deliver parts to critical deadlines, where others simply cannot.

Speaking about the customisation and delivery times, Smith concludes, "Our manufacturing process is always the same and in this way we can get good customisation through digital manufacturing…. we have delivered designs in as little as two weeks which is completely unheard of in our industry, but typically I'd say we reduce times from years to six to nine months."

Conclusion

The examples shown here are provided by some of the leading companies in the aerospace sector, but there are many more examples that can be found in articles and press releases all over the internet. Twenty years ago this would have been a very short story to tell, but nowadays it would be very easy to dedicate a whole book to the subject.

Metal Additive Manufacturing has propelled the aerospace industry into a new era of design freedom, lightweight structures, and enhanced performance. The successful application of Powder Bed Fusion, Directed Energy Deposition, and – no doubt very soon to follow – Binder Jetting technologies, has far from simply disrupted the status quo, it has revolutionised the potential to produce greater functional parts, with more complex intricate geometries, to improve fuel efficiency, reduce emissions, and increase durability.

As the aerospace sector continues to explore the capabilities of metal AM throughout the entire value chain of producing its parts, there will be continuous development of the way in which: build files are prepared, modelling is used to compensate for distortion, tool paths are optimised, materials handling and recycling will be more sustainable, and post-processing, inspection, qualification and certification will be standardised.

This is being underpinned by the parallel development of much-needed industry standards by bodies such as the ISO, ASTM and SAE International. All have focused working groups dedicated to producing documented requirements for processes, materials, and parts that can be used in the production of aerospace products, and the ISO and ASTM have combined their efforts on some of the published standards. To date, the ASTM, led by the F42 Committee, has published three standards that are aimed at machine qualification, operator qualification and part classification specifically applied to the aerospace sector.

Four further standards are currently in various stages of development. Similarly, the go-to

"This is being underpinned by the parallel development of much-needed industry standards by bodies such as the ISO, ASTM and SAE International. All have focused working groups dedicated to producing documented requirements for processes, materials, and parts that can be used in the production of aerospace products."

industry body for standards in the sector, SAE International, also has its ASM AM – Metals working groups. Although the SAE has been a little late to consider standards for the production of aerospace parts, since 2016 it has now published a total of thirty-three Standards and Recommended Practices. Following this are a further thirty-six documents that are currently being worked on, with half a dozen or more very close to being published later this year. These cover everything from metal powder and wire feedstock composition and physical properties, process minimum requirements and specific documentation of records, and even the requirements to monitor and re-qualify the recycling and re-use of feedstock materials.

Furthermore, the future of metal Additive Manufacturing is assured now that organisations such as the FAA (in the USA) and EASA (in Europe) are working together to ensure there is a robust foundation for certifying the airworthiness of AM parts. The recent meeting in Köln, Germany, of these organisations that have been holding a joint conference on AM for several years already, emphasised that in-situ monitoring has to be a key area to be developed further by system vendors and users alike. A working group, 'Developing a Five-Year Plan to Allow EASA/FAA acceptance – Machine Monitoring' and now in its third year, will be setting out the measures that will enable the supply chain to pass the FAA/EASA acceptance criteria. This very much lays down the gauntlet to all the AM machine OEMs; they must respond by taking their technology past the level of simply creating data from builds, to turning this into fully meaningful build reports that assure part quality.

Metal Additive Manufacturing has disrupted aerospace manufacturing far more quickly than any other group of manufacturing technologies, and yet even after twenty years we are still just in the early days of adoption. As this article goes to press there are already announcements of multi-million dollar, pound, and euro-funded programmes to further the use of metal AM in the aerospace sector. This will see an even faster take up and development of AM, all largely driven by a desire to be more sustainable in manufacturing, or to create more efficient use of fuel, or cleaner forms of power. It is a certainty that we can anticipate even more impressive advancements in the years to come, further solidifying the role of Additive Manufacturing in shaping the very future of aerospace engineering.

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Slowly but surely: Industrialising metal Additive Manufacturing the Norwegian way

While the Norwegian market for Additive Manufacturing has long revolved around prototyping and polymer materials, metal Additive Manufacturing has seen rapid development in recent years. This is in large part thanks to the opportunities that the country's oil and gas industry is now seeing in the technology. In this article, Joppe N Christensen considers why it has taken so long to get started with metal AM in Norway and introduces companies and individuals who are now leading the way.

After oil was discovered on the Norwegian continental shelf in December 1969, much of the country's industry has centred around oil and gas; this sector is more than seven times the size of all other industries combined. This is the first and foremost thing that has to be taken into consideration when looking at the development of metal Additive Manufacturing in the country.

As in many other regions, the earliest activities around metal AM were led by academia and research institutions. In Norway, this was towards the end of the 1990s, when the SINTEF, based in Trondheim and one of Europe's largest independent research organisations, started conducting research into metal Additive Manufacturing. Since then, the academic community in Norway has done a good deal of AM research, and the Research Council of Norway has supported nearly 300 AM projects since 2004 [1].

SINTEF and the Norwegian University of Science and Technology (NTNU), Trondheim, now have a joint AM lab where they actively work on industry-based projects together. The University of Agder, the Mechatronics Innovation Lab (MIL), and the Norwegian Defence Research Establishment (FFI) also focus on metal AM. The latter has produced a report on the current use of the technology, research fronts, and market forecasts up to 2045 [2].

So, if there is a lot of activity in academia, why have manufacturing companies in the country waited until now to embrace metal AM? If we are to find the reason, we must look at the composition of Norwegian industrial companies and what they produce. Here we see many small businesses, 90% of all businesses

Fig. 1 After oil was discovered on the Norwegian continental shelf in December 1969, much of the country's industry has centred around oil and gas, a sector that has played a defining role in the growth of metal AM in the country. This image shows the NorSea Polarbase in Hammerfest, now a hub for AM technology (Courtesy NorSea Polarbase)

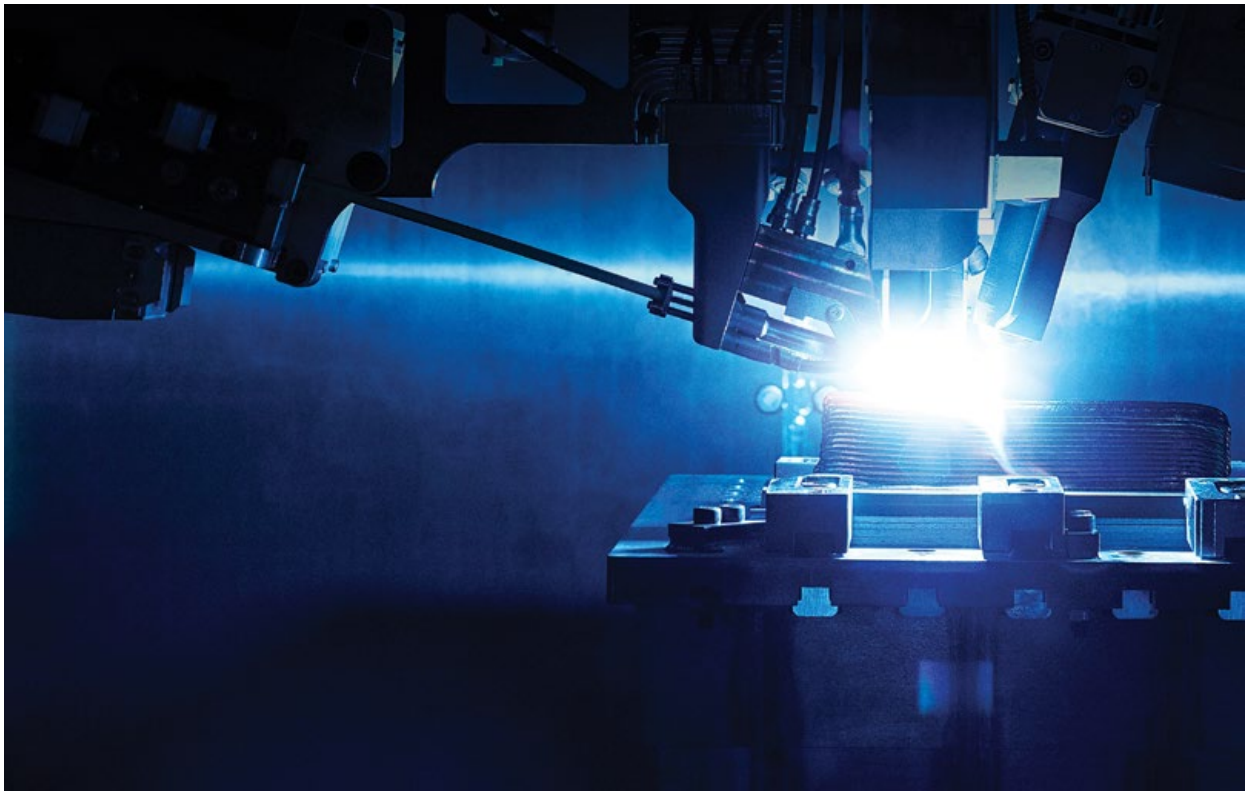

Fig. 2 Norsk Titanium worked for more than ten years on materials research and process control before it was able to commercialise its wire/plasma Directed Energy Deposition (DED) technology (Courtesy Norsk Titanium)

"Through its process, Norsk Titanium opened up the possibility of additively manufactured structural titanium components for the aircraft industry. That is impressive, especially when you know that the aerospace industry has some of the strictest quality requirements."

that produce metal components have fewer than fifty employees [3]. For purposes of comparison, it must be noted that the small businesses that are very active in the oil and gas industry have little to no influence on how the industry actually develops. Most subcontractor companies regularly receive orders with many variants and small series, i.e. mainly piece production, which would speak for the use of AM technology. But why has this technology not become as widespread in Norway as in other European countries?

The answer is that it is actually the oil and gas industry in Norway that has lagged behind, but that is about to change.

Early success with titanium

Before we take a deeper look at the Norwegian oil and gas industry, we must mention the industrial success of Norsk Titanium, which clearly stands out in the Norwegian – and global – metal AM landscape. A small team of Norwegian researchers and engineers formed the company in 2004 and, after more than ten years of materials and process research, the company perfected its wire/plasma Direction Energy Deposition (DED) process in which titanium wire is melted in an inert argon atmosphere to quickly and accurately build layers into a near-net shape part that was ready for subsequent machining (Fig. 2).

Through its process, Norsk Titanium opened up the possibility of additively manufactured structural titanium components for the aircraft industry. This is impressive, especially when you know that the aerospace industry has some of the strictest quality requirements. Norsk Titanium has several AM patents and is certified according to AS9100C, AS9100D and NORSOK M-650. Later, the company established production in the USA and, in 2021, Norsk Titanium went public.

NORSOK

Although Norsk Titanium is a Norwegian success story in metal AM, its output is primarily for the aircraft industry. The majority of industrial activity in Norway, however, is aimed at the oil and gas sector, another industry known for its stringent manufacturing requirements.

In order to supply critical components to the oil and gas sector, suppliers must, among other things, satisfy the requirements set out in NORSOK standards. Since 1994 NORSOK standards have been developed by the Norwegian petroleum industry to ensure sufficient safety, value creation and cost effectiveness for industry development and operation on the Norwegian continental shelf. Furthermore, the standards are intended to replace the oil companies' individual specifications and serve as references in the authorities' regulations.

A lot of time, work and industry knowledge goes into these standards and, as such, they may not necessarily reflect the most up-to-date manufacturing processes. It has, therefore, taken many years to develop specifications relating to metal Additive Manufacturing for use in the oil and gas industry.

So far, so good...

Compared to other countries in Europe, the Norwegian AM environment has relatively few industrial metal AM machines. For example, when the German AM contractor FIT AG built a new factory in 2016, it had thirty industrial metal AM machines and just as many industrial polymer ones. Norway, meanwhile, had just two metal AM machines in academia and two in industry. Progress was made, however, with two notable examples of early development.

Tronrud Engineering AS

In 2010, the innovative industrial group Tronrud Engineering AS acquired an EOS M280 metal AM machine, which it used to make parts that it developed and built for its customers. By 2017, the company had really gained momentum and was in series production of its patented and in-house developed titanium silencers. Later, the company went on to invest in an EOS M290 and an EOS Formiga. The company also offers Additive Manufacturing services to third party companies.

Fig. 3 UiS participated in a project, led by the industrial company EnergyX, which resulted in Norway's first known downstream tool for cleaning pipes additively manufactured in Inconel 718 at Promet AS (Courtesy EnergyX)

Promet AS

The subcontractor Promet AS was the second industrial company to invest in industrial metal AM, getting its SLM Solutions 280 HL in December 2014. Promet has customers almost exclusively within the oil and gas industry and operates 24/7 on piece production using CNC milling and turning machines.

The company, which is based just outside Stavanger, organised an open house in 2015 where professionals from the oil and gas industry and academia met. Promet had many meetings with players in the oil and gas industry – from oil companies to subcontractors – and developed a good relationship with, among others, the University of Stavanger (UiS). The UiS participated in a project led by the industrial company EnergyX which resulted in Norway's first known downstream tool for cleaning pipes additively manufactured in Inconel 718 (Fig. 3).

This was in 2016, before any AM processes were defined in standards for the oil and gas industry in Norway, so it was the customer, BP, who approved the tool for use in the field. The road ahead for Promet was long, and because NORSOK at this point did not have AM processes for metal defined in standards, there

"...when the German AM contractor FIT AG built a new factory in 2016, it had thirty industrial metal AM machines and just as many industrial polymer ones. Norway, meanwhile, had just two metal AM machines in academia and two in industry."

Fig. 4 Forty professionals from all over Norway participating the first phase of a pilot project at NTNU Gjøvik, June 2016. The aim was to demonstrate the viability of AM technology for the Norwegian oil industry (Courtesy Joppe N Christensen)

were limited orders from the oil and gas sector. After a few years, the company retired its AM offerings and sold its AM machine.

The breakthrough

In 2015, the magazine *Maskinregisteret* took the initiative to encourage players in the oil and gas industry to accept metal AM. The Dutch consulting firm Berenschot was invited to lead a project that aimed to demonstrate the value of metal AM for all actors in the value chain, from 3D models to fully-produced, tested, and documented applications.

On September 7, 2016, the AM pilot project started. This was the first project of its kind to invite the entire Norwegian industry, academia, and the public sector to take part in a joint promotion across industrial clusters. Three seminars were held in collaboration with the Norwegian University of Science and Technology and the University of Stavanger. The turnout was good, and the enthusiasm even greater, but after the seminars it was clear that the Norwegian oil and gas industry was not ready for metal Additive Manufacturing.

Onno Ponfoort, AM manager at Berenschot, wanted to know what was in the way; he had shown what had been achieved in the Netherlands, how difficult could it be to adopt in Norway? Ponfoort was encouraged to create an industrial project just to get a foot in the door and develop an understanding of AM technology in the oil and gas industry. He contacted key players such as the energy company Equinor and the certification and classification company DNV to probe the terrain and get a dialogue going. This resulted in the start of a 'Joint Industry Project' (JIP) in January 2018, which aimed to 'standardise and optimise qualification processes for Additive Manufacturing, reduce the costs and environmental impact of production through the use of AM, and enable the use of AM in relevant design applications in the energy and maritime sectors.'

The project's consortium included Equinor, BP, Total, Shell, Kongsberg, Aidro, OCAS/ Guaranteed (a spin-off from ArcelorMittal), Ivaldi Group, TechnipFMC, Siemens, Voestalpine, Vallourec, SLM Solutions, Additive Industries, Quintus Technologies, HIPtec, IMI CCI, Advanced Forming Research Centre of the University of Strathclyde, Immensa Lab and Sandvik. This was a breakthrough for the oil and gas industry's investment in metal AM in Norway and the start of a long journey.

Equinor as a driver of AM

With several AM processes now defined for the oil and gas industry, Equinor could set about exploring exactly why one should produce components by metal Additive Manufacturing. There was a lot of talk about how wonderful the technology was, but were there really any gains to be made? "From Equinor's perspective, we looked at what AM technology could do for the end users, what we were solving with metal," stated Brede Lærum, Head of the AM Center of Excellence, the AM venture of Equinor.

Lærum has been a keen promoter of Additive Manufacturing for many years and has a strong profile within the Norwegian AM community. He believes there are several reasons to use the technology, both within and outside of the oil and gas industry. "Additive Manufacturing is a technology that is exclusively based on digital information. Without a 3D

There was a lot of talk about how wonderful the technology was, but were there really any gains to be made? "From Equinor's perspective, we looked at what AM technology could do for the end users, what we were solving with metal," stated Brede Lærum."

model, there is no part. If we follow the digital trail, we soon find out that spare parts, which are very critical in the oil and gas industry and other industries, do not necessarily have to be physical and be stored in a warehouse. We can have digital spare parts and produce them when we need them," explained Lærum.

He painted a picture in which all actors have digital drawings, which are sent to and from each other as needed, and where everyone can make money from their efforts along the way until the finished part is produced. "If everyone who has a spare parts warehouse starts calculating the costs of having such a facility, they will find out that there are very large sums invested in things that are not in use. With digital warehouses, we can make big gains," Lærum stated.

He also urged consideration about the environmental impact of unused spare parts and time to market. "Of course, we get a better environmental footprint when we don't have to 'overproduce' spare parts that are never used, but there is another dimension in that we can produce locally. Not only do we save transport costs and environmental emissions, but we get solutions delivered faster to where they are needed most, because AM technology has great advantages in terms of time."

He continued, "A digital part can be moved in seconds to where the part is needed. Although with today's technology you have to allow many hours to build a metal component, AM technology is competitive compared to a traditionally produced part when you take into account all the upsides. This bodes well for more sustainability, not only in our industry, but in all other industries as well."

Lærum added that Equinor is not alone in its AM investment, "We have established a collaborative project with a total of eight energy companies. Our goal is to create an entire ecosystem and develop new methods to extract the benefits from the use of AM technology and digital spare parts warehouses. Furthermore, we want the positive results we achieve together, by using AM technology, to also reach other industries."

Fig. 5 Svein A. Hjelmtveit, CTO Additive Manufacturing, at FieldMade. The company has shown how to make a commercial success of metal AM in Norway. In 12 months, there have been more than 380 unique orders and more than 6,000 manufactured parts in the NOMAD container, which was far above the expected number of parts of 100 unique orders (Courtesy Joppe N Christensen)

He also urged consideration about the environmental impact of unused spare parts and time to market. "Of course, we get a better environmental footprint when we don't have to 'overproduce' spare parts that are never used, but there is another dimension in that we can produce locally."

"As I see it, we have four clear advantages when using AM: Firstly, a cost reduction; secondly, a significantly reduced environmental footprint; thirdly, increased delivery security; and, last but not least, local value creation. The latter is important, and will create momentum, because if we can produce locally and sell globally: anything is possible. For example, as with music streamed on Spotify, the whole world will get a boost on several levels, and the biggest perhaps is a sustainability improvement," Lærum emphasised.

Examples of activity today

FieldMade

In 2016, a start-up company called FieldMade spun out of the Norwegian Defence Research Institute. As the company name suggests, it is about Additive Manufacturing in the field, and, unsurprisingly, the initial focus was on the Norwegian Armed Forces. FieldMade quickly took part in the Norwegian Armed Forces' field exercises and proved that it was entirely possible to produce spare parts for combat units at sea and on land (Fig. 5).

The concept FieldMade works from is a micro-factory in a purpose-built

"In collaboration with DMG MORI, FieldMade rebuilt a Lasertec 30 to withstand the shaking and vibrations that occur while transporting the container without affecting the quality of the AM parts. Over time, tests with a container on a truck driving off-road have resulted in what is now a well-functioning system for metal AM in the field."

Fig. 6 Additech produced this titanium strainer for Equinor, delivered in record time using AM. It was designed, produced and assembled in ten days and led to savings in the millions of NOK (Courtesy Additech)

container, called NOMAD, containing all the inputs and machines needed to produce functional parts directly from a finished 3D model, or by reverse engineering using 3D scanning. In the beginning, the company produced polymer parts, but, as its ambitions grew, it aimed to additively manufacture metal parts using a full-scale industrial AM machine.

In collaboration with DMG MORI, FieldMade rebuilt a Lasertec 30 to withstand the shaking and vibrations that occur while transporting the container without affecting the quality of the AM parts. Over time, tests with a container on a truck driving off-road have resulted in what is now a well-functioning system for metal AM in the field.

Word spread quickly and FieldMade gained attention both in and outside of Norway. "We received enquiries from NATO and others who wanted to know more, and one of the topics that was discussed early on was IP rights," stated Christian Duun Norberg, founder of FieldMade and Fieldnode.

Challenges included the question of who has the right to produce what, how to verify the 3D models, and, not least, how to create a secure system. "Digitisation is the key to Additive Manufacturing. You can send 3D files anywhere, but there are many factors that come into play and thus the way was open to establish a new company: Fieldnode," explained Norberg. Fieldnode delivers a digital warehouse ecosystem that allows for the local production of spare parts, thus reducing inventory build-up and improving operational efficiency. The solutions the company delivers also aroused interest in the oil and gas industry. "We have a good collaboration with Equinor, who challenged us by giving us a field assignment. They wanted to see if it was possible for us to demonstrate the technology at the shipyard at Aker Solutions in Stord, Vestland County," Norberg stated.

Originally, FieldMade was given an agreement that would run from October 2022 to October 2023, but this has now been extended. "Over the course of twelve months, there have been more than 380 unique orders and more than 6,000 manufactured parts, which was far above what was expected, and now Equinor has extended the agreement until May 2024," added Norberg.

As well as metal parts, FieldMade has promoted mobile AM solutions also in collaboration with the UK's Mark3D, a large agent for Markforged, in which plastic and composite materials are produced on a ruggedised version of the Markforged Mark Two AM machine.

Additech

On April 26, 2023, the Additive Manufacturing specialist Additech AS received DNV's Certificate of Qualification as AM manufacturer/facility certification for demonstrating compliance with DNV-ST-B203, making it the first in the world as DNV-qualified BPQ in grade 5 titanium (Ti-6Al-4V) produced by Laser Beam Powder Bed Fusion (PBF-LB).

According to Anders Helland, CEO of Additech AS, this certification serves as an indication of the company's strong position in the Norwegian AM industry for the energy, oil and gas, and maritime sectors. Additech is one of the leaders in industrial AM in Norway and runs training courses for its

own staff as well as others who require a higher level of expertise. For this, the company uses CADS Additive's AM-Studio suite.

"For Additech, as part of the Norwegian catapult programme, which aims to support innovation in small and medium-sized companies in specific areas of the country, education also plays a big role in our company. We see the enormous potential of AM and want to establish our way of thinking about 'Learning by Doing' in industry and university," stated Helland.

Aker Solutions

Aker Solutions and partners Aker BP, F3nice and Additech have taken an important step towards a more circular economy using Additive Manufacturing. A pilot project demonstrated the potential for resource conservation by using scrap in the production processes. The partnership is additively manufacturing pipe hanger protectors for underwater wells, produced with atomised material recycled from Aker Solutions' workshops in Tranby, Norway.

The job of converting scrap metal into powder suitable for Additive Manufacturing was left to the specialists at F3nice, based in Oslo and near Milan, Italy. F3nice processed the metal scrap and delivered this to Additech, who manufactured the parts. The result of this process was reduced energy consumption, transportation and scrap, contributing to an improved environmental footprint.

Nordic Additive Manufacturing

Nordic Additive Manufacturing (NAM) originates from the innovation and industrial environment in Raufoss, in the interior of Norway, and is a leading company in industrial laser-based DED (DED-LB) AM. In close cooperation with Sintef Manufacturing and key customers such as Equinor and Nammo, its production process has now been certified according to DNV and international standards. "With a DNV qualification [on laser-based DED], NAM is the first of its kind in the world and literally sets a new standard in

Fig. 7 Aker Solutions and partners Aker BP, F3nice and Additech have taken an important step towards a more circular economy. A pilot project for Additive Manufacturing shows the great potential for saving resources by adding waste to the production processes (Courtesy Aker Solutions)

Fig. 8 NAM will be exhibiting at Formnext 2023 together with the Italian collaboration partner and materials supplier Mimete. From left: Sture H Sørli, General Manager of NAM, Magne Manskow Vik, Technology Manager, and Tor Henning Molstad, co-owner and chairman of the board (Courtesy Joppe N Christensen)

"Aker Solutions and partners Aker BP, F3nice and Additech have taken an important step towards a more circular economy using Additive Manufacturing. A pilot project demonstrated the potential for resource conservation by using scrap in the production processes."

Fig. 9 NAM partnered on a project to build this 100 kg DED impeller in duplex stainless steel in collaboration with Equinor and Eureka (Courtesy Joppe N Christensen)

Fig. 10 NAM produced this demonstration propeller to show what the DED technology can offer. Here, shown with 'raw build', finish machined and surface-treated blades (Courtesy Joppe N Christensen)

this technology. This puts NAM in a unique position and paves the way internationally," stated Sture H Sørli, General Manager of NAM.

Årdal Maskinering

Årdal Maskinering AS, based in Nærbø, in Rogaland, is the first and only company in the world with the Mazak Integrex i500-AM, featuring a 3 m turning length and diameter of 300 mm. This type of machine is large; it weighs 31 tonnes and, in addition to being a five-axis milling-turning centre, it also has the option of laser/powder DED Additive Manufacturing. The machine was delivered in 2020, but its use was delayed until 2022 due to the pandemic. Now, Årdal carries out successful repairs in exotic alloys.

"In another assignment, the customer delivered a part of 3,100 mm in length on which a thread was torn. We removed the thread, applied new material, and machined a new thread to specifications. The result was a success and the customer avoided scrapping the part."

"Among other things, we have received orders from customers where we have repaired broken and worn parts, as well as cast products from China which have not been according to specifications," explained Frode Hegle, quality and HSE manager at Årdal. "In another assignment, the customer delivered a part of 3,100 mm in length on which a thread was torn. We removed the thread, applied new material, and machined a new thread to specifications. The result was a success and the customer avoided scrapping the part. In this way, they avoid a long delivery time and the possible long transportation of a new part, in addition to reducing material consumption: this is sustainability in practice," Hegle stated.

Aarbakke

Aarbakke AS, based in Bryne, also in Rogaland, is Norway's largest machining company with over 300 employees. Here, 70% of the orders are for new parts (i.e. a lot of piece

production). Customers are within the oil and gas sector and its speciality is advanced components in exotic alloys, with much in Inconel, super duplex stainless steels and titanium. The company also surface coats products using the same alloys. The experience gained from this activity has led to the company now investing in wire/arc DED.

"We have great faith in DED, which has been defined for the oil and gas industry, and we have good experience with dredging, so now we are working to start up Norway's first facility, which we have built according to our own specifications," stated Inge Brigt Aarbakke, Aarbakke's owner. "As our DED process uses wire, it is more readily available than metal powder, and the process is cheaper than other metal AM processes. In fact, the raw material is cheaper than powder. The build speed is fast, and we believe this will become a leading process both for repairs and for new components within the oil industry."

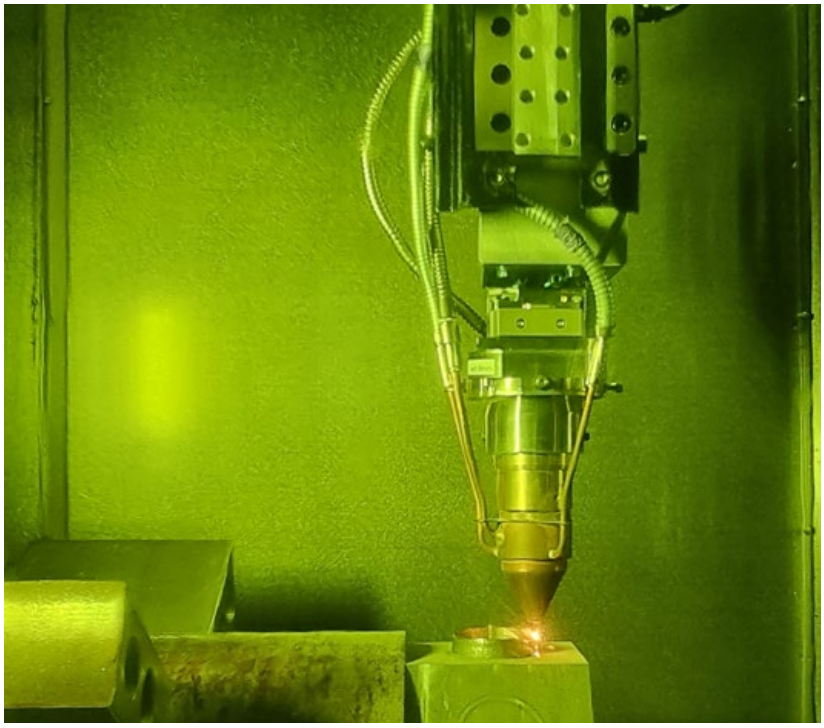

Fig. 11 Årdal Maskinering has the only Mazak Integrex i500-AM with 3,000 mm turning length (Courtesy Joppe Næss)

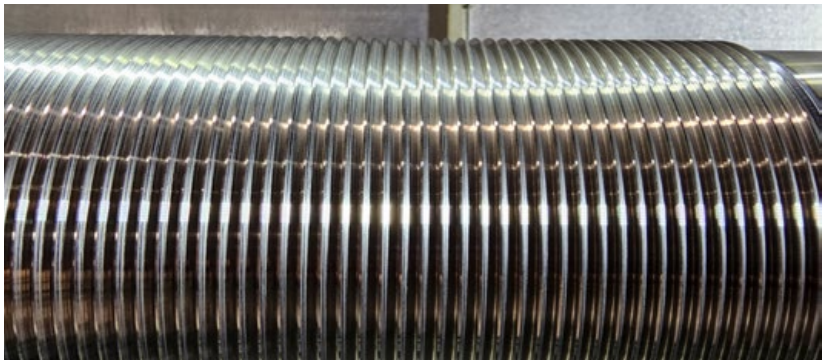

Fig. 12 A fully-machined thread post-build using DED (Courtesy Årdal Maskinering)

Wilhelmsen and ThyssenKrupp

Through a partnership focused on Additive Manufacturing, the Norwegian shipping company Wilhelmsen and the German industrial group ThyssenKrupp aim to transform the supply chain for marine and offshore parts, replacing the existing inefficient and rigid supply chain process with an adapted, on-demand, and more-efficient AM process.

In a digitisation and certification process, parts are produced on demand without having to go through the time-consuming and expensive storage, shipping, and customs and receiving processes. AM changes the status quo of the expensive and time-consuming spare parts business, so that suitable components can be produced close to a vessel's location with a short lead time.

"The savings from reduced cost, time and environmental footprint provided by Additive Manufacturing, digital inventory and localised production of maritime spare parts are a huge opportunity for our customers to be ahead of their

Fig. 13 Wilhelmsen and ThyssenKrupp offer decentralised production, with a workflow held together by a quality assurance framework (Courtesy Wilhelmsen)

Fig. 14 A DMG MORI Lasertec 30 Dual machine in place at AM North AS, with Ketil Holmgren, Managing Director at NorSea Polarbase (left) and Roger Erlandsen, General Manager at GSG AS (Courtesy Joppe Næss Christensen)

Fig. 15 "In the long term, we will look beyond the region and the country, and we believe in becoming a global player", stated Jan-Inge Kongsbak, General Manager of AM North AS (Courtesy AM North)

"Our location is perfect in several ways. Not only are we physically located in the same building as the spare parts warehouse for the oil and gas production ship Johan Castberg, all seagoing customers from outside the oil and gas industry also come to the Polar base. We are talking about fisheries, farming and all other maritime players."

rivals," explained Hakon Ellekjaer, until recently the Head of Additive Manufacturing at Wilhelmsen and now Chief Commercial Officer at Pelagus 3D, a new ThyssenKrupp Wilhelmsen joint venture.

DNV and Siemens Energy

Norwegian DNV and Swedish Siemens Energy are in the process of taking Additive Manufacturing into the next phase of maturity. Siemens Energy's experts in Finspång, Sweden, have developed the first generation of the AM Cockpit platform that provides automated, reliable quality control of the metal AM process. For its part, DNV has developed the Independent Quality Monitor (IQM) platform – a customer portal that continuously ensures the quality of digital solutions. By combining these two solutions, DNV can launch a commercial solution for the AM industry which ensures that parts can be easily compared with an 'approved master print.' The combination also makes automated and external process certification possible.

Investment in Northern Norway

AM North AS

In the summer of 2023, AM North AS started metal Additive Manufacturing operations in Hammerfest, northern Norway. The city is located at Longitude 70.7°, so the metal AM machine located there is perhaps the most northerly of its kind in the world. The machine that AM North has invested in is a DMG MORI Lasertec 30 Dual SLM with the intention of making parts for the oil and gas industry, but at AM North there is a bigger vision.

"Our location is perfect in several ways. Not only are we physically located in the same building as the spare parts warehouse for the oil and gas production ship, Johan Castberg (Fig. 16), all seagoing customers from outside the oil and gas industry also come to the Polar base. We are talking about fisheries, farming and all other maritime players. We are also close to mining and other industrial activities

Fig. 16 The Johan Castberg is behind schedule, so AM technology is helping to reduce delays and errors during its completion (Courtesy Joppe N Christensen)

in the region. In the long term, we will also look beyond the region and the country; we believe in becoming a global player," explained Jan-Inge Kongsbak, General Manager of AM North.

Industrial AM AS

Industrial AM AS, in Mo i Rana, Nordland, is also staking a claim to become a preferred supplier of industrial metal AM components (Fig. 17). Owned by Momek Robotics, Testpartner and Kunnskapsparken Helgeland, the company's plan is to develop a complete value chain with 3D scanning, construction, Additive Manufacturing, machining, heat treatment, testing and certification. Industrial AM will collaborate with leading companies and research and development players within modern manufacturing technology and Additive Manufacturing.

Equinor and Aker BP are supporting the establishment of the operation, recognising the need for AM production in Northern Norway. The drivers for this are reducing stock, shorter delivery times, short-distance deliveries, lower CO_2 footprints and the benefit of readily available expertise and capacity.

Korall Engineering AS

One of the few companies within AM engineering in Norway is Korall Engineering AS, a design engineering company that is part of StartupLab Bergen, a member of the GCE Ocean Technology Cluster, that uses the latest advanced design optimisation technologies. The company's team automates product design workflows to reduce engineering and lead times, and redesigns existing industrial products through the use of Artificial Intelligence to reduce material waste, production costs, and environmental impact, whilst increasing efficiency.

Fig. 17 From left: Kyrre Sørensen, Aker BP, Thomas Borgen, Ocean Cluster Helgeland and Hans Holand, Equinor, entered into a cooperation agreement regarding the establishment of Industrial AM (Courtesy Industrial AM AS)

Fig. 18 The Norwegian AM Cluster was successful in attracting 170 participants to the association's first national conference in Trondheim, March 2023 (Courtesy Haleema Saadia)

Fig. 19 Activity levels were high during the breaks during the Norwegian AM Cluster's first conference in Trondheim 2023 (Courtesy Joppe N Christensen)

"The network seeks to promote the development of an ecosystem and knowledge around AM in Norway, connect relevant stakeholders across industries, and stimulate growth, innovation and new sustainable solutions."

The Norwegian Additive Manufacturing Cluster

Norwegian Additive Manufacturing Cluster (NAMC) was established in 2022. It is an association that aims to be the national network for Additive Manufacturing in Norway. The network is open to companies and organisations from all industries, including educational and research institutions. The network seeks to promote the development of an ecosystem and knowledge around AM in Norway, connect relevant stakeholders across industries, and stimulate growth, innovation and new sustainable solutions.

In March 2023, NAMC organised its first conference, hosted by SINTEF and NTNU in Trondheim. The aim of the conference was to present use cases for industrial Additive Manufacturing. As demonstrated, several AM technologies are in the process of gaining a foothold in Norway in sectors such as health, defence, maritime, goods production, and the oil and gas industry. Actors from business, public institutions, and academia participated in the conference. Companies such as Equinor, Wilhelmsen, Ivaldi, Vår Energi, Kongsberg Maritime and Lærdal Medical were among some twenty speakers who explained how they utilise the opportunities inherent in Additive Manufacturing. With 170 participants at the first meeting, its success was evident.

NAMC is exhibiting at the Nordic partner pavilion at Formnext 2023 in Frankfurt. "We will strive for a good partnership both at the AM Summit collaboration and the Formnext exhibition and establish a long-term mutually valuable collaboration. In any case, we have a couple of good stories to share on the programme," stated Jan Tore Usken, the Head of Norwegian AM.

AMMA: the Additive Manufacturing for Military Applications conference

AMMA – Additive Manufacturing for Military Applications – is an annual event organised by the Norwegian Defence Research Establishment.

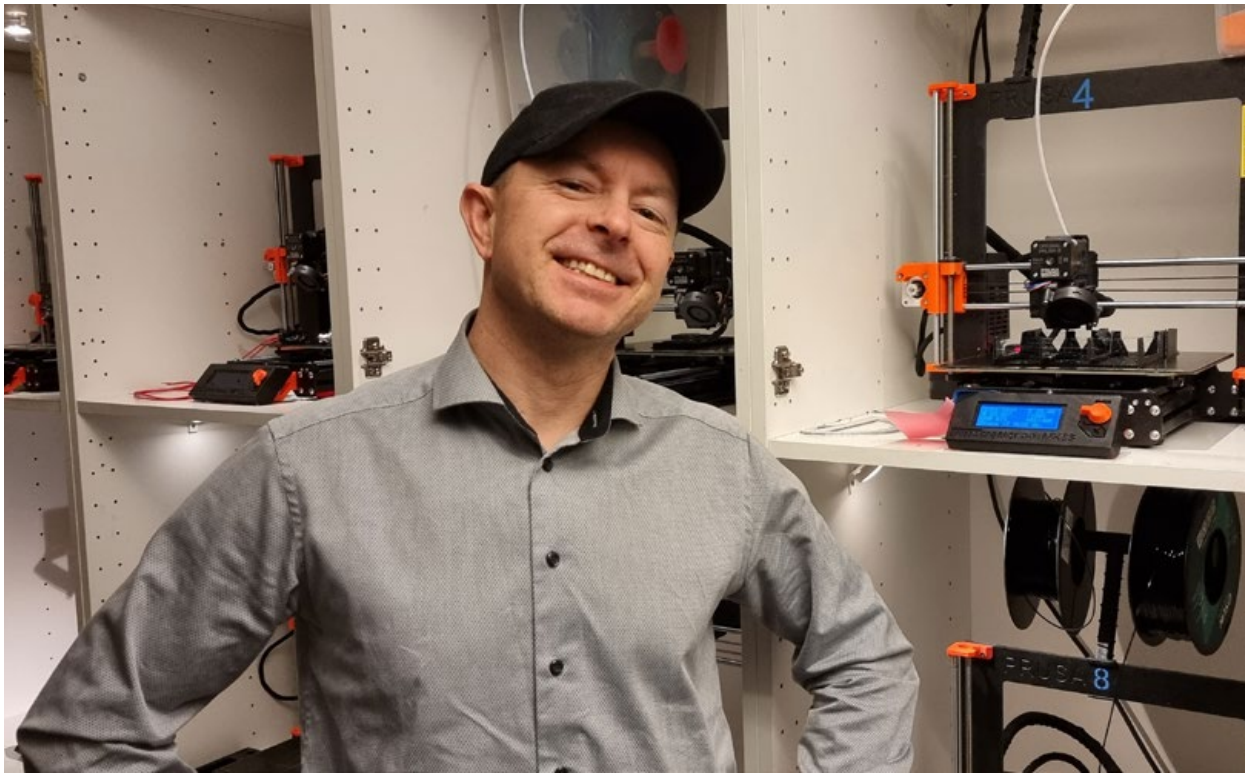

Fig. 20 The leader of the industry association, Norwegian AM, Jan Tore Usken, is happy about the great commitment within metal AM in Norway (Courtesy Joppe N Christensen)

AMMA 2023, which takes place on November 3, is the seventh event in the series. Its aim is to offer a platform for the presentation of recent R&D advances in Additive Manufacturing, and to bring together professionals from the armed forces, state, defence, R&D, industry and academia.

Numerisk Bruker Forening

Over the past few years, trade associations, educational organisations, and companies in the various regions have also organised gatherings and seminars to make all players in the industry aware of the potential within AM. Numerisk Bruker Forening (Norwegian CNC user group) includes AM presentations in its User Meetings.

Norsk Industri

Norsk Industri, the Federation of Norwegian Industries, is active through its Forum for machining and Additive Manufacturing and, in March 2023, Norsk Industri and Offshore Norway organised a dialogue meeting on Additive Manufacturing in future supply chains in the energy sector. The event took place at Vår Energi in Stavanger; 100 people attended.

"Ever since the world began to try to 'industrialise' metal AM, there has been a critical need to train and educate enough – and the right – personnel to utilise AM's potential. Whilst this challenge is universal, some countries are more ahead of the game than others."

The elephant in the room: education

Ever since the world began to try to 'industrialise' metal AM, there has been a critical need to train and educate enough – and the right – personnel to utilise AM's potential. Whilst this challenge is universal, some countries are more ahead of the game than others. In Norway, we have lagged behind.

Now that the oil and gas industry has opened up to metal Additive Manufacturing, the problem is a shortage of specialists trained in Additive Manufacturing. Customers in the oil and gas industry have few specialists in AM who know how to order metal parts, and the individual companies who offer industrial AM

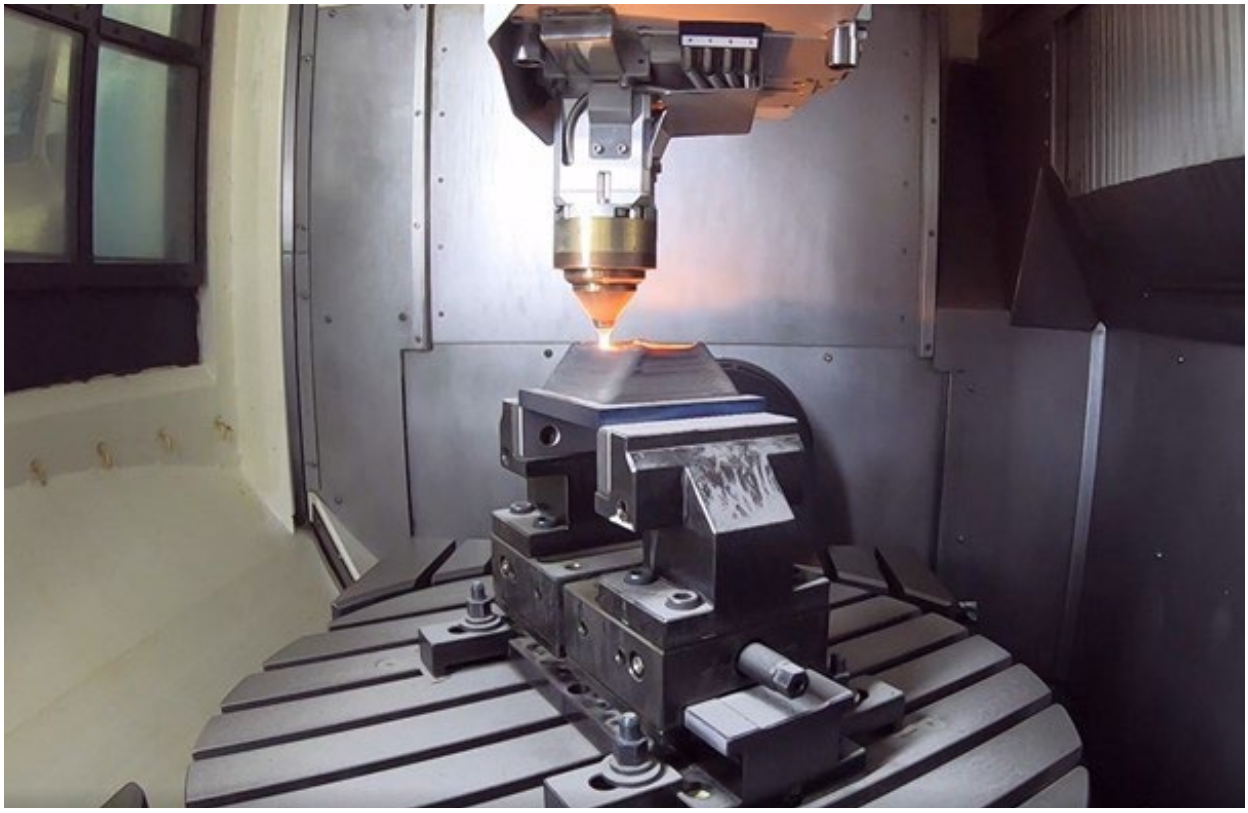

Fig. 21 AM activity in the Mechatronics Innovation Lab (MIL), showing a DMG MORI Lasertec 65 hybrid machine in action (Courtesy MIL)

as a service struggle with recruiting designers and operators. Many metal AM projects start with either reverse engineering or the transfer of traditional technology to AM. There is a long way to go before true Design for AM (DfAM) becomes 'general knowledge.'

Although there is no educational course on AM from a vocational school, college or university which can give any form of qualification, there are several initiatives from individual actors. Below are some examples:

Mechatronics Innovation Lab (MIL) was established with the aim of increasing companies' competitiveness through the use and understanding of new technology. Through involvement and grants from private business and the public sector, MIL has built up Norway's largest and strongest technology lab. This collaboration between industry, academia, and the public sector has made MIL today a technological hub of international standard.

MIL offers technology, test equipment and expertise for innovation in mechatronics and associated disciplines, such as robotics, sensors, autonomy, Artificial Intelligence, virtual reality, and industrial Additive Manufacturing in all types of materials. As a partner in the Future Materials catapult, MIL participates with equipment and expertise in materials development.

MIL is part of the national infrastructure for innovation, pilot testing, experimental development of industrial products, systems, and services for introduction into the market.

In line with what MIL offers in Grimstad, in Southern Norway, the Norwegian Technology Catapult Center (MTCN) in Raufoss offers additive and hybrid manufacturing with DED technology, which is now available through the Catapult.

"The network seeks to promote the development of an ecosystem and knowledge around AM in Norway, connect relevant stakeholders across industries, and stimulate growth, innovation and new sustainable solutions."

Here, companies can get help to further develop, simulate, and test the production line before starting full-scale production on their own premises.

Steinar Killi, professor at the School of Architecture and Design in Oslo (AHO), has written the book 'Additive Manufacturing: Design, Methods, and Processes' in English (Fig. 22). This is a textbook for graduate students in design, engineering, computer science, marketing, technology, and for those who are not students but are curious about what Additive Manufacturing can offer.

Several AM machine manufacturers also offer training in AM to designers, production managers, operators and business managers, which most of the Norwegian buyers of metal AM machines have made use of.

Conclusion

Despite the fact that academia in Norway was an early adopter of metal AM, it took a relatively long time to establish the technology on an industrial basis. The oil and gas industry, which is so strong in the country, sets the conditions for how components are to be manufactured; without guidelines for producing approved and certified parts with metal AM, it is no wonder that the investments were delayed.

The fact that there are now several AM processes defined for the oil and gas industry means that the industry has really invested in metal Additive Manufacturing. New AM centres are being planned in several locations in the country.

The fact that a separate AM association has been put in place contributes to all the actors in the AM environment in Norway getting faster development on several levels. Cooperation across industry clusters often leads to positive synergies.

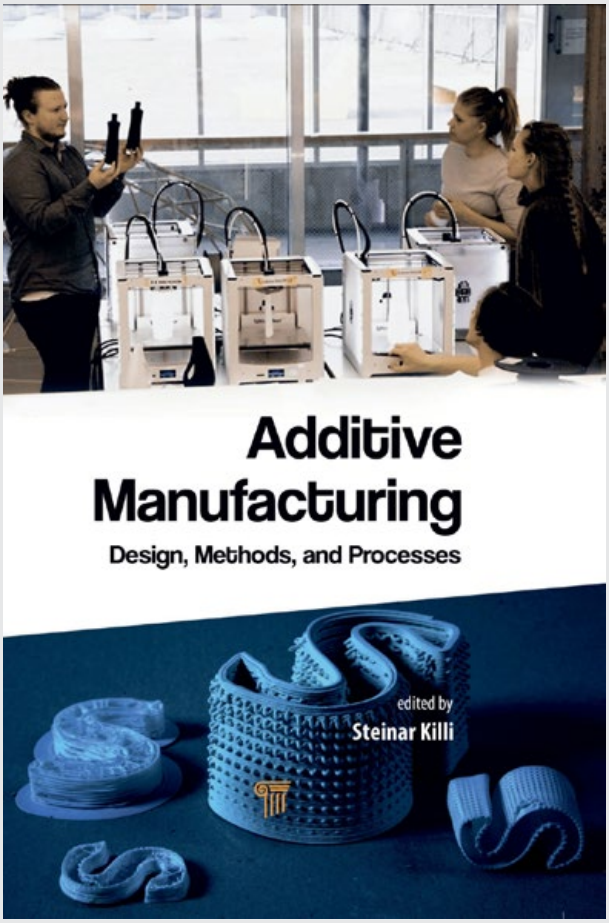

Fig. 22 Steinar Killi, professor at the School of Architecture and Design in Oslo (AHO), has written the book "Additive Manufacturing: Design, Methods, and Processes" in English

The few unique examples presented in this article demonstrate that the industry in Norway invests where there is both need and opportunity. Only time will tell whether Norway can be a major player on the world stage of Additive Manufacturing.

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Hot Isostatic Pressing and AM: How to improve product quality and productivity for critical applications

Metal Additive Manufacturing is rapidly gaining momentum across a broad range of industries and is often used for producing components for challenging applications such as medical implants and rocket engines. To maximise the mechanical strength and fatigue resistance of such critical AM parts, they must be processed by Hot Isostatic Pressing (HIP) to eliminate any residual porosity, and heat treated. Jim Shipley from Quintus Technologies provides an overview of HIP and High Pressure Heat Treatment technology for Powder Bed Fusion AM and considers the opportunities that a new generation of HIP equipment presents.

Over the past decade, metal Additive Manufacturing, and in particular Laser Beam Powder Bed Fusion (PBF-LB), has become an established technology in a number of industrial sectors. Without some of the limitations of traditional production methods, Additive Manufacturing has enabled engineers to design products with higher performance, lower production cost, longer service life, reduced weight, and a potentially reduced environmental impact.

In parallel to the advancement of AM technology, methods to improve mechanical properties through post-processing have been adopted by the industry. Post-processing methods such as Hot Isostatic Pressing (HIP) and High Pressure Heat Treatment (HPHT™) can significantly improve durability and fatigue resistance while offering the potential for shorter overall production times.

Companies in a wide range of industries are rapidly adopting this new technology, especially for use in critical applications in demanding industries such as automotive, aerospace, defence, energy and medical, where performance and safety are crucial. There are four technologies that will be covered in this article:

- Hot Isostatic Pressing
- High Pressure Heat treatment Technologies for the minimisation of oxidation, and alpha-case discolouration
- Digitalisation

Understanding the benefits offered by these technologies allows manufacturing companies to optimise their production, improve product performance, and reduce cost.

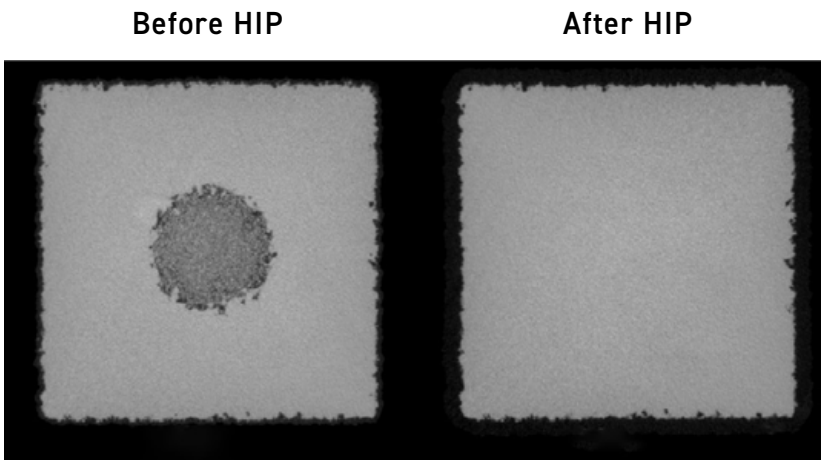

Fig. 1 HIP treatment closes pores and cracks in AM parts, improving mechanical strength substantially. X-ray tomography showing pore closure (Courtesy A Du Plessis, E MacDonald) [1]

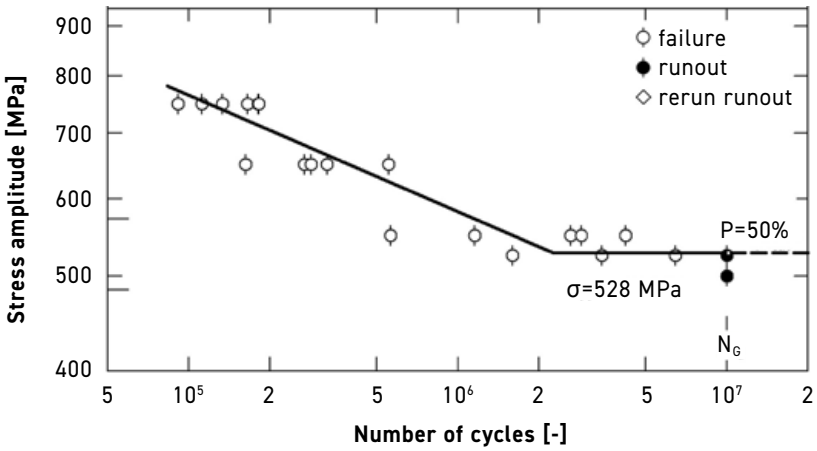

Fig. 2 S-N curve of specimens with hatch distance of 0.15 mm (initial RD = 98%) after HIP with in-HIP quenching and ageing (Graph courtesy of A Kaletsch from work leading to publication [3])

HIP for increasing mechanical strength and improving quality

The mechanical strength of AM parts in their as-built condition is generally extremely good, although, as with all manufacturing processes, there can be quality considerations. The process of adding layer after layer may give rise to pores, pockets of unfused powder, and micro cracks. These defects cause stress concentration and act as crack initiation points, having a detrimental effect on fatigue resistance and ductility [2].

Hot Isostatic Pressing is a well-proven technology for minimising porosity in AM components. During the HIP process, the manufactured parts are subjected to both high temperatures and very high pressures in a controlled atmosphere, usually argon or nitrogen gas.

The combination of high temperature and pressure closes the pores and cracks in the material, eliminates residual stresses, and ensures the metal is properly fused. The result is up to a hundred times higher fatigue resistance, and often significantly higher ductility and fracture toughness compared to as-built parts.

A well-calibrated AM process can minimise the risk of porosity in AM components to an acceptable level for some applications. For critical applications, however, porosity must be eliminated as it can lead to differences in mechanical strength, either between parts from the same batch, or in different sections of larger components. The HIP treatment of AM parts can mitigate this problem, resulting in a homogenisation of the as-built microstructure and a minimised variation in mechanical properties. HIP treatment leads to more predictable minimum design limits, and, in turn, offers the potential to save weight and cost. This is not only relevant for industries where weight is an important factor, such as aerospace and automotive, but also means that all types of products can be manufactured using less material and, thus, be more sustainable.

"Hot Isostatic Pressing is a well-proven technology for minimising porosity in AM components. During the HIP process, the manufactured parts are subjected to both high temperatures and very high pressures in a controlled atmosphere, usually argon or nitrogen gas."

New HIP cycles promise even better results

HIP has been successfully used to densify castings for many decades. The nature of the Additive Manufacturing process is quite different from conventional casting, resulting in different microstructures in the as-manufactured condition. For example, the solidification and cooling rates in Laser Beam Powder Bed Fusion (PBF-LB) are very high compared to a few degrees per minutes for castings, resulting in microstructural differences even for the same alloy.

Despite these differences, some of the commercial HIP treatment cycles used for AM parts today are the same as for cast and wrought material and are not optimised for AM [4]. Several studies have shown that there is potential to achieve significant improvements in material strength when optimising the HIP process specifically to AM material, and these cycles can be different depending on the additively manufactured microstructure.

The answer to the question of why existing standards for HIP treatment are suboptimal lies in how high temperatures affect the crystalline grains that make up metal objects. The yield stress at room temperature is inversely proportional to the square root of the average diameter

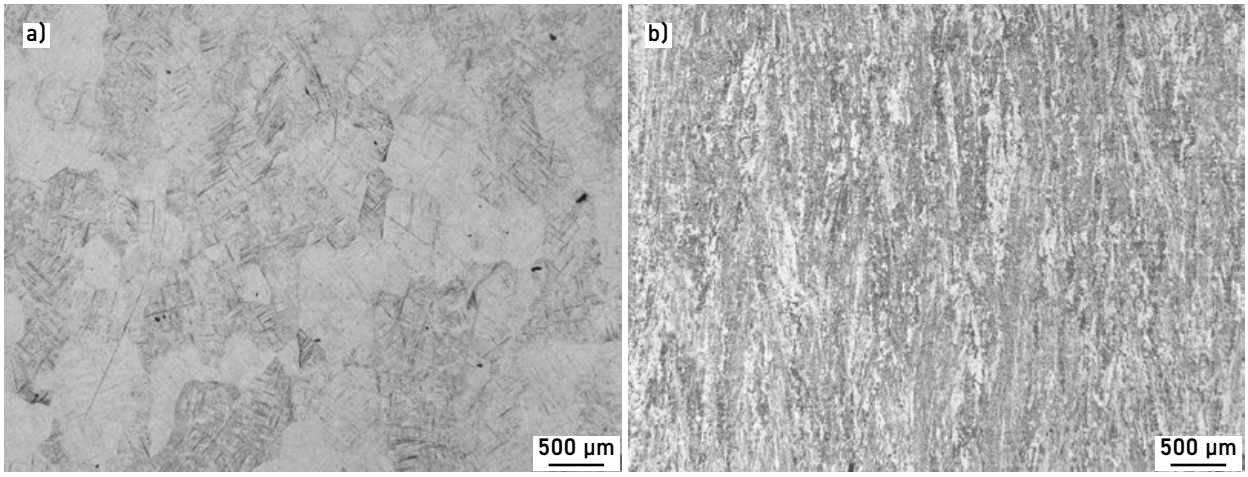

Fig. 3 Micrographs of Ti-6Al-4V produced by PBF-EB showing the results of two different tailored HPHT cycles to tailor micro-structures depending on end use (Courtesy Quintus Technologies)

of these grains. In other words, the smaller the grains, the stronger the material.

When a metal is exposed to temperatures above its recrystallisation temperature, the grains increase in size. The higher the temperature and the longer the exposure time, the more the grains grow. Several studies have shown that temperatures and exposure times traditionally used for HIP treatment cause substantial grain growth, with a detrimental effect on fatigue strength.

The solution to this problem is usually to reduce the temperature and/or the exposure time, unless specific structures with large grains are needed. A study performed with Quintus Technologies examined the effect of HIP treatment of Inconel 718, an alloy commonly used for Additive Manufacturing in the aerospace industry. The use of different temperatures showed that all the positive effects in terms of defect elimination can be achieved at lower temperatures than traditionally used, and without significant grain coarsening [5].

In the study, the porosity and microstructure of test samples of Inconel 718 that had been HIP treated at 1,120°C and 1,185°C respectively were compared. The results showed that the elimination of pores was just as effective at 1,120°C as at 1,185°C. Additionally, significant grain growth took place at the higher temperature, but not at 1,120°C. These results indicate that grain coarsening can be avoided by using lower temperatures in HIP cycles.

Another way to control grain growth is to shorten the HIP treatment time, which can be done with increased pressure. In another study, the effect of doubling the pressure while reducing cycle time was investigated. The researchers compared the defect content of test specimens subjected to a standard four-hour HIP treatment at 100 MPa with that of specimens HIP treated at 200 MPa for one hour. The defect content of the test specimens were equivalent to one another, proving that the higher pressure makes it possible to reduce the HIP treatment time by 75% without affecting the densification.

"Studies where HIP cycles with lower HIP temperatures, shorter thermal processing time, and higher pressures have been used on AM parts show that there is potential to achieve significant improvements in material properties when optimising HIP processes specifically to an AM material."

Studies where HIP cycles with lower HIP temperatures, shorter thermal processing time, and higher pressures have been used on AM parts show that there is potential to achieve significant improvements in material properties when optimising HIP processes specifically to an AM material. As an example, researchers studying the titanium alloy Ti-6Al-4V have found that a modified HIP cycle with lower temperature and higher pressure resulted in improved fatigue strength and significantly higher yield and tensile strength with retained ductility compared to the traditional HIP cycle.

To be able to run these new AM-optimised HIP cycles, the HIP equipment must be able to provide higher pressures and higher cooling rates than most HIP units currently used in the service sector. Quintus

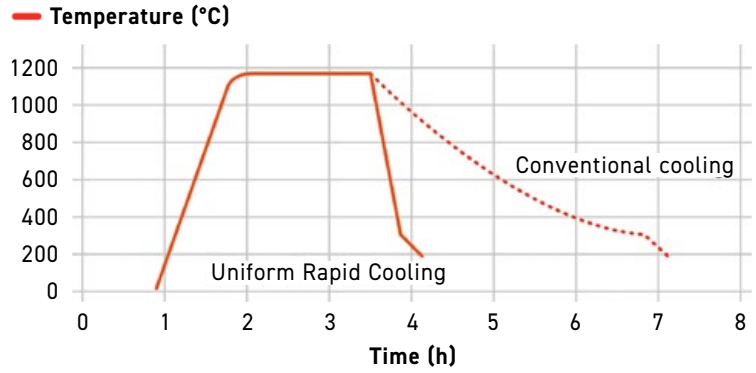

Fig. 4 Quintus' Uniform Cooling technology (URC) reduces production time dramatically by shortening the cooling time (Courtesy Quintus Technologies)

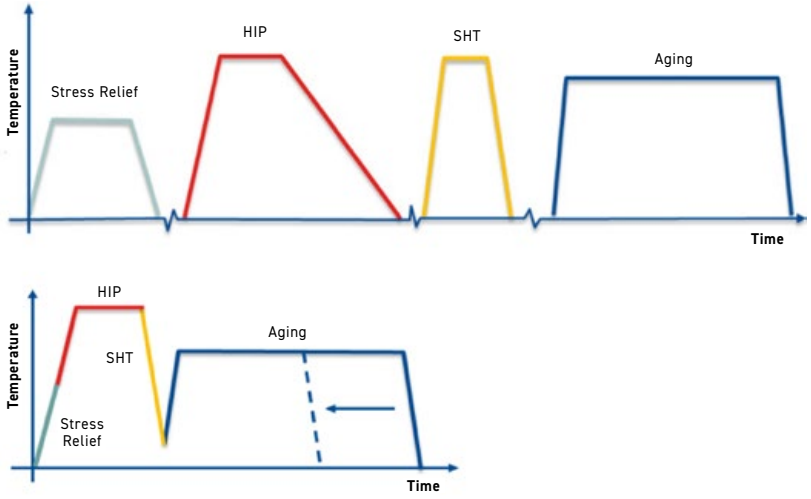

Fig. 5 Using High Pressure Heat Treatment, the cycle time for a typical thermal treatment process for additively manufactured parts is reduced significantly (Courtesy Quintus Technologies)

"HIP is often combined with different heat treatments (e.g. quenching, solution heat treatment and ageing) to further enhance the mechanical strength of AM parts. The latest generation of HIP equipment from Quintus Technologies offers the possibility to perform heat treatment directly in the HIP unit."

Technologies has spearheaded the development of new, improved HIP cycles for Additive Manufacturing and offers equipment designed for HIP treatment at pressures up to 207 MPa (2,070 bar/30,000 psi). These HIP systems offer excellent pressure and temperature control and can perform HIP treatments at extreme temperatures and pressures – up to 2,000°C and 207 MPa (2,070 bar/30,000 psi).

Boosting productivity with High Pressure Heat Treatment

HIP is often combined with different heat treatments (e.g. quenching, solution heat treatment and ageing) to further enhance the mechanical strength of AM parts. The latest generation of HIP equipment from Quintus Technologies offers the possibility to perform heat treatment directly in the HIP unit. This technology is called High Pressure Heat Treatment (HPHT) and not only reduces energy and operational costs, but also enables substantial increases in productivity and product quality.

High Pressure Heat Treatment is made possible by Uniform Rapid Cooling (URC®) and Uniform Rapid Quenching (URQ®) technologies designed and developed by Quintus. Thanks to the wire-wound design of Quintus HIP systems and patented cooling solutions, precise control over the processing temperature and cooling rate are possible. This, in turn, enables operators to tailor the microstructure and mechanical properties of the material.

The gas circulating in the furnace acts as an intermediary cooling medium between the HIP treated objects and the cooling water and has a temperature similar to the payload. This makes the cooling process much gentler than oil or water cooling, for example, and minimises the risk for cracks and deformations. Quintus URC HIP systems can cool payloads at rates of 1,700°C/minute at critical temperatures and URQ systems offer cooling rates of more than 4,000°C/

minute (i.e. cooling rate and isostatic pressure gives microstructures equivalent to oil quench for carbon steels).

For maximum accuracy in steering the temperature, a thermocouple can be placed in the AM part and connected to the control system, ensuring cooling rates are kept within the tightest temperature corridors.

The precise control of the temperature in a Quintus HIP system, enabling it to both serve as a HIP and thermal treatment solution, makes it possible to save substantially on investment costs, since fewer pieces of equipment are required. It also speeds up production and saves energy as the AM parts do not have to be cooled and then reheated, as in traditional processes with separate heat treatment steps. Avoiding re-heating also prevents further grain coarsening, as discussed above [6].

Integrating HIP and heat treatment reduces processing time and, therefore, promises a considerable increase in productivity. Quintus' unique cooling technology was initially developed to increase productivity by speeding up the cooling step of the HIP cycle. In a Quintus HIP, the payload can be cooled in a matter of minutes rather than hours as with conventional units (Fig. 4). Productivity is improved even further when combining HIP and heat treatment. The time for heating and cooling in several of the steps is shortened or eliminated, just as time spent on transport, storage, goods receipt controls and waiting. A typical heat treatment process for AM parts is shown in Fig. 5, clearly demonstrating the time savings. The actual treatment time (not counting transport, etc.) is often reduced by more than 50%, enabling a 100% increase in productivity [7].

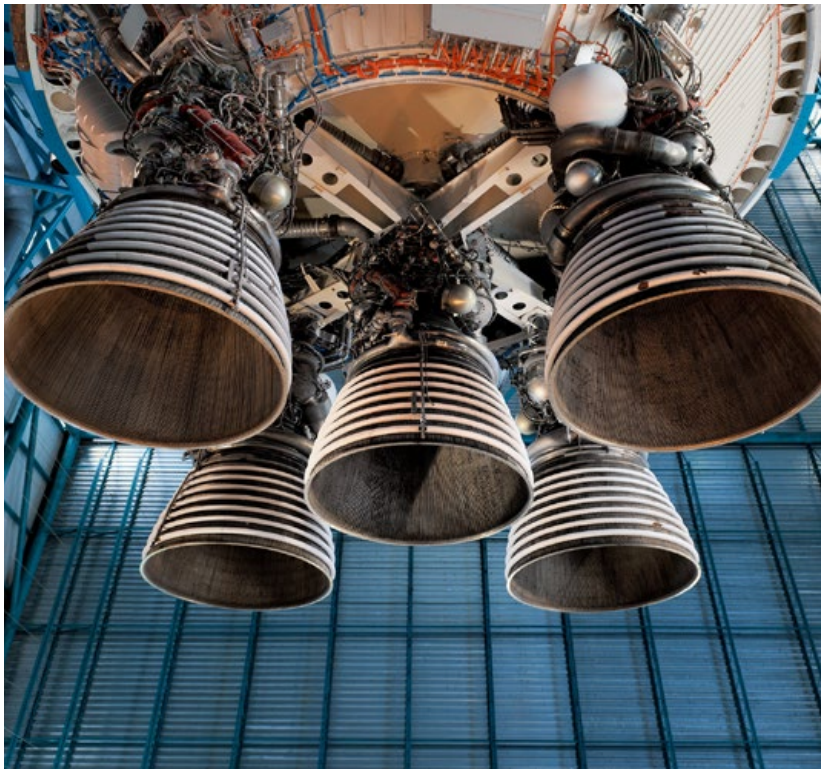

Fig. 6 Rocket propulsion is a growing application area, where the use of HIP is critical to ensure the mission safety and reusability of optimised AM produced engines with maximised fuel efficiency and thrust (Courtesy Quintus Technologies)

Fine tuning material properties

With the accurate control over the heating profile, densification segment, cooling profile, and pressure profile comes the possibility to control the microstructure of the processed AM parts and, in turn, customise mechanical properties.

"With the accurate control over the heating profile, densification segment, cooling profile, and pressure profile comes the possibility to control the microstructure of the processed AM parts and, in turn, customise mechanical properties."

With High Pressure Heat Treatment, grain growth is generally not a problem since the material is exposed to heat for a shorter total time compared to traditional heat treatment processes. This has a positive effect on fatigue resistance and mechanical strength. Another benefit of HPHT over conventional heat treatment is that the treatments are performed under pressure, which offers new possibilities to control the microstructure. The pressure during heat treatment also helps mitigate the risk of thermally induced porosity.

In addition, the combination of HPHT and HIP reduces the problem of anisotropic mechanical properties, which are common with AM parts. Due to the nature of the

Fig. 7 Example of an additively manufactured Ti-6Al-4V medical implant part, manufactured to an open porous surface structure for cementless fixation in the bone. Surface oxides, alpha case, and contaminants formed inside the porous structure during manufacturing can be difficult to remove and can affect fatigue properties as well as bone ingrowth (Courtesy Quintus Technologies)

PBF-LB process, the grains are columnar in the build direction, which gives the parts different mechanical properties in different directions. This is problematic in many cases. Since HIP is performed at a temperature above the recrystallisation temperature, a HIP treatment can help homogenise the microstructure.

Tailored HIP cycles that improve mechanical properties are of great interest for a wide range of safety-critical applications. HPHT offers a way to increase the mechanical performance of the produced components that ensures a robust production process with consistent results.

"Contamination of the HIP atmosphere during processing can lead to the formation of oxides, nitrates, and carbides on AM parts. Even at low concentrations, the partial pressure of reactive gases such as oxygen becomes very high, resulting in oxidation on the surfaces of materials with high oxygen affinity..."

The high pressure heat treatment of CoCr ASTM F75

Post-treatment of ASTM F75, a cobalt-chrome alloy commonly used for orthopaedic implants, illustrates the benefits of integrating HIP and heat treatment. During processing, ASTM F75 is prone to form carbides that, in some scenarios, may negatively affect mechanical properties. The standard HIP treatment of this material dissolves the carbides, but they will form again during the cool down from the HIP temperature unless the cooling is done fast enough, at around 200°C/min.

Conventional thermal processing involves HIP and an extra solution anneal treatment in a vacuum furnace at 1,200-1,230°C for 4 hours after the HIP treatment, with the sole purpose of removing the carbides to obtain the desired microstructure. Thanks to the rapid cooling offered by a Quintus HIP system, ASTM F75 parts can be cooled directly in the HIP at a high enough rate to avoid carbide formation, eliminating the need for a separate solution treatment. This means that only one thermal treatment is required instead of two; one piece of equipment is required instead of two; and the material will spend four hours less at high temperature, which is beneficial for the microstructure.

Avoiding oxidation and discolouration

Contamination of the HIP atmosphere during processing can lead to the formation of oxides, alpha case, nitrates, and carbides on AM parts. Even at low concentrations, the partial pressure of reactive gases such as oxygen becomes very high, resulting in oxidation on the surfaces of materials with high oxygen affinity, such as aluminium, titanium and chromium, as well as a wide range of alloys containing these elements. This oxidation can cause discolouration, and, more importantly, have a negative effect on corrosion and fatigue resistance.

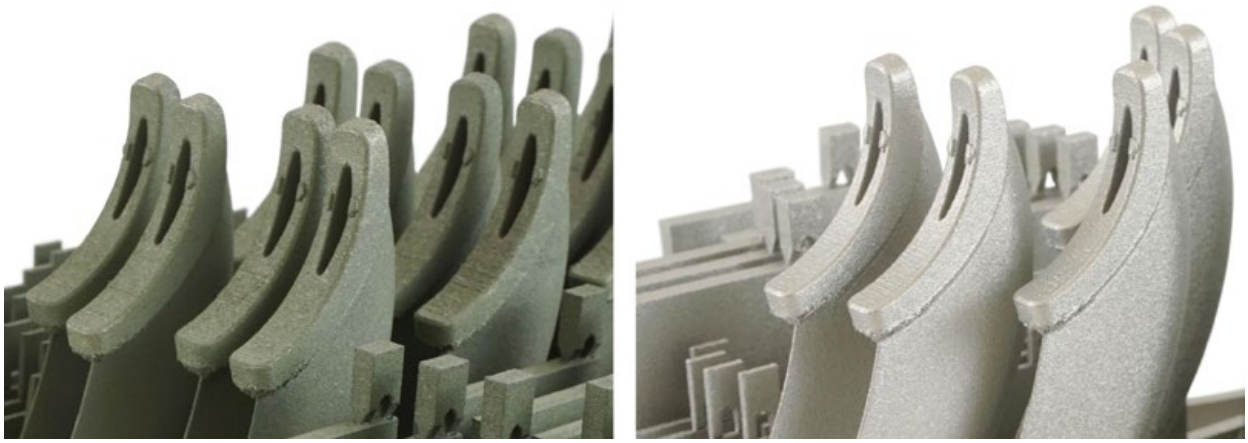

Fig. 8 Stainless steel AM parts processed with traditional hot isostatic pressing (left) and Quintus Purus processing (right). The surface oxide is clearly visible in the left image (Courtesy Quintus Technologies)

Titanium alloys are among the materials that are most affected by oxidation. The high pressure and temperature during HIP, along with potential contaminants, can cause surface oxidation. Oxygen can also diffuse into the material to cause alpha case, a brittle phase that is detrimental to fatigue performance. Alpha case is often removed electro-mechanically or through machining, adding cost and production time [8].

However, for some complex structures with internal channels and complex structures, removing alpha case afterwards is very challenging or impossible. The consequences of this should not be underestimated – for example, in trabecular structures on medical implants for bone ingrowth in cementless systems where strength and fatigue resistance are critical (Fig. 7) [9].

The traditional way of minimising oxidation is to wrap components in high oxygen affinity foil such as titanium. However, protecting all the parts individually adds to production time and cost while reducing productivity. Oxidation under certain conditions can also damage the heaters in the HIP unit and carbon oxides can form soot that must be removed between batches.

The aforementioned problems can be addressed with Quintus Purus®, an innovative solution that allows the user to control the amount of oxygen species in the HIP vessel before running the cycle. Purus comprises a special control software, well-defined best-practice routines, and a hardware component. It is available with all new Quintus compact HIP equipment and can also be retrofitted to existing compact HIP units from Quintus Technologies.

The result is extremely clean parts. Quintus Purus makes it possible to produce titanium parts with significantly reduced oxidation problems, and the same is true for stainless steel and nickel-base alloys where oxides are an issue due to high alloy content of elements with high affinity for oxygen, such as chromium, aluminium and titanium.

Quintus Purus reduces the need for costly post-processing after the HIP cycle, as well as the need for wrapping or bagging parts to shield them from the HIP atmosphere. The result is a time- and resource-efficient manufacturing process with significantly lower cost and shorter production time. Fig. 8 shows the effect of using and not using Quintus Purus technology on two samples of additively manufactured stainless steel parts. The left sample shows clear discolouration resulting from oxidation, whereas the right sample is unaffected.

Fig. 9 Large-scale HIP system from Quintus Technologies featuring integrated High Pressure Heat Treatment technology for maximum productivity and product quality (Courtesy Quintus Technologies)

Insourcing vs. outsourcing HIP treatment

Many manufacturers outsource their HIP processes to external service providers rather than having the HIP process inhouse. This is a cost-effective alternative when volumes are relatively small, since a service provider can consolidate AM parts from different customers in one HIP cycle. As the HIP market continues to grow, so does the number of HIP service providers. Quintus can assist in connecting you with relevant partners. Many are operating modern Quintus HIP equipment and offer the possibility to run customised HIP cycles and HPHT, meaning the question of whether or not to insource often comes down to factors such as flexibility, control, and lead times. However, an increasing number of manufacturers are insourcing HIP treatment. Their most common reasons for this include:

Shorter production time
Since transport time to and from the service provider is eliminated, the lead time for HIP treatment can be significantly reduced. Investing in a modern HIP press where HIP and heat treatment are integrated, can often eliminate certain process steps, reducing production time even further.

Risk reduction
Since transportation to and from a service provider is eliminated, so are the risks related to transport delays and damaged or lost goods.

Production flexibility
Insourcing HIP gives manufacturers full flexibility over their production schedule and lead times. When needed, time-critical deliveries can be fast-tracked through the internal schedule. This can be very valuable in industries where short lead times and flexibility are key. Lean processing in state-of-the-art AM production is made possible by on-site digitalised HPHT equipment.

Control over quality and process improvement
With the full HIP and heat treatment process inhouse, the quality system can be further developed to avoid mistakes and the number of inspections can be reduced. Issues that may arise with external HIP treatment can include a loss of traceability, components being treated with the wrong HIP parameters, and surface contamination such as surface oxidation and alpha casing. Internal know-how and expertise on how to run the HIP process will be developed over time to avoid quality issues and delays.

Optimised HIP and HT processes
When operating the HIP process inhouse, manufacturers are not limited to the standard HIP cycles generally offered by service providers. Instead, the HIP process can be tailored for the needs and requirements of specific parts and materials to achieve maximum performance and quality. This possibility is extremely important for AM parts since optimised HIP cycles specifically designed for AM materials can result in significantly improved mechanical properties compared to the standard HIP cycles. This can also lead to the development and control of their own IP.

Lower total production cost
Having a high utilisation rate on an inhouse HIP system yields the lowest operating cost for the HIP process. The cost for heat treatment can be reduced if a combined HIP and heat treatment approach can be used. Since transportation to external subcontractors can be avoided, the cost of transportation is eliminated, as well as insurance during transport. There are also potential indirect cost savings from improved quality control routines, more flexible planning, and shorter delivery times.

Increased productivity through digitalisation

The digitalisation of HIP equipment introduces new possibilities for automation, increased productivity, higher operational reliability, and lower operating cost. Quintus Technologies offers digital capabilities for its HIP equipment that allow customers to fully integrate their HIP units in a digital production line and leverage the benefits of Industry 4.0 and IoT.

The processing data from a Quintus system is collected and stored on the customers' servers, but can also be accessed in a private cloud as needed. This enables instant access to data to create tailored reports, product overviews, and updated documentation. Analysing the data allows for process optimisation and an increase in productivity (e.g. by rationalised production flows and improved production planning). Operating data can also be exported to a quality system for automatic creation of quality documents, eliminating substantial amounts of administrative work and reducing human error.

Quintus' connected services allow the condition of a machine to be continuously monitored to ensure the highest operational reliability and safety possible. Customers can perform condition-based, predictive maintenance instead of relying on set service intervals in order to maximise uptime and reduce service costs. As part of the agreement with the customer, the predictive maintenance package is connected to the Quintus Care Portal for quick and easy access to spare and wear parts.

The route to more sustainable production

The development of modern HIP systems where HIP and heat treatment can be performed in one cycle, and the process can be controlled to prevent oxidation, has resulted in substantial gains in productivity, product quality, and production economy. There are, however, also

"Contamination of the HIP atmosphere during processing can lead to the formation of oxides, alpha case, nitrates, and carbides on AM parts. Even at low concentrations, the partial pressure of reactive gases such as oxygen becomes very high, resulting in oxidation on the surfaces of materials with high oxygen affinity..."

significant sustainability benefits offered by modern HIP systems. The most obvious is perhaps the large energy savings that are realised when integrating HIP and heat treatment since the produced parts are no longer cooled and reheated for every step in the process.

Another important sustainability factor is reduced powder consumption and waste. Adding HIP with heat treatment capabilities to a production line enables stronger materials and higher structural integrity, making it possible to design lighter

Trends in the HIP industry

Jim Shipley, Manager for Business Development at Quintus Technologies, shares his view on the trends in the HIP industry.

How is the HIP market?
"The HIP market is growing steadily due to an increased need for HIP in key industries such as medical, aerospace, defence, energy and automotive. These industries are growing faster than the general economy, many at a double-digit pace. In addition, the utilisation of AM equipment is growing at over 25% per year, meaning AM machines are producing more and more components. These parts often need HIP treatment, and as a consequence, we see a growing number of service providers for HIP treatment, as well as more and more OEMs investing in in-house HIP capacity."

Which developments in AM and heat treatment do you find most interesting?
"Personally, I am very excited to see what will happen over the coming years in the area of high entropy alloys. These materials have exceptional properties, such as extreme mechanical strength or corrosion resistance. Additive Manufacturing and HIP are key technologies when producing components in these alloys and Quintus Technologies is involved in several research projects. These new materials will have a great impact in many applications in the future, including aerospace and electric vehicles."

What trends do you see for HIP equipment?
"The first thing is that we see a demand for bigger and bigger systems. Customers are becoming increasingly aware of the benefits of HIP with integrated heat treatment and want systems capable of handling larger components and higher throughput. We are currently designing highly productive HIP equipment with a hot zone diameter of over four metres. The second trend is a strong interest in High Pressure Heat Treatment, and a renaissance for our URQ® systems that enables very fast quenching in the HIP. Much of this is driven by Additive Manufacturing of aluminium alloys and wear resistant steels (e.g. in defence applications), and these materials need a very high-speed quench."

What are you currently working on at Quintus?
"We are more and more interested in controlling the microstructure of components during the HPHT cycle, which is of course also dependent on the microstructure prior to HIP. Our aim is to be able to advise customers on how to achieve the desired microstructure time after time dependent on their own AM processing knowledge. We're moving to real Lean Additive Manufacturing, and away from the focus on powder and printing only, what we prefer to call pre-processing. We are also continuing to develop methods to minimise issues with oxidation, new HIP cycles for different materials, and a lot of other things. There are many exciting projects in the pipeline."

components with longer service life. It also ensures consistent product quality and minimises yield loss due to fluctuating quality. The combination of Additive Manufacturing, HIP, and High Pressure Heat Treatment has already proven to result in substantial sustainability benefits. As development continues to accelerate, the combination of these technologies holds great promise for future enhancements in both productivity and sustainability.

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The convergence of Additive Manufacturing and Artificial Intelligence: Envisioning a future that is closer than you think

The frenzy of media attention surrounding Artificial Intelligence (AI) dwarfs the past hype surrounding Additive Manufacturing (AM). Whether you look to the future with fear or excitement, there is no escaping the wave of change that is coming. Whilst we once again hear words like 'revolution' being used – to which so many have become immune – Dr Omar Fergani believes that we are now at a crucial point of convergence for AM and AI. Here, he explains why AM is in an especially strong position to leverage the potential of AI, with the power to transform many areas of our industry, from part design to machine operation, quality management and beyond.

Much like the advent of electricity or the internet, the blending of Artificial Intelligence and big data is not just an incremental improvement. Instead, it represents a foundational shift that is reshaping the bedrock of our industries and society. As we harness this unprecedented convergence, we are not just building better tools – we are redefining the very essence of how we work, think, and live.

In this article, we will explore in depth how AI will impact the Additive Manufacturing industry, from a new wave of advanced design possibilities to autonomously controlling AM machines and ensuring part quality and repeatability. We will share insight gathered from those at the cutting edge of the convergence of AI and AM, whose voices are not often heard in the media but who promise to transform our industry through their research. We will also offer advanced use cases, insight into existing products and services and, by the end, hope to have presented a clear picture for AM experts, corporate decision makers, and engineers.

I believe that right now, rather than in the distant future, there is an opportunity for the AM industry to leverage the power of machine learning and deep learning models to bring a new level of efficiency to AM processes, operation and businesses, co-piloting Additive Manufacturing on the path to industrialisation.

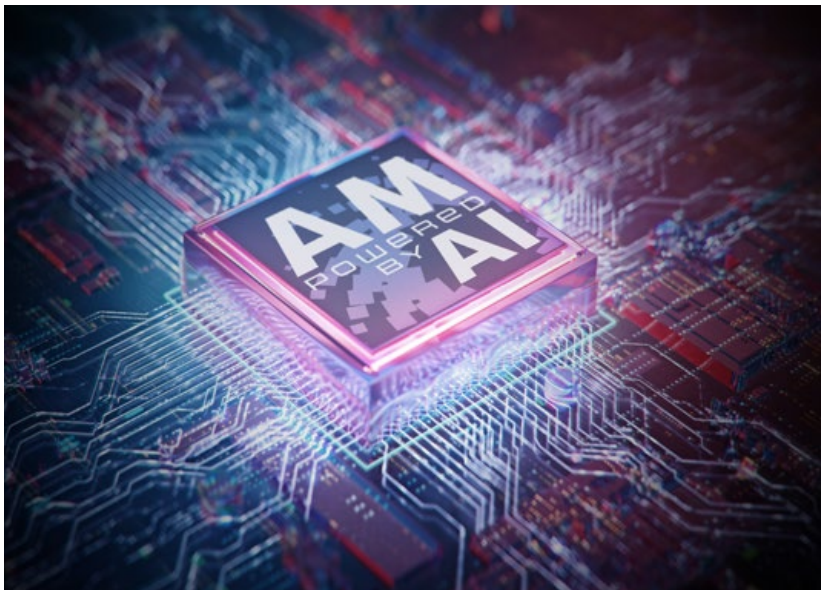

Fig. 1 AI will impact the Additive Manufacturing industry, from a new wave of advanced design possibilities to autonomously controlling AM machines and ensuring part quality and repeatability (Base image credit: Connect world/ Shutterstock.com)

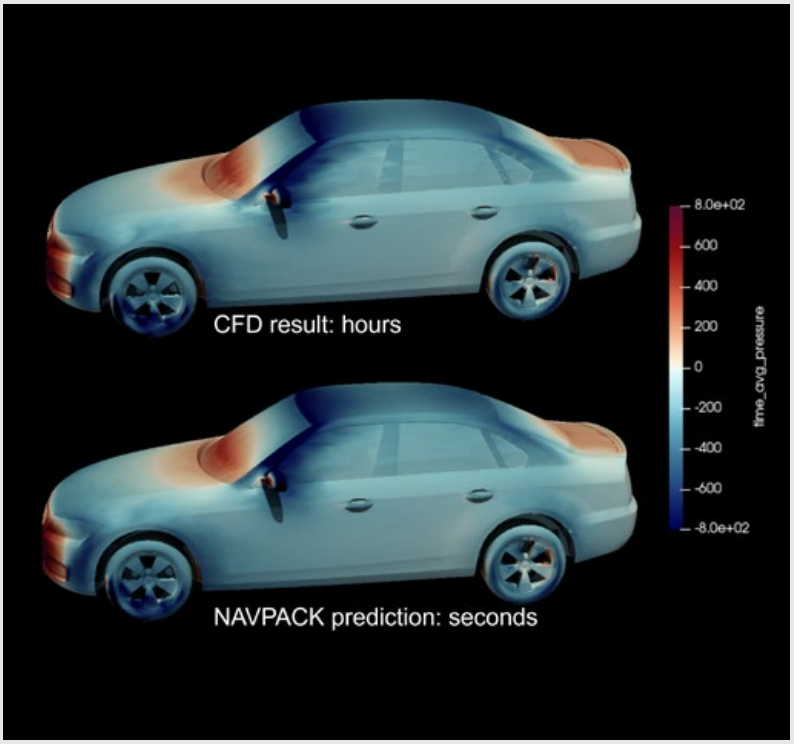

Fig. 2 Predicting the drag coefficient is a key measure of aerodynamic efficiency in automotive design. Engineers and designers often spend a significant number of days iterating on the drag coefficient as an input variable. Traditionally, they rely on High-Performance Computing (HPC) based CFD solvers, which can take multiple hours to generate data for a single design. With AI models, automotive OEMs can obtain the same results in seconds, drastically reducing engineering iteration time and unlocking new collaborative possibilities. This allows aerodynamicists and designers to sit in one room and iteratively converge on an optimal design in real time.

The same principle is employed by Navasto in designing complex AM heat exchangers and other components. AI models, trained on historical company data, are approaching a universal model that could, in the near future, facilitate workflows such as 'Make me a car.' (Courtesy Navasto)

True AI: a profound transformation

Over the past few years, we've witnessed the initial sparks of this transformation as AI models taught themselves to recognise faces, interpret languages, and even compose music, all by sifting through mountains of data. But we are just scraping the surface of what is possible. With each passing day, AI is becoming increasingly adept at learning from all types of data, delivering insights that until now have been impossible to generate.

I believe that a new industrial era – powered by AI and quality big data, along with impressive computational capabilities powered by cloud and quantum computing – will make the transition from steam to electricity seem minor in comparison. From healthcare to manufacturing, transportation to agriculture, no sector of the economy will remain untouched. Jobs that once seemed firmly in the realm of human creativity and intuition are now on the verge of being automated.

As a millennial, I'm amazed to live in this time of rapid technological change. Alan Turing's early ideas about smart machines once read like science fiction, but now they're all around us and becoming ever more capable.

We now find ourselves at another pivotal juncture, with AI's potential magnified by its integration with that other groundbreaking technology with which we are all much more familiar: Additive Manufacturing. With AM, we find a technology ripe for the transformative impact of AI. Despite being an industry in relative infancy, AM has already demonstrated its potential, offering unprecedented flexibility in design and production, optimising the use of resources and reducing waste. However, we must not be so enamoured by its potential that we overlook the significant challenges standing in its path. The first set of challenges are efficiency, yield, and throughput. Traditional manufacturing methods, honed over decades, can deliver products at a scale

"With AM, we find a technology ripe for the transformative impact of AI. Despite being an industry in its relative infancy, AM has already demonstrated its potential, offering unprecedented flexibility in design and production, optimising the use of resources and reducing waste."

and speed that current Additive Manufacturing processes currently struggle to match. For industries that rely on volume, this discrepancy can't be ignored. The current slower pace of AM risks hindering its wider adoption in sectors where time is of the essence.

Yet it's not just about the speed or volume. The promise of additive lies in its precision, material efficiency, the promise of part consolidation and part customisation. But, as with all new technologies, this promise comes with questions about the quality, repeatability, and, ultimately, the economic competitiveness of the process. While one additively manufactured component might meet all quality benchmarks, ensuring that the next thousand or ten thousand pieces meet those same standards is critical. Variability in factors such as material quality, machine calibration, and environmental conditions risk the introduction of inconsistencies in the final product. For industries such as aerospace or healthcare, where a minor defect can have grave consequences, this unpredictability is a concern.

Lastly, as with any new technology, the spectre of standardisation looms large. The AM industry is still relatively young, with a plethora of machines, materials, and processes vying for dominance. Without universal standards, there's a risk of creating siloed ecosystems, where interoperability becomes a challenge. Manufacturers, regulators, and consumers alike need clear guidelines on what constitutes quality, safety, and reliability in the realm of Additive Manufacturing.

As we address these challenges, the burgeoning field of AI offers the potential for accelerated progress. AI, with its ability to analyse vast datasets, predict anomalies, and optimise processes, could be a key to help unlock the full potential of AM. By marrying the capabilities of Additive Manufacturing with the predictive power of AI, I believe that we stand on the cusp of a new era in manufacturing.

"Additive Manufacturing companies stand to gain substantially. By harnessing AI-accelerated engineering, they can fully explore the design freedoms inherent to AM. The potential for designing high-performance systems is clear: AI-accelerated simulations will enable engineers to more easily produce superior heat exchangers, lightweight structures, and advanced fluidic applications."

Design for AM and beyond

It is widely understood within the AM industry that simply transplanting designs from traditional processes such as injection moulding to Additive Manufacturing misses the mark. Without tapping into AM's design freedom, we're not realising its full potential. This results in a situation where AM isn't scaling as fast as it might because manufacturers aren't seeing enough components that are designed for AM (DfAM). There is something happening here that is bigger than DfAM.

AI, and, specifically, the power of deep learning surrogate models, should not be underestimated when it comes to AM part development. The shift is more than just technological – it's a reimagining of how we design, evaluate, and innovate. Traditionally, the product creation journey was iterative. Designers, using CAD, would create designs that simulation experts would appraise, critique, and refine using CAE's analytical lens. Evaluations and adjustments would be made, often reconciling disparate file formats, and navigating the complexities of tools that were powerful yet computationally expensive.

AI-driven surrogate models trained on quality physics-based data leveraging traditional CAE models can cut the simulation time from hours to seconds (Fig. 2). Using the generative nature of deep learning, they can adapt and iterate until identifying the optimal shape based on the product engineering requirements, generally based on the criteria of stress, fatigue, thermal behaviour, weight reduction, or any combination of these.

I spoke with Dr Matthias Bauer, CEO and co-founder of Navasto, one of the leading providers of accelerated AI. He commented, "In the realm of engineering, AI has significantly accelerated processes. I foresee that, within a year, every design and simulation solution will necessitate this technology; with a failure to incorporate AI comes the risk of obsolescence."

Additive Manufacturing companies stand to gain substantially. By harnessing AI-accelerated engineering, they can fully explore the design freedoms inherent to AM. The potential for designing high-performance systems is clear: AI-accelerated simulations will enable engineers to more easily produce superior heat exchangers, lightweight structures, and advanced fluidic applications.

When it comes to lattice designs, Dr Todd Doehring, CEO of ABEMIS,

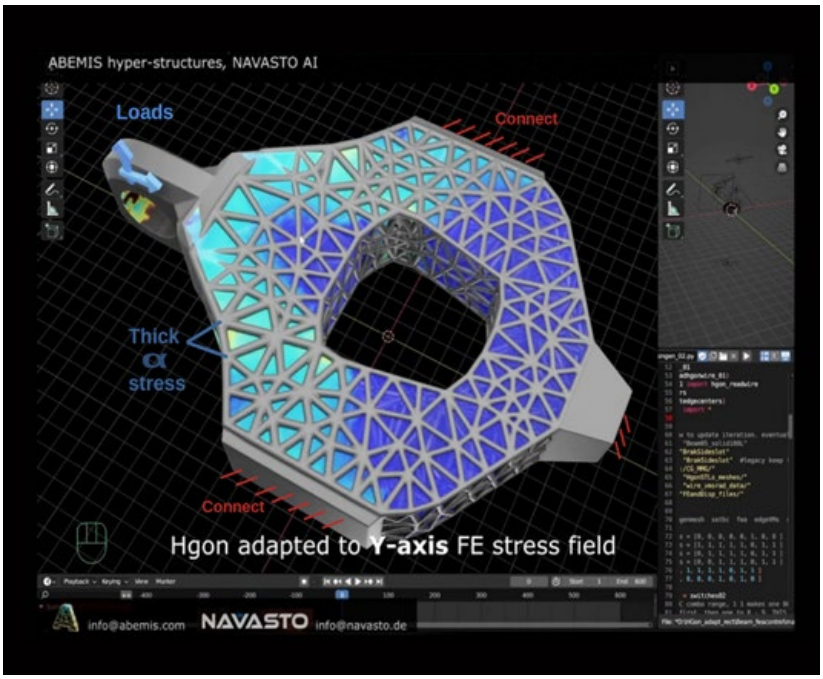

Fig. 3 The future of lightweighting in Additive Manufacturing: a joint innovation by Abemis and Navasto integrates design and prediction AI models. This combined solution computes mechanical performance of hyperstructures in milliseconds, enabling real-time optimisation algorithms for design iteration. The result is the identification of optimal, lightest structures that meet performance requirements, setting the stage for engineers to systematically and rapidly achieve weight efficiency in future Additive Manufacturing projects (Courtesy Abemis/Navasto)

> ***"While we once relied on our empirical understanding of meta-lattice behaviour, or on CAE simulations that required many days of computation on powerful machines, we can now achieve results in seconds using AI simulations."***

recently shed light on a pertinent challenge that engineers often encounter. "Determining the correct meta-geometries for a specific application is often tricky because there can be a large number of parameters, conditions, and constraints." This complexity has long been a bottleneck, particularly when working with advanced materials and complex geometries that defy easy categorisation or modelling.

However, Dr Doehring's team found a groundbreaking solution by leveraging the AI capabilities of its partner, Navasto. The team successfully designed a high-performance, ultra-light, vibration-damping camera mount – a feat that was previously daunting due to computational limits (Fig. 3). "While we once relied on our empirical understanding of meta-lattice behaviour, or on CAE simulations that required many days of computation on powerful machines, we can now achieve results in seconds using AI simulations," he elaborated.

This real-world application serves as a compelling case study for what AI-accelerated engineering can achieve, even in the most challenging of scenarios. Dr Doehring concluded, "This kind of speed-up is revolutionary and I'm convinced it will pave the way for widespread use of metamaterials and optimised hyperstructure components that are very computationally intensive to generate using standard FEA-based procedures."

Contrary to the perception that AI-driven product development is a far-off future, the reality is that the transition is happening more rapidly than many anticipate. Leading aerospace and automotive design departments are in a competitive race to master AI technologies, particularly deep learning surrogate models. Their goals are clear: to significantly reduce their 'time-to-market' Key Performance Indicators (KPIs).

Take SimScale, for instance. This leader in cloud-simulation technology has already partnered with Navasto to offer AI-accelerated engineering solutions. Engineers can leverage these tools today to speed up their design and simulation processes, thus gaining a competitive edge (Fig. 4).

For the AM industry, the advent of AI-integrated design tools is especially impactful. Traditional computer-aided design (CAD) software has evolved to enable the design of complex lattice structures. However, the challenge has always been to understand the physics-based behaviour of these intricate geometries. Conventional approaches often require heavy reliance on experimental data, which is both time-consuming and resource-intensive to collect. AI-driven surrogate models can dramatically cut down this time, allowing for the rapid exploration of design spaces that were previously considered too complex or time-consuming to investigate. Moving beyond the

limitations of complex physics-based behaviour or the necessity for cumbersome experimental data, with AI-accelerated simulations, the industry can quickly validate intricate designs, thus unleashing the true potential of design freedom that AM offers.

The accelerated pace at which these technologies are being adopted is creating a domino effect across sectors. As more companies adopt AI-based tools, those who delay risk falling into obsolescence, as noted by Dr Matthias Bauer. The technology is no longer just an enhancement; it is becoming a requirement for staying competitive.

The integration of AI into product development, and particularly into AM, is not a speculative future – it is a present day reality. Companies and industries that recognise this and act swiftly stand to gain significant advantages, from reduced time-to-market to the unlocking of previously unimaginable design possibilities.

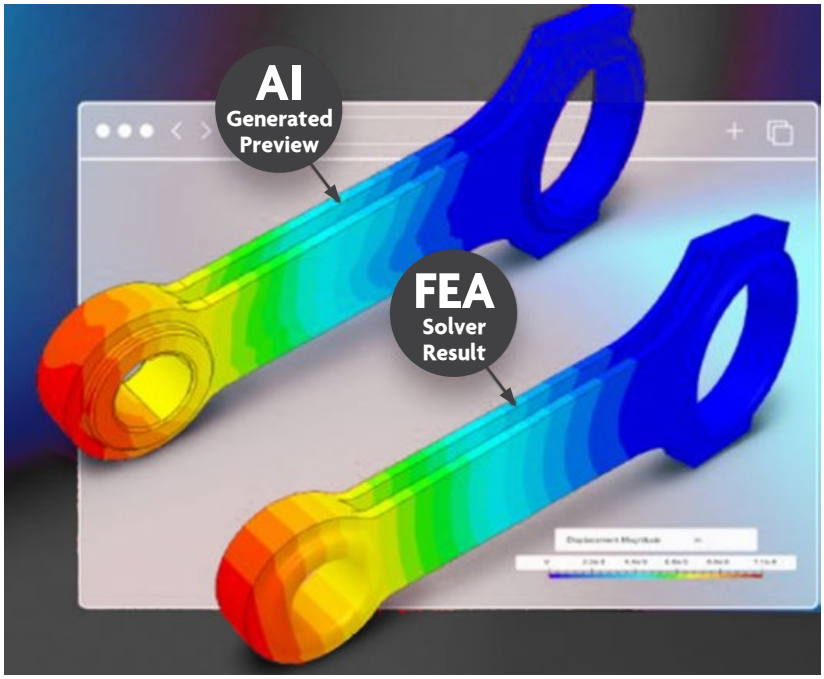

Fig. 4 From hours to seconds: SimScale's cloud-based simulation joins forces with Navasto to unveil an AI prediction tool. This partnership delivers a tangible product for immediate application, dramatically accelerating simulation times and enabling real-time design iterations in the present landscape (Courtesy SimScale)

Software-defined autonomous machines

Of all metal Additive Manufacturing processes, Laser Beam Powder Bed Fusion (PBF-LB) stands out as arguably the most commercially successful and widely available technology. However, the current hardware seems to have reached its operational limits. Modern PBF-LB machines are growing in size, with some accommodating up to twenty lasers in a 1 x 1 x 1 m volume. The resulting increase in machine complexity, while enhancing capabilities, also introduces the potential for operational issues. "The sophisticated interactions between components in AM machines challenge the consistency of performance and manufacturing stability."

Moreover, the generation of toolpaths, pivotal for machine function, may not always result in the desired accuracy. Much currently used software can overlook the intricate relationship between energy, material, and the design's geometry and the result can be uneven thermal stresses during production, leading to distortion, varied microstructures, and potentially a reduction in the final product's mechanical strength. These inefficiencies lead to higher scrap rates and more frequent non-conformance in final parts.

Adding to these challenges, the combined complexities of both hardware and software – along with limited proactive control – risk further burdening engineers during part qualification and certification. Predicting the performance of parts – particularly large, critical and complex parts – is notably difficult given the nuanced interactions of machine components and software

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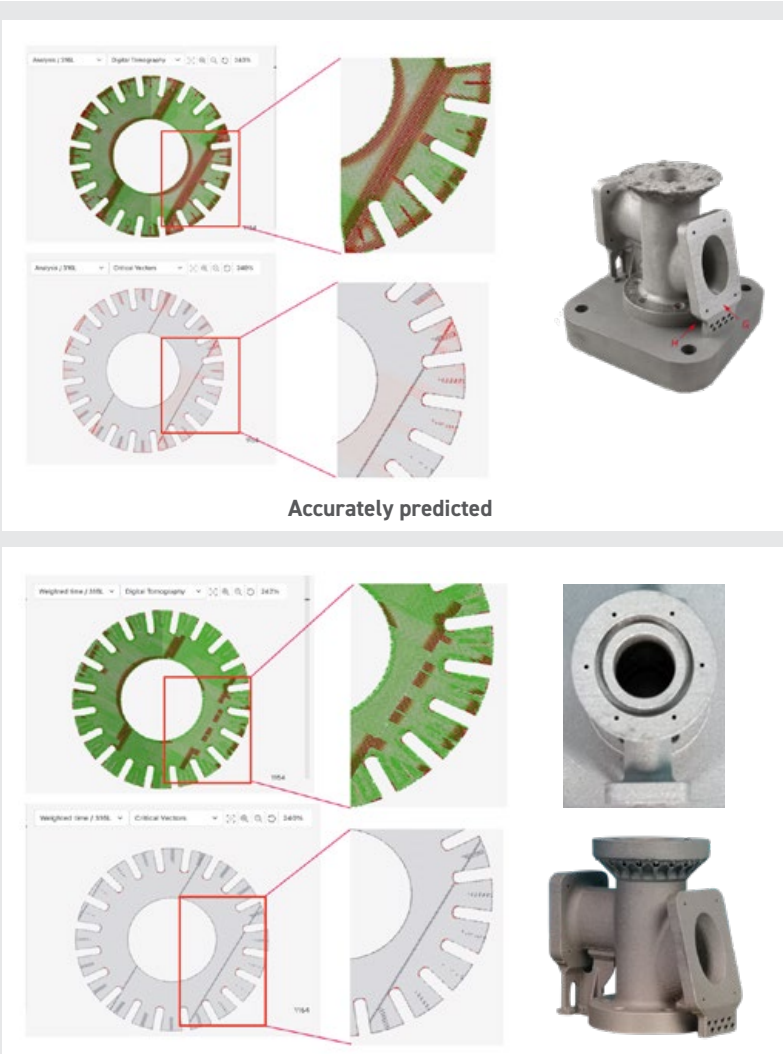

Fig. 5 The power of AMAIZE in addressing suboptimal thermal management enables a shift from iterative design and support structures to 'first-time-right' complex geometries. The figure highlights AI-predicted thermal profiles as pivotal enablers for precise correction strategies, enabling maximum hardware utilisation and unlocking the potential of AM machines (Pipe courtesy VTT Technical Research Centre of Finland)

protocols. Any unpredictability risks lengthening qualification phases and complicates certification processes, resulting in an extended and more complex pathway to final part approval.

Given these challenges, the potential role of AI in this space becomes paramount. Could AI provide solutions to address these hardware and software intricacies, streamline the qualification processes, and bring about more predictable and efficient manufacturing outcomes?

One of the advances in this field is coming from 1000Kelvin, a company that I co-founded, which is building a next-generation AI-enabled software control platform for AM. Based in Berlin and Los Angeles, California, the firm is working closely with leading machine builders such as EOS and Nikon SLM Solutions to deploy its AI technology, AMAIZE, at scale.

Dr Katharina Eissing, CTO and co-founder of 1000Kelvin, is a theoretical quantum physicist who leads a team of seven mathematicians and physicists working on the development of AMAIZE. She has been convinced since the first day she learned about AM that it is the ideal use case for a deep learning-based control model. "Physics-based models and numerical simulations have been instrumental in the success of our civilisation. Integrating these models with a deep learning approach opens an entirely new domain of opportunities in terms of precision and speed," she stated.

"Consider a one-metre high part. It would contain tens of thousands of slices and millions of vectors within its toolpath. Using academic-type simulations to understand the full part would, without exaggeration, take millennia. At 1000Kelvin we have for several years been developing a deep learning model to expedite these predictions, optimising thermal management and enabling our customers to produce higher-quality parts using the PBF-LB process with minimal iterations" (Fig. 5).

"This is extremely complex technology that requires superior

"Physics-based models and numerical simulations have been instrumental in the success of our civilisation. Integrating these models with a deep learning approach opens an entirely new domain of opportunities in terms of precision and speed."

Fig. 6 Located an hour south of Berlin, BTU's first AM research and pre-production facility is fully equipped with end-to-end hardware and an AI-enabled software platform from 1000Kelvin for generating optimal build files. BTU is collaborating with 1000Kelvin to develop next-level monitoring capabilities for closed-loop feedback and advanced material characterisation. This advanced integrated environment is aimed at unlocking new capabilities in Laser Beam Powder Bed Fusion (PBF-LB) (Courtesy Brandenburg Technical University)

understanding of the physics of the process, a massive amount of computing power, and a physical platform to test and validate these large-domain, expert AI models. From the start, we have been fortunate to work with leading space and industrial companies to validate our technology on their extremely complex parts and gain traction from day one," stated Eissing.

The company has established a long-term strategic R&D partnership with the Brandenburg Technical University (BTU), Berlin, and the Chair of Hybrid Manufacturing, Prof Sebastian Härtel, giving it access to a world-class research facility that includes seven industrial grade PBF-LB machines equipped with all types of monitoring and materials characterisation technologies (Fig. 6).

"In collaboration with 1000Kelvin's research and development team, we are actively exploiting the machine learning algorithms instantiated in AMAIZE. The recursive learning paradigms demonstrated by this Artificial Intelligence are nothing short of transformative. Currently, we are spearheading an initiative that employs this computational framework to deterministically forecast material properties. The implications of this technology are not merely incremental; they represent a paradigmatic shift in the field," stated Härtel.

> ***"From the start, we have been fortunate to work with leading space and industrial companies to validate our technology on their extremely complex parts and gain traction from day one."***

Access to these advanced models will unlock potential that goes beyond simply achieving accurate builds at the first attempt. The predictive software capabilities of the technology are already allowing customers from aerospace, industrial manufacturing, and service bureaux to reduce the amount of scrap, distortion and necessary support structures substantially. The software's ease-of-use enables users to

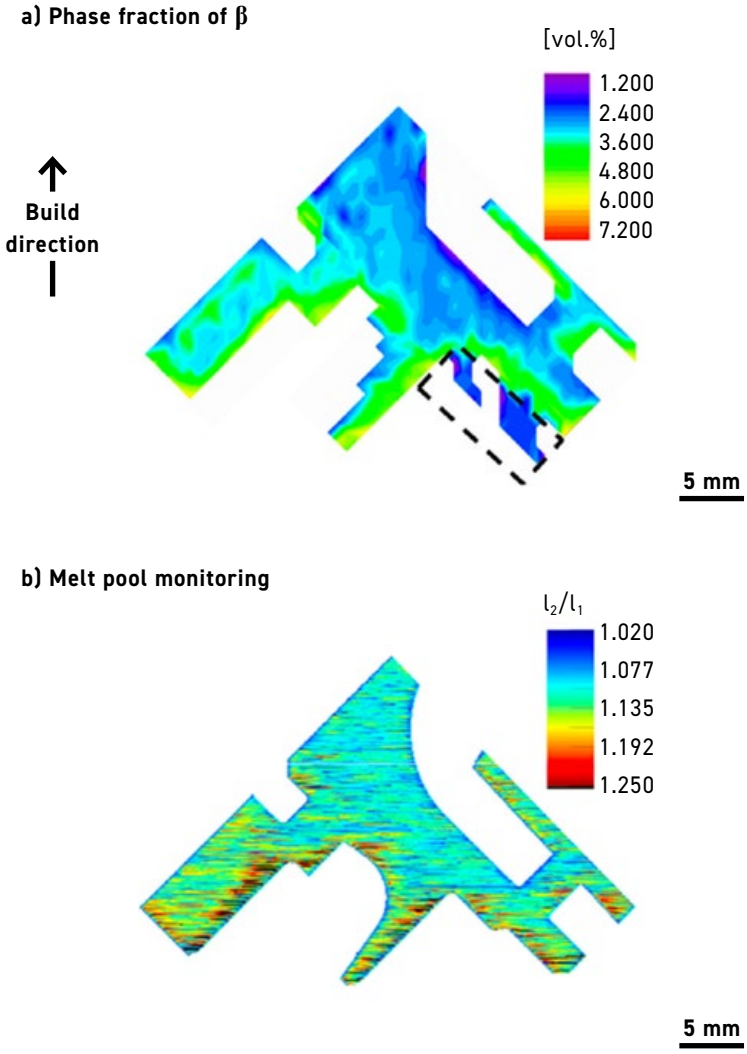

Fig. 7 Digital material will be a key enabler to achieve material properties consistency. This figure indicates how in the downskin areas that received higher thermal exposure, measured here using a melt pool monitoring system, demonstrated a microstructure change proved using XRD. The prediction of the temperature profile at the scale of scan strategies is a key enabling technology to develop a digital material framework (Courtesy DLR Institute of Structures and Design)

benefit from AI immediately – not at some distant point in the future. The predictive nature of the technology has other benefits, such as the ability to fix a user's process upfront with a high level of traceability.

Furthermore, AI technology is enabling the 'holy grail' of digital manufacturing – that is, the concept of digital materials built on advanced understanding and control of processes; so, not just to build a 3D geometry, but to induce the desired properties in a localised manner (Fig. 7). On this front, the team at 1000Kelvin is already developing a proof of concept for the control of phases during the manufacturing of Ti-6Al-4V, a well-known problem in the aerospace industry.

Combining the ability to reduce engineering time and iterations through increased software automation, achieve accurate builds on the first attempt, minimise the need for support structures, and customise material properties will unlock the vast market potential for PBF AM. What might have seemed impossible just a year ago is immediately within reach. An AI-powered future for Additive Manufacturing will see increasing autonomy and, thus, better yield and quality. As AI models mature and improve in performance, they will become central to the systems of the industry, making future developments all the more interesting and providing powerful tools to help accelerate the scaling of AM.

Quality Assurance: AI watch

The maturation of Additive Manufacturing, particularly in metal-based PBF-LB, hinges not just on the sophistication of process technologies but also on robust quality control mechanisms. Although effective, traditional post-mortem techniques, such as X-ray tomography and ultrasound, introduce latency and resource inefficiency into the production cycle. AI-powered in-situ monitoring, leveraging advanced machine learning and deep learning

"Although effective, traditional post-mortem techniques such as X-ray tomography and ultrasound introduce latency and resource inefficiency into the production cycle. AI-powered in-situ monitoring, leveraging advanced machine learning and deep learning algorithms, offers a transformative solution."

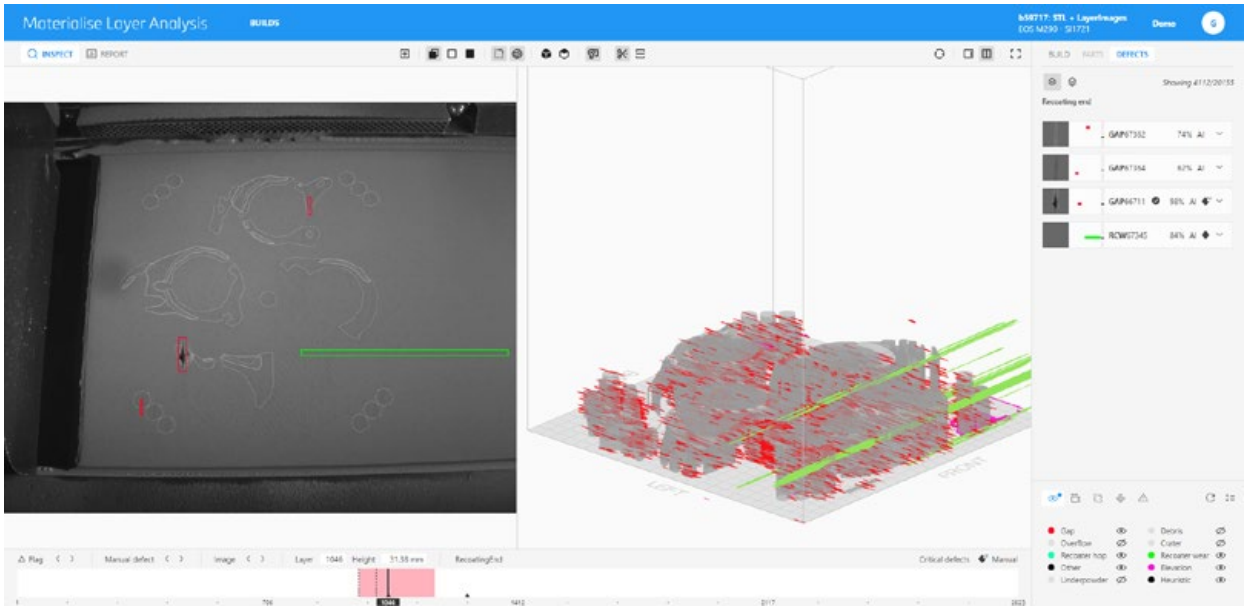

Fig. 8 AI-based defect detection is leveraged across multiple software and monitoring systems. A large amount of training data enables the detection of failed builds and various other defects. The primary business cases currently focus on stopping nonconforming builds to save both time and materials, as well as reducing the costs of quality control – often a requirement in high-end industrial applications. Challenges remain in the transferability of these solutions from one system to another and in their level of reliability. However, these issues are expected to be overcome soon due to the increasing volume of available data (Courtesy Materialise)

algorithms, offers a transformative solution.

These AI systems provide real-time insights into the integrity and quality of the part being manufactured, allowing for immediate corrective actions and resource optimisation. By integrating sensor data and machine learning analytics directly into the manufacturing process, AI sets the stage for not only higher reliability but also for the operational agility required in next-generation manufacturing ecosystems. This essentially evolves AM from a 'build-then-check' to a 'build-and-check' paradigm, marking a significant leap in both performance and cost-efficiency.

Moreover, commercially available image-based analysis tools from companies such as Materialise (Fig. 8), Zeiss (in collaboration with EOS), Addiguru, and Additive Assurance are accelerating this transformative shift. Utilising diverse machine learning methodologies, these tools offer turnkey solutions for real-time defect detection during the build process. They serve as critical decision-making instruments, enabling manufacturers to either halt a failing build – thereby mitigating the cost of failure – or enhance quality control measures dynamically. This further solidifies the role of AI in transitioning from build-then-check to build-and-check, adding another layer of performance and cost-efficiency.

The efficacy of this AI-driven in-situ monitoring is underpinned by process signatures – data amalgamated from machine control systems and an array of sensors. These process signatures serve as real-time health indicators of the PBF-LB process, enabling nuanced control over structural integrity and surface roughness. Ideally, a fully-realised in-situ monitoring system will promptly detect and rectify anomalies, thereby auto-calibrating PBF-LB process parameters or even the machine itself.

However, challenges persist. Correlating these process signatures with user-defined quality attributes for accurate anomaly and defect characterisation remains an open research question. The selection of sensors and monitoring techniques, particularly their spatial and temporal resolutions, is an ongoing debate among experts.

Moreover, the issue of measurement error is often underestimated, calling for a more rigorous approach to uncertainty quantification. Further complexities include the standardisation of measurements for precision, and the interpretation of data to assess the holistic health state of a PBF-LB system. There is an evident need for more focused research to comprehend the intricacies of adopting either on- or off-axis process sensing and monitoring, considering variables like accuracy, frequency, and spatial-temporal resolutions. In a recent comprehensive review of the state of the literature, Dr Tuğrul Özel, a full professor at Rochester Institute of Technology (RIT), New Jersey, USA, stated, "The long-term aims for in-process monitoring can include utilising machine learning and Artificial Intelligence to develop processes that are self-learning and intelligent, and also transferable from machine-to-machine."

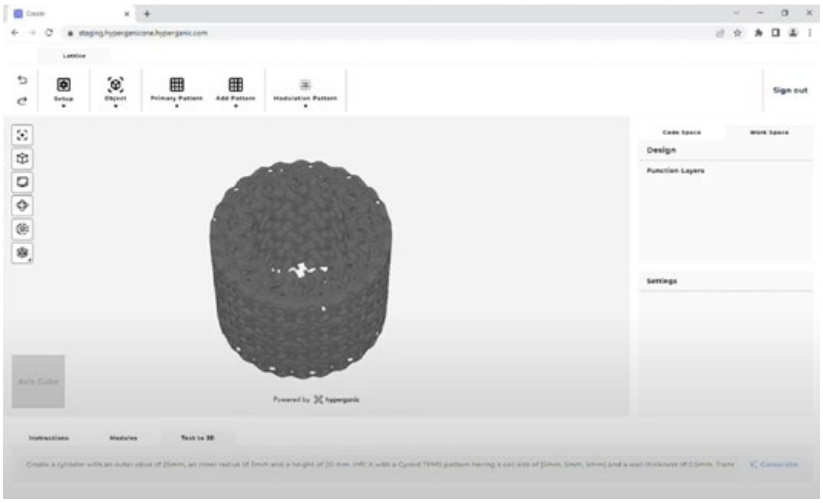

Fig. 9 Hyperganic's Text-to-3D technology leverages large language models such as OpenAI's GPT and Meta's Llama. These models are trained on specialised data and prompts to enable end-users to generate designs via natural language inputs. This utilisation of natural language models has the potential to unlock unprecedented design capabilities. While Hyperganic's programmatic design approach has historically been viewed as requiring specialised programming skills and, therefore, be potentially difficult to use, the integration with large language models could propel the technology to new heights (Courtesy Hyperganic)

The role of large language models

Large language models (LLMs) such as GPT-4 are fundamentally redefining the way humans interact with technology, solidifying natural language processing as the new human-machine interface. The evolution of software development paradigms has reached a stage where the most intuitive programming language is increasingly becoming English itself. As the technology undergoes rapid advancements, these models are not just confined to language but are becoming multi-modal, capable of understanding and processing various types of data. Their fine-tuning capabilities allow them to adapt to specialised tasks, thereby making them invaluable across diverse sectors.

> ***" ...there's a rising concern about the misuse or overextension of the term AI in product labelling – particularly when the integration is minimal. Adding a chatbot interface powered by GPT to a product does not necessarily make it a transformative AI solution, especially in specialised fields such as AM, design, and engineering."***

In the context of AM, companies are already leveraging these capabilities to solve industry-specific challenges. For instance, Hyperganic is actively researching how to leverage LLMs to make its algorithmic engineering design technology more accessible, removing the necessity for specialised software or coding skills, and thus broadening its user base. In a recent demonstration of a proof of concept during the CDFAM symposium in New York, Hyperganic demonstrated a direct human language interface supporting the systematic design of complex lattice structures (Fig. 9).

While LLMs offer groundbreaking capabilities for human-machine interaction, there's a rising concern about the misuse or overextension of the term 'AI' in product labelling – particularly when the integration is minimal. Adding a chatbot interface powered by GPT to a product does not necessarily make it a transformative AI solution, especially in specialised fields such as AM, design, and engineering.

Before delving further, it is crucial to understand what multi-modality means in the context of LLMs. Multi-modality refers to the model's ability to understand, interpret, and generate multiple types of data – such as text, graphs, numerical data, and 3D designs – rather than just text. This capability is vital for complex tasks in specialised industries. The challenge in Additive Manufacturing is not merely adding a chat-based interface, but involves rigorous fine-tuning of the model for the specific tasks at hand. This fine-tuning demands high-quality, specialised data – often requiring the model to master complex concepts such as multi-modality – in order to provide actionable insights or generate usable outputs. For instance, in AM, a simple chatbot function would be vastly insufficient for tasks like generative design optimisation, which could involve interpreting CAD files, material stress simulations, and natural language inputs, all in an integrated manner.

Given these complexities, the emergence of Text-to-CAX (Computer-Aided Design, Manufacturing, and Engineering) solutions is on the horizon. However, it comes with some caveats. Companies venturing into this space should be prepared for substantial time and resource investment to nail the true value proposition expected by customers. Therefore, while it's tempting to jump on the AI bandwagon by merely integrating a chatbot into a product, stakeholders should be cautious. Such a simplified approach risks diluting the meaning of AI and could lead to customer disillusionment, particularly when the technology fails to deliver on substantial, industry-specific challenges.

A call to action: seize the AI-driven future of Additive Manufacturing now

The convergence of AI and AM represents more than an incremental upgrade – it is, in my view, a seismic shift, capable of reshaping industries. As we've explored in this article, AI is no longer confined to academic circles or niche applications. It is an enabling technology that's infiltrating every aspect of AM, from design and simulation to quality assurance and beyond and is already being leveraged by leading companies within our industry.

We're at a crucial inflection point. The challenges facing AM – efficiency, quality, and standardisation – are not trivial. Yet they are not insurmountable either, especially with the AI tools at our disposal. Companies such as Navasto and SimScale are already using AI to cut simulation times from hours to seconds, opening a huge world of opportunities to DfAM and reduction of time-to-market. Leveraging deep learning to optimise thermal management and enable predictive first-time-right outcomes improves part quality and reduces cost per part, allowing AM to be more competitive. Multiple monitoring companies are leveraging their understanding of data and reinforcement learning to enable in-process quality control. And the role of LLMs such as GPT-4 is just beginning to be understood; their potential to simplify complex tasks and democratise technology is vast.

Now is the time for action. Every stakeholder in the AM ecosystem, from engineers and designers to decision-makers and investors, is encouraged to recognise the transformative potential of integrating AI into their processes. The question is not whether AI will revolutionise AM – I can see that it is already happening. Those who embrace the synergistic potential of AI and AM have, I believe, the opportunity to place themselves at the forefront of an industry on the cusp of extraordinary change.

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ADAXIS: On a mission to reduce the layers of complexity in robotic Additive Manufacturing

France's ADAXIS is tackling two of the most complex advanced industrial manufacturing disciplines head on — Robotics and Additive Manufacturing. Its solution aims to make robotic Additive Manufacturing more accessible to any company that wants it, including for metal processes, irrespective of background or industry sector. Rachel Park spoke with Henri Bernard and Emil Johansson, two of ADAXIS' co-founders, as well as project partners, to discover their story and ambitions.

Necessity is the mother of invention. This centuries-old proverb still has a ring of truth to it, even in the 21st century. It often proves to be a key driver for taking many new business ideas into commercial reality. In the case of ADAXIS, necessity was certainly one driver to the founding of the company, accompanied by passion.

To explain, ADAXIS was founded early in 2021 when four people, Henri Bernard, Guénolé Bras, Emil Johansson and Vasan Churchill, were driven by a shared frustration towards the time-consuming and complex task of programming industrial robots for Additive Manufacturing and the resulting access barriers within the industry.

Prior to 2019, Bernard and Bras (at the ESTIA Institute of Technology in France) and Johansson and Churchill (at the RISE Research Institute of Sweden) simultaneously undertook years of applied research into using industrial robotics for advanced manufacturing. In 2019, serendipity brought all four together following the launch of EIT Manufacturing, an EU-funded institution backing the most innovative manufacturing projects in Europe.

At a match-making event hosted in San Sebastian, Spain, Johansson, who was only in attendance because his manager was unable to be there, "presented a pitch that sparked interest from numerous companies and also got the attention of the team at ESTIA. None of us knew each other at this time, but we joined together for an applied research project that was granted funding."

The project itself highlighted a number of things, not least the frus-

Fig. 1 The ADAXIS founders, from left to right: Guenole Bras, Vasan Churchill, Emil Johanson and Henri Bernard (Courtesy ADAXIS)

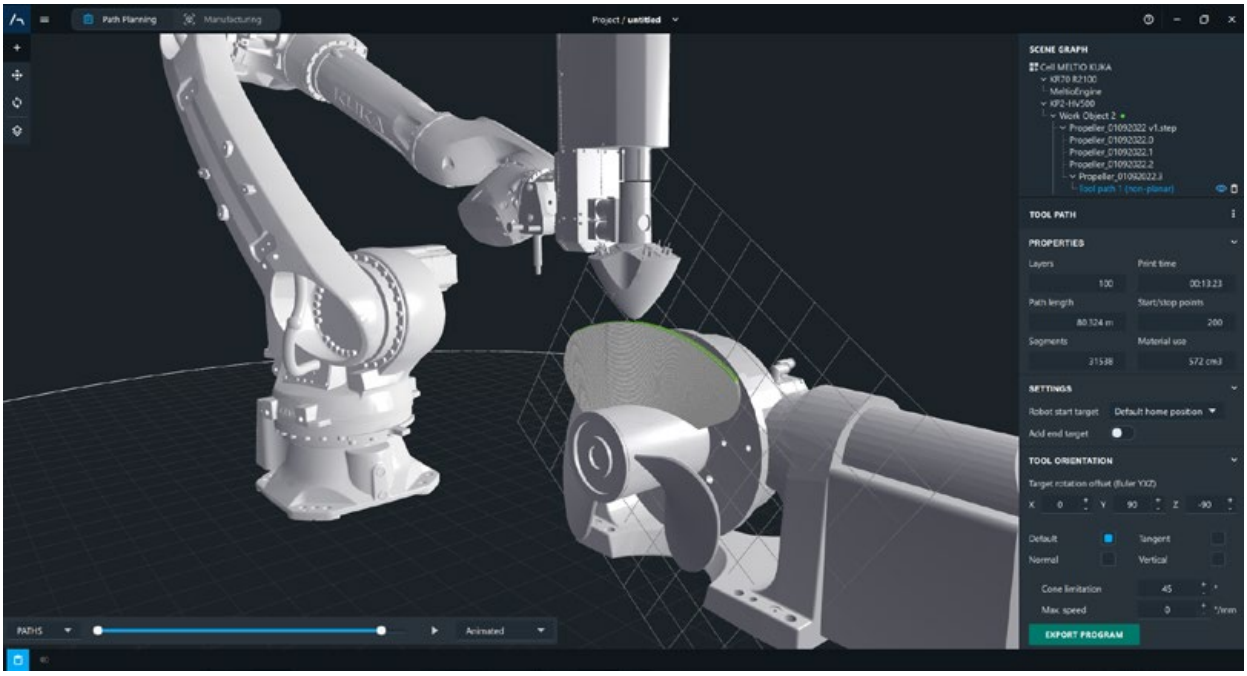

Fig. 2 Path planning preparation in ADAXIS' AdaOne software (Courtesy ADAXIS)

"The challenge that the company is addressing is that with each industrial robot there is different control software, and with each Directed Energy Deposition (DED) technology, there is different control software, with different parameters for each alloy used."

trations as outlined above, but also the passion and depth of knowledge across the project's partners. It also began to lay the foundation for a real solution that could dramatically impact industry. Johansson added, "The project took place during the COVID years (2020-21), so we spent a lot of time sharing ideas and knowledge remotely, which in the end formed a solid foundation for ADAXIS." Today, ADAXIS is a fully commercialised French-Swedish robotics software company, delivering its innovative solution to a growing customer base.

The challenge that the company is addressing is that each industrial robot comes with different control software, with each Directed Energy Deposition (DED) solution there is different control software, and there are different parameters for each alloy used. The consideration of the almost-unlimited possible combinations of robot, printhead and alloy is a very complicated task of software integration.

The company's solution? Its AdaOne software takes away the pain of writing custom code for each new system integration.

Technical challenges in robotic AM

Today, it is possible to use most metal DED technologies on a robotic arm to provide flexibility in deposition rate, surface finish and material choice – from stainless and carbon steels to aluminium and titanium alloys. Each technology has its own unique control challenges and limitations which need to be taken into account during path planning in order to produce defect-free parts. Using the full multi-axis potential of robotic arms for metal AM requires a fundamental understanding of each process.

A crucial factor in metal deposition, whether it's for Additive Manufacturing, repair or any other application, is achieving a uniform and stable melt pool. This is controlled and optimised through common process parameters, including traverse speed, material feed rate, and energy input.

Path planning for Additive Manufacturing and multi-axis deposition brings another level of complexity and additional important factors:

Fig. 3 A robotic arm at Addimadour controlled by AdaOne (Courtesy Additimadour)

- Orientation of material deposition
- Trajectory generation strategy
- Homogeneity of heat distribution
- Variation in bead height and width
- Variation in workpiece distance

These factors directly impact the final quality of the part, for example dimensional tolerances, internal stresses, and porosity.

AdaOne has been specially developed to handle the above challenges through its custom-built path planning engine. It can handle state-of-the-art trajectory generation on planar and non-planar substrates and optimises layer height variation and tool orientation to follow part geometries. Each layer can be segmented to adapt deposition strategy and path traversal, and dynamic process control can be used to optimise the different deposition phases.

Henri Bernard further explained, "The mastery of thermal control, and thus process control, becomes pivotal. The approach adopted for piece fabrication substantially influences the final result. Parameters such as fill methods, pause durations, arc restarts, and modes tailored to each specific component are indispensable. None of this is easy, but these features in AdaOne empower users to rapidly, effortlessly, and efficiently program their robots according to their specific application requirements."

This is where AdaOne stands out: it enables users to precisely and easily configure all of these parameters.

The ability to seamlessly translate this outcome into a precise robotic language (whether KUKA, ABB, Yaskawa, Fanuc, et al) to optimise trajectory (position, orientation, speed, acceleration, interpolation) and the process itself (material feed, power, etc.) becomes vitally important.

"AdaOne has been specially developed to handle the above challenges through its custom-built path planning engine. It can handle state-of-the-art trajectory generation on planar and non-planar substrates and optimises layer height variation and tool orientation to follow part geometries."

Fig. 4 Inspecting a DED build powered by AdaOne at Addimadour (Courtesy Additimadour)

> ***"We're streamlining task automation and geometry computation, to facilitate the effortless generation of intricate trajectories in just a couple of clicks. This empowers the operator to use a workflow and enjoy a user experience that is comprehensible to all users, regardless of their levels of expertise..."***

The ADAXIS approach is straightforward, according to Bernard, who explained, "We're streamlining task automation and geometry computation, to facilitate the effortless generation of intricate trajectories in just a couple of clicks. This empowers the operator to use a workflow and enjoy a user experience that is comprehensible to all users, regardless of their levels of expertise in programming."

He continued, "This endeavour encompasses various facets, including the intricate programming of highly complex parts, automated segmentation based on shape, layers, and modes (perimeter, infill), and the slicing of non-planar components to preserve their form by leveraging the process's inherent flexibility whenever possible. The integration of material-specific rules, for example, aluminium versus titanium in DED, advanced business rules (consider the distinction between printing a dense, compact 300 kg part versus a delicate topological component), and the flexibility to modify a point, curve, or parameter within a program comprising millions of points are integral. All of this must be achieved while ensuring a seamless and precise simulation, affirming that no issues will arise during actual production. Once satisfaction is attained, the build profile can be saved for subsequent applications."

And if all of that was not enough, AdaOne also enables real-time monitoring of the system and the process. This invaluable feature allows users to observe the robot's exact position, speed, material and energy consumption (including laser power/arc current and voltage), shielding gas quantities, and a comprehensive array of secondary parameters essential for a thorough process understanding. This digital twin serves a dual purpose: enhancing process comprehension and configuration, and guaranteeing process repeatability and compliance.

The grand challenge AdaOne has solved through automatic configuration and initiation is to deliver these features and facilitate them with just three clicks. This is literal – not figurative!

Talking applications

ADAXIS is already seeing successful deployments of its software. The company quotes that AdaOne is currently running on more than 200 industrial robots globally, allowing them to produce AM parts in a range of materials. Of these, eighty are being used to produce metal components.

Bernard expanded on this, stating, "AdaOne is being used across many industry sectors and we are seeing feedback from users that are directly printing large, complex parts as well as some users that are utilising robotic AM to repair existing parts. You can probably guess that I can't go into details on specific applications, but, to give you an idea, companies in the aerospace and defence sector are working with us. The transport sector features heavily, notably for train parts and brakes. Unsurprisingly, the energy sector also features strongly for blades and turbines. The versatility that AdaOne brings to their existing industrial robot capabilities is proving to be very useful. As is the flexibility. The feedback we have received highlights that this is in relation to the technology itself in fulfilling previously difficult applications, but also geographically flexible because the equipment can be moved between locations, to meet requirements at the place of need."

He continued, "Across our community of metal AM users, we are also starting to see a new hybrid approach. Because of the nature of the DED process, which allows users to print a wide variety of metal materials onto a substrate (which can be an existing part, or part of a part), manufacturers are combining traditional manufacturing processes with robotic AM, where complex features can be produced with AM only where

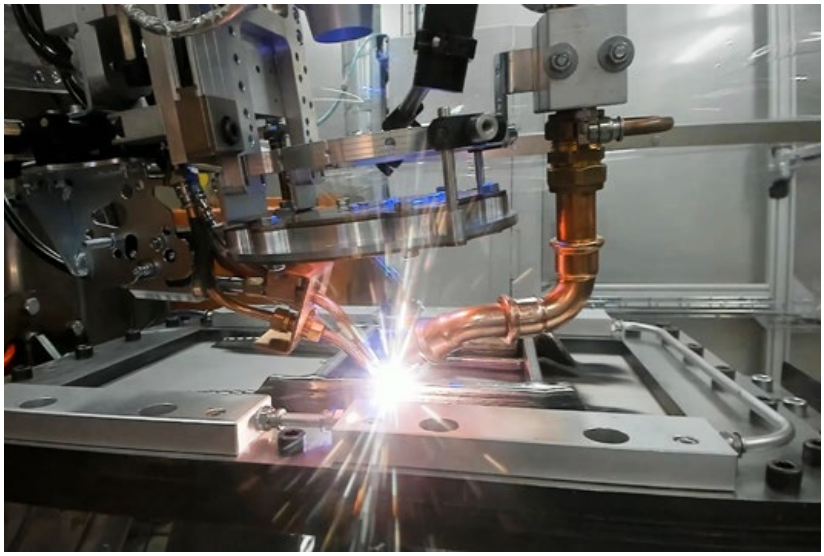

Fig. 5 An aerospace structure being built using DED technology controlled by AdaOne at Procada (Courtesy Procada)

Fig. 6 Top: An as-built DED aerospace structure, and below: an as-built structure image combined with a machined structure image (Courtesy Procada)

Fig. 7 A metal AM structure produced by Exafuse using a robotic arm controlled by AdaOne (Courtesy Exafuse)

they need it. This approach is proving to save time and money for our users."

Johansson described how ADAXIS has worked with early adopters from the beginning and has grown its user base over the past eighteen months, "Early on during the first year, we contacted about ten companies that we had worked with to be pilot users and worked with them throughout that first year until one year later, in 2022, we launched the product commercially. From there we have basically penetrated every industry sector in one way or another and today we run more than 200 robots as industrial AM machines."

"We see robotic AM as a key enabling technology for large-scale complex parts manufacturing. Robotic AM enables repeatable precision for highly complex components of any size. It is also a very flexible technology that can cater to a wide variety of material specifications."

Successful partnerships

The ADAXIS leadership team views partnerships as a foundational growth strategy for the company. These partnerships span the AM ecosystem and include OEMs and metal material companies. ADAXIS is currently working closely with Addimadour, an R&D centre located in Bayonne, France, not far from ADAXIS, that is dedicated to large-scale metal AM. It is equipped with technologies for laser-based DED (DED-LB) and arc-based DED (DED-Arc), laser cladding, and Cold Spray Additive Manufacturing (CSAM). Backed by the Compositadour platform, Addimadour was launched in 2017 by, and for, companies to support the development of their metal AM projects.

According to Addimadour's Pierre Michaud, "We see robotic AM as a key enabling technology for large-scale complex parts manufacturing. Robotic AM enables repeatable precision for highly-complex components of any size. It is also a very flexible technology that can cater to a wide variety of material specifications. At Addimadour, we provide tailored research and engineering capabilities together with training for students and company engineers at different levels."

He continued, "Our advanced robotic AM capabilities are significantly enhanced by our partnership with ADAXIS. The ADAXIS software controls our robotic systems simply and painlessly. The software eliminates the time-consuming and complex programming of our industrial robots for Additive Manufacturing which has always been a bottleneck. ADAXIS has helped us transform how we operate robots for Additive Manufacturing in the most positive way."

ADAXIS has also established successful and ongoing collaborations with several other key organisations. This includes industrial applications with Procada based in Sweden; Fortius Metals based in Colorado, USA; and Exafuse based in Germany; as well as partnerships with leading universities and research institutes,

such as Politecnico di Milano, Italy, Technalia and AIMEN in Spain, CCAT in Connecticut, USA, Tampere University of Applied Sciences, Finland, and Nagaoka University of Technology, Japan.

Procada is a startup specialising in controller solutions for large scale laser DED — with wire feedstock — for critical applications in sectors such as energy, marine and aerospace. Petter Hagqvist, CTO at Procada AB commented on the partnership between Procada and ADAXIS, stating, "At Procada, we have identified the process of turning a CAD-file into robot movements as a critical link in the chain for realising reliable DED builds. For our wire/laser DED process, tool positioning and build path planning is especially crucial due to the unforgiving process dynamics. ADAXIS' solution to these problems, for us, seems to be a particularly competent and flexible one that suits our needs very well."

Fortius Metals has developed proprietary robotic AM welding wires designed specifically for wire DED Additive Manufacturing processes using arc, laser and electron beam energy sources. The company has a complete wire manufacturing capability located at its Lafayette, Colorado, facility and utilises AdaOne software.

Conclusion

When the ADAXIS team say they want to keep it simple and accessible, they really mean it. Bernard rounds up, "We deliver AdaOne as an on-premises software, and we keep it really straightforward — one key allows AdaOne to be activated on one computer and program an unlimited number of robots. It is competitively-priced and as a company we offer ongoing support and encourage community engagement and sharing. This means that robotic AM becomes accessible, cost-efficient, and easy to use."

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Exploiting your metal Additive Manufacturing data assets: Faster industrialisation and new revenue streams

While metal Additive Manufacturing is revolutionising industries from aerospace to healthcare, the need for efficient process development and the acquisition of validated material data is becoming increasingly important. In this context, a groundbreaking solution emerges – that of the platform-based exploitation of metal AM data assets to accelerate industrialisation and unlock new revenue streams. Here, Rosswag GmbH's Philipp Schwarz and Gregor Graf delve into the significance of this concept and how it fits as a crucial piece in the AM industrialisation puzzle.

In the dynamic landscape of metal AM, the quest for optimised and rapid process development is a prevailing trend. There are currently only a few dozen materials that are qualified for industrial metal AM applications. Conventional manufacturing processes, however, have the option to choose from thousands of iron-based alloys, for example. This leads to slower AM application development, among other things, resulting in a reduced speed of industrial adoption despite the tremendous technological potential of the technology. In addition to this, we have yet to consider the development of new materials with previously unobtainable properties that can only be processed by metal AM.

The complexity challenge

Laser Beam Powder Bed Fusion (PBF-LB) is currently the leading metal AM process, yet it remains complex to master. Depending on machine type, there are numerous different parameters that influence the quality, production time and cost of an additively manufactured metal part. As with all metal forming processes, complexity increases further if raw material production or complex heat treatment cycles are considered. With new developments such as beam shaping, high-temperature preheating or multi-material manufacturing, there are additional factors that contribute to a further growth of parameter complexity.

So, when there is such complexity, why should an AM user even think about optimising their standard parameter sets? The simple answer is that if they don't, they are not leveraging the full potential of their expensive hardware.

Process parameters can be optimised not only for higher productivity. There is a wide range of

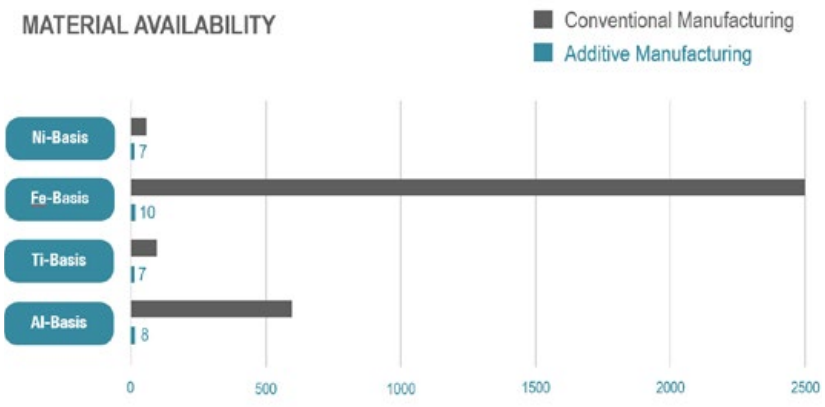

Fig. 1 Metal material availability for comparison of conventional and Additive Manufacturing processes (Courtesy Rosswag)

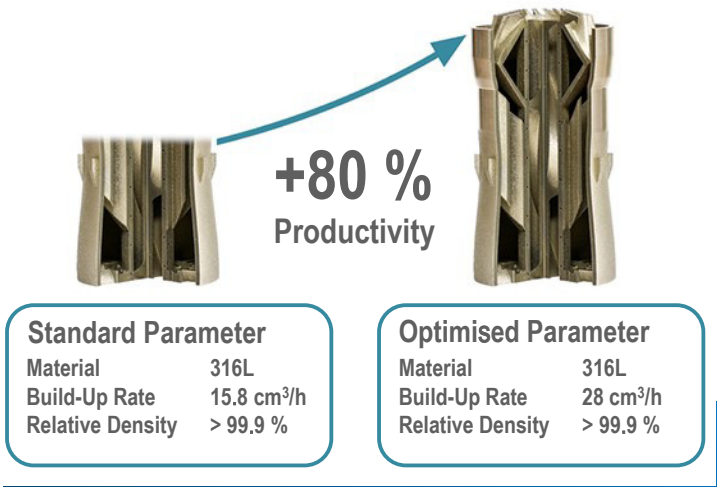

Fig. 2 Process parameter optimisation potential for higher build-up rates on 316L parts (Courtesy Rosswag)

"The reality is that so many AM users have the potential to relatively easily double their output – and revenue – through parameter optimisation. But all too often, for years, only the standard parameters from the machine manufacturer are used."

possibilities for application-oriented optimisation, whether parameters for thin-walled structures in heat exchangers, special downskin parameters for optimising surfaces, or the combination of different parameter sets in one component.

Normally, the implementation of all these possible optimisations largely remains on the AM user. With the growing complexity of metal AM – including diverse machines, system configurations, materials, and stringent part certification demands – the number of potential parameter combinations for PBF-LB machines appears virtually limitless. Yet, the question arises: are these possibilities effectively harnessed by the average AM user or are they simply overwhelmed by the complexity?

The reality is that so many AM users have the potential to relatively easily double their output – and revenue – through parameter optimisation. But all too often, for years, only the standard parameters from the machine manufacturer are used.

Optimised and rapid process development: an emerging trend

As industries seek cost- and time-efficient methods to qualify new materials and streamline production, several approaches have emerged. Companies such as Materialise have introduced innovative tools such as the Process Tuner, facilitating the design of comprehensive parameter studies supported by simulations. Additionally, the integration of Artificial Intelligence (AI) tools by entities such as Senvol has enabled the design and analysis of parameter studies, propelling the AM industry toward quicker and more informed decision-making.

Despite the abundant opportunities for process optimisation, a significant efficiency gap persists within the metal AM industry. A common starting point is the optimisation of build rates using standard alloys like 316L or AlS10Mg, often relying on the standard parameter sets provided by AM machine OEMs. This standardised approach results in redundant efforts and a lack of progress, stifling overall industry efficiency.

The repeating of productivity studies on standard alloys raises a pertinent query – is it truly advantageous to undertake exhaustive material qualification efforts when others in the market have already traversed the same path? The generation of material data involves substantial costs, making viable business cases challenging to establish unless catering to industries such as aerospace and medical. Even simple parameter studies with some cube and tensile specimens built and analysed can cost about €10,000. For a qualification of new parameters for more demanding series components and dynamic load cases, qualification with the large number of samples required quickly costs more than €200,000.

These costs are, of course, influenced by whether the work is done in-house, externally, or using certified test houses. The need for a more collaborative, efficient, and sustainable approach to data acquisition and optimisation in metal AM becomes evident or even essential.

The AddiMap marketplace: transforming metal AM through data monetisation

A real innovation that holds the potential to reshape metal AM

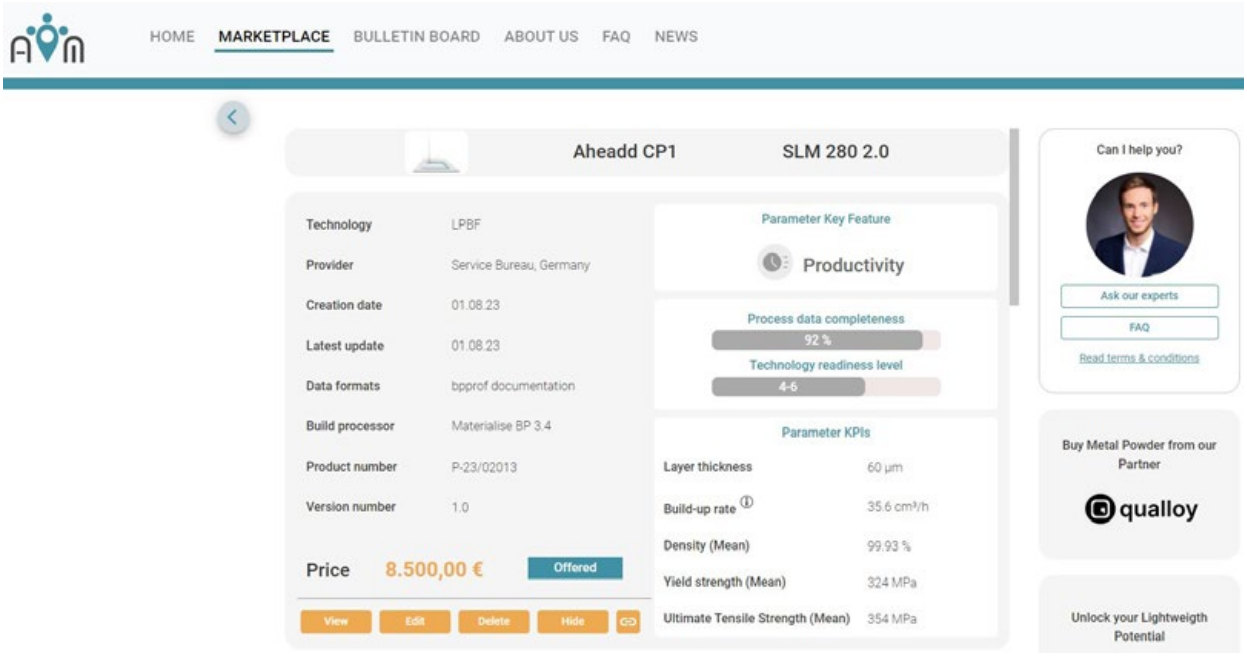

Fig. 3 An example of a parameter set for the aluminium alloy Aheadd® CP1 from Constellium for a SLM® Solutions 280 2.0 system (Courtesy Rosswag)

optimisation and development is the world's first process parameter marketplace for PBF-LB: AddiMap. This platform introduces a novel approach to expedite process parameter development and material data acquisition. Companies armed with self-developed process parameters can list their parameters on AddiMap, alongside relevant material and process data. The uniqueness and quality of data influence the pricing of these parameters.

The platform's approach raises a pertinent question – why not offer initial parameter sets with preliminary results? Particularly in the context of new materials, any data foundation serves as a valuable asset for subsequent optimisations. Enhanced data quality paves the way for data monetisation, including scenarios where certification necessitates the use of data, effectively enabling businesses to recover their investments. This novel approach transforms into an entirely new business model for experienced AM users.

Leveraging metal AM's full potential

A noteworthy advantage of the AddiMap model is its potential to unlock previously untapped avenues for leveraging metal AM's full potential. Companies can acquire process parameters that cater to specific needs, such as thin-walled parts or high productivity for non-critical components. This eliminates the need to invest in new machinery or extensive parameter studies for enhanced productivity. The metal AM industry, ripe for innovation and collaboration, can substantially benefit from this shift away from protectionism toward broader market growth and the exploration of exciting new applications.

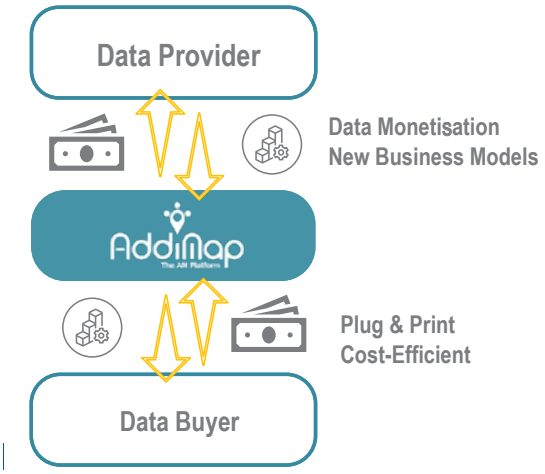

Fig. 4 Advantages for data providers and data buyers by using the AddiMap platform (Courtesy Rosswag)

The power of collaborative partnerships

In the ever-evolving landscape of metal AM, collaborative partnerships are proving to be pivotal in driving innovation, overcoming challenges, and expediting the industrialisation process. Given the intricacies of AM, spanning from complex process development to material qualification, strategic collaborations offer a multifaceted approach that propels the industry's growth.

Knowledge sharing and exchange
Collaborative partnerships facilitate the exchange of knowledge and expertise among diverse stakeholders, including companies, research institutions, and experts. This sharing of insights and best practices encompasses both theoretical and practical aspects of AM. By tapping into a collective pool of experiences across various technologies and processes, partnerships enable rapid problem-solving and informed decision-making.

Accelerated innovation
Metal AM is characterised by swift technological advancements. Partnerships allow participants to combine resources and capabilities, accelerating innovation and development. Collaboration encourages shared investment in research, exploration of emerging technologies, and experimentation. This collaborative momentum not only expedites innovation but also reduces the risk associated with high-cost endeavours, benefitting the entire industry.

Holistic problem solving
Metal AM is a multifaceted process involving materials, machines, processes, and post-processing techniques. Collaborations encourage holistic approaches to problem-solving. Solutions to challenges that may appear insurmountable in isolation can be found when approached from different angles within a collaborative framework. This comprehensive problem-solving strategy is essential for addressing complex issues like consistent material properties and efficient certification processes.

Resource optimisation
The resources required for metal AM development – financial, technological, and human – are substantial. Partnerships optimise resource allocation by sharing costs, equipment, and workforces. This efficient distribution enables partners to concentrate on their strengths and achieve a more effective return on investment.

Risk mitigation
Inherent uncertainties and risks are part of the metal AM landscape. Collaborative partnerships offer risk mitigation strategies. By pooling efforts partners diversify approaches, share the burden of setbacks, and provide collective expertise for proactive risk management.

Access to diverse markets
Partnerships often involve companies from diverse industries or regions. This diversity opens avenues for market expansion. Cross-industry collaborations allow the application of ideas and approaches from one sector to another, fostering innovation and revenue streams.

In the end, a new metal AM application can be qualified much faster and cheaper than before, and the data provider is paid for its earlier development efforts. So, overall market efficiency increases, leading to faster adoption and industrialisation.

Conclusion

AddiMap cooperates with other marketplaces like www.qualloy.com in order to offer users the right metal powder for the right parameter set. Together with Autodesk, there is an effort to integrate AddiMap as a service in Fusion 360, offering users the option to directly purchase and use the appropriate parameter set during job preparation in the future.

In the relentless pursuit of AM's industrialisation, the missing piece of the puzzle might just be the strategic exploitation of metal AM data assets. As the industry faces increasing complexities and demands, the traditional approach to process parameter development and material qualification proves inefficient. The introduction of AddiMap and its parameter marketplace concept challenges the status quo by enabling efficient data monetisation, optimising processes, and opening doors to novel revenue streams.

With this innovation, the metal AM industry takes a significant step closer to realising its full potential and becoming a driving force behind transformative industrial advancements. Collaborative partnerships are a driving force in the dynamic world of metal Additive Manufacturing. Their advantages – knowledge sharing, accelerated innovation, holistic problem-solving, resource optimisation, risk mitigation, market access, and regulatory compliance – collectively shape the metal AM industry's growth and success.

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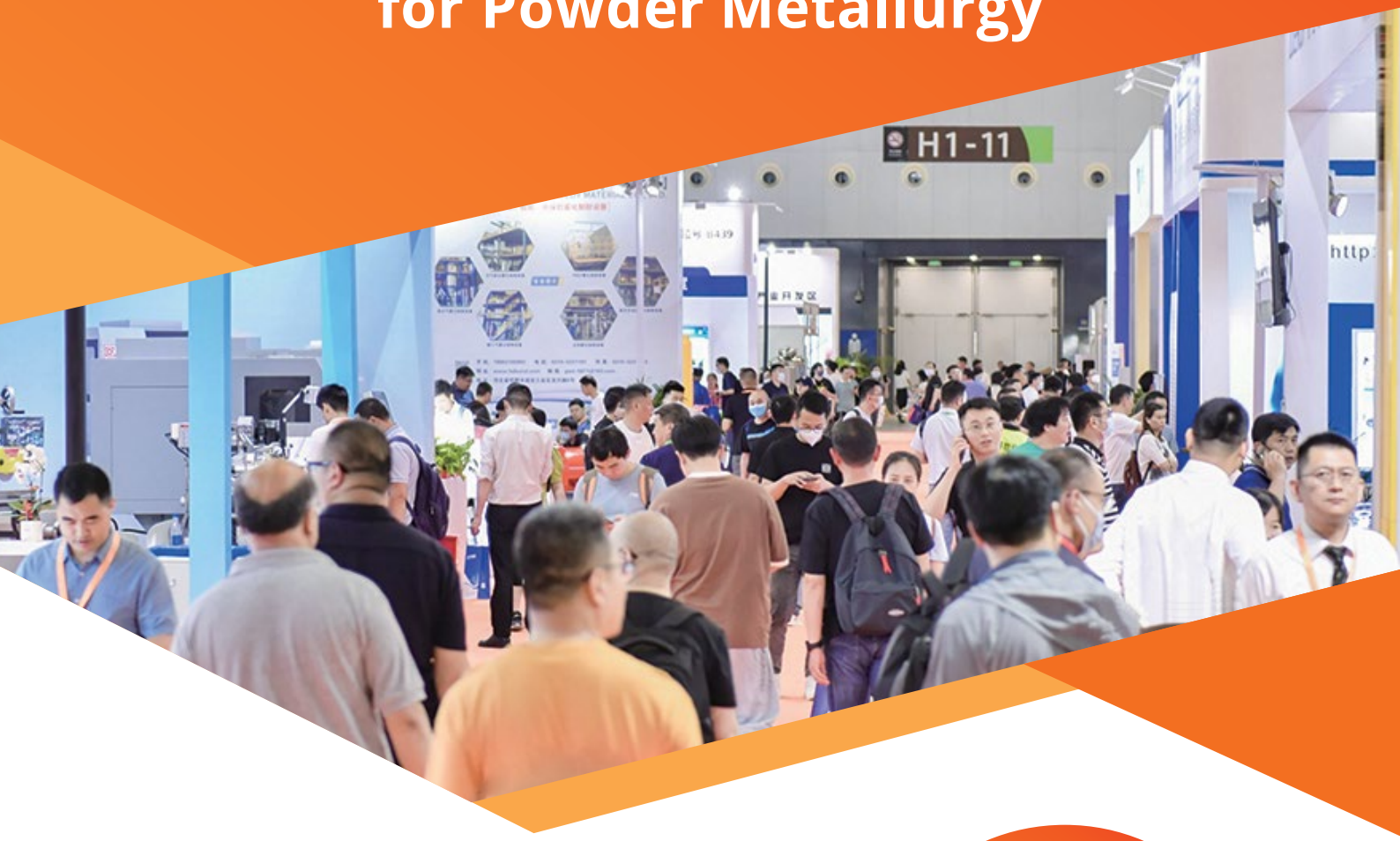

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www.manufacturingexposcotland.com

ASTM ICAM 2023
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implement-am.com/register

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implement-am.com/register

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www.tctjapan.jp

Additive Manufacturing Strategies 2024
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www.additivemanufacturingstrategies.com

Digital Twin & Smart Manufacturing Summit
February 21–22, Berlin, Germany
www.digitaltwintechsummit.com

MIM2024
February 26–28, Raleigh, NC, USA
www.mim2024.org

AM for Aerospace, Defence & Space
February 27–28, Bristol, UK
www.defenceiq.com/events-additivemanufacturing

AM China 2024 / PM China 2024
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www.amatex.cn / en.pmexchina.com

AMUG
March 10–14, Chicago, IL, USA
www.amug.com

Hannover Messe
April 22–26, Hannover, Germany
www.hannovermesse.de

Rapid + TCT
April 23–25, Anaheim, CA, USA
www.rapid3devent.com

AMC 2024
April 25–27, Antalya, Turkey
www.amctr.org

Space Tech Expo US
May 14–15, Long Beach, CA, USA
www.spacetechexpo.com

3D Print Lyon
June 4–6, Lyon, France
www.3dprint-exhibition-lyon.com

TCT 3Sixty
June 5–6, Birmingham, UK
www.tct3sixty.com

EPHJ
June 11–14, Geneva, Switzerland
www.ephj.ch

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June 16–19, Pittsburgh, PA, USA
www.powdermet2024.org | www.ampm2024.org

PMTi 2024
September 4–6, Madrid, Spain
www.pmti2024.com

EURO PM2024
September 29– October 2, Malmö, Sweden
www.europm2024.com

World PM2024
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www.worldpm2024.com

2025

DDMC 2025
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